Chapter 1

Physical World

Solutions

SECTION - A

Objective Type Questions

1. Origin of the word 'Science' is from

   (1) French word 'Scientia'
   (2) Greek word 'Scientia'
   (3) Latin word 'Scientia', which means 'scientific'
   (4) Latin word 'Scientia', which means 'to know'

Sol. Answer (4)

2. Scientific method involves

   (1) Systematic observations, controlled experiments, qualitative and quantitative reasoning, mathematical modelling and prediction
   (2) Systematic observations, controlled experiments, qualitative and quantitative reasoning and mathematical modelling
   (3) Systematic observations, controlled experiments, qualitative and quantitative reasoning, mathematical modelling, prediction and verification
   (4) Systematic observations, controlled experiments, qualitative and quantitative reasoning

Sol. Answer (3)

3. Origin of the word 'Physics' is from

   (1) French word 'Fusis'
   (2) Latin word 'Fusis'
   (3) Greek word 'Fusis', which means 'Nature'
   (4) Greek word 'Fusis', which means 'Physical'

Sol. Answer (3)

4. Main thrust in physics is on

   (1) Unification
   (2) Reduction
   (3) Both (1) & (2)
   (4) Experiments

Sol. Answer (3)

5. Explaining diverse physical phenomena in terms of a few concepts and laws is

   (1) Reduction
   (2) Unification
   (3) Law
   (4) Fact

Sol. Answer (2)

6. Deriving the properties of a bigger, more complex system from the properties and interaction of its constituent simpler parts is

(1) Unification (2) Reduction (3) Law (4) Fact

Sol. Answer (2)

7. Logical possibility that an assertion, hypothesis or a theory can be contradicted by an observation or the outcome of a physical experiment is

(1) Law (2) Hypothesis (3) Fact (4) Falsifiability

Sol. Answer (4)

8. Which of the following statements is/are correct?

(1) Universal law of gravitation is an assumption or hypothesis

(2) Universal law of gravitation can be proved

(3) Universal law of gravitation can be verified

(4) Both (1) & (3)

Sol. Answer (4)

9. A theory proposed to explain observed phenomena is

(1) Postulate (2) Hypothesis (3) Law (4) Model

Sol. Answer (4)

10. A truth, which is self-evident is a/an

(1) Axiom (2) Postulate (3) Either (1) or (2) (4) Hypothesis

Sol. Answer (3)

11. "Science is not just a collection of laws, a catalogue of unrelated facts. It is a creation of human mind, with its freely invented ideas and concepts." Who made these remarks?

(1) Newton (2) Maxwell (3) Einstein (4) Raman

Sol. Answer (3)

12. "The most incomprehensible thing about the world is that it is incomprehensible." Who made these remarks?

(1) Newton (2) Maxwell (3) Einstein (4) Raman

Sol. Answer (3)

13. "We know very little and yet it is astonishing that we know so much, and still more astonishing that so little knowledge (or science) can give us so much power." Who made these remarks?

(1) Newton (2) Maxwell (3) Einstein (4) Bertrand Russel

Sol. Answer (4)

14. "I do not know what I may appear to the world, I seem to have been only like a boy playing on the sea-shore and diverting myself every now and then finding a smoother pebble or a prettier shell than ordinary, while the great ocean of truth lay undiscovered before me." Who said this?

(1) Newton (2) Maxwell (3) Einstein (4) Raman

Sol. Answer (1)

15. A thought experiment in Physics is one which is
    (1) Theoretically possible but experimentally not feasible
    (2) Neither theoretically possible nor experimentally feasible
    (3) Performed by a non-physicist
    (4) Performed by a chemist

Sol. Answer (1)

16. In ‘Mesoscopic Physics’, we deal with
    (1) Phenomena at laboratory (2) Molecular phenomena
    (3) Nuclear phenomena (4) Few tens or hundreds of atom

Sol. Answer (4)

17 "Classical Physics" deals with
    (1) Macroscopic phenomena (2) Mesoscopic phenomena
    (3) Microscopic phenomena (4) Sometimes mesoscopic sometimes microscopic

Sol. Answer (1)

18. The scope of physics covers almost
    (1) 10^{-14} m (or even less) to 10^{26} m range of length (2) 10^{-22} s to 10^{18} s range of time
    (3) 10^{-30} kg to 10^{55} kg range of mass (4) All of these

Sol. Answer (4)

19. Strategy of approximation involves
    (1) All the complexities of a phenomena
    (2) Extracting essential features of a phenomena from its less significant aspects
    (3) Qualitative thinking
    (4) Both (1) & (3)

Sol. Answer (2)

20. An Indian scientist who won Nobel Prize for Physics is
    (1) Sir J.C. Bose (2) H.J. Bhaba (3) M.N. Saha (4) Sir. C.V. Raman

Sol. Answer (4)

21. Which of the following statements is not true?
    (1) Solar cells may be future source of power for cars
    (2) Development in medicine may increase average life expectancy
    (3) X-rays were discovered by Roentgen
    (4) Radioactivity was discovered by Madam Curie

Sol. Answer (4)

22. Albert Einstein was awarded Nobel Prize for his work on
    (1) Special theory of relativity (2) General theory of relativity
    (3) Photoelectric effect (4) Mass-energy equivalence

Sol. Answer (3)

23. The India born and USA based Nobel LaureateProf. Chandrasekhara is known for his work on
    (1) Study of cosmic rays
    (2) Development of relativistic theory of electron
    (3) Prediction of tachyons
    (4) Stability of stars and existence of a stable mass limit for white dwarfs

Sol. Answer (4)

24. Abdus Salam, a Pakistan national won Nobel Prize in the field of
    (1) Inelastic scattering of light by molecules (2) Unification of weak and electromagnetic interaction
    (3) Superconductivity (4) Laser technology

Sol. Answer (2)

25. Who gave quantum model of atom?
    (1) Rutherford (2) Bohr (3) Newton (4) Faraday

Sol. Answer (2)

26. Which of the following statements given below are false?
    a. Becquerel discovered radioactivity
    b. Fraunhoffer lines were first discovered by Wollaston
    c. Photoelectric effect was discovered by Einstein
    (1) a, b & c (2) a & c (3) b & c (4) c only

Sol. Answer (4)

27. The persons, who were given Nobel prize twice, are
    (1) Madame Curie and Albert Einstein (2) John Bardeen and Albert Einstein
    (3) Max Planck and Albert Einstein (4) Madame Curie and John Bardeen

Sol. Answer (4)

28. The country, which awards the prestigious Nobel prize, is
    (1) USA (2) UK (3) Sweden (4) Germany

Sol. Answer (3)

29. The scientific principle involved in supercomputers is
    (1) Electromagnetic induction (2) Thermodynamics
    (3) Superconductivity (4) Amplification by population inversion

Sol. Answer (3)

30. The scientific principle involved in radio and TV broadcast is
    (1) Superconductivity (2) Propagation of electromagnetic waves
    (3) Electromagnetic induction (4) Amplification by population inversion

Sol. Answer (2)

31. It has been postulated that there may be some particle moving with speed greater than the speed of light. Such particles have been named as

(1) Mesons (2) Pions (3) Tachyons (4) Leptons

Sol. Answer (3)

32. The scientific principle involved in LASER is

(1) Newton's laws of motion
(2) Faraday's laws of induction
(3) Coulomb's laws of induction
(4) Amplification by population inversion

Sol. Answer (4)

33. If F_g, F_N, F_W and F_E be the gravitational, nuclear, weak and electromagnetic forces respectively, then arrange them in proper order as per their strength.

(1) $F_g > F_N > F_W > F_E$ (2) $F_g < F_W < F_E < F_N$ (3) $F_E > F_N > F_W > F_g$ (4) $F_W < F_g < F_E < F_N$

Sol. Answer (2)

34. Forces which obey inverse square law are

(1) Gravitational forces
(2) Electromagnetic forces
(3) Nuclear forces
(4) Both (1) & (2)

Sol. Answer (4)

35. Choose the correct statement.

(1) Gravitational force is weakest force
(2) Electrostatic force is weakest force
(3) Nuclear force is weakest force
(4) Electromagnetic force is strongest force

Sol. Answer (1)

36. Choose the correct statement.

(1) Strong nuclear forces are charge independent
(2) Weak nuclear forces are charge independent
(3) Gravitational forces are charge independent
(4) All of these

Sol. Answer (4)

37. Choose the correct statement.

(1) Gravitational forces are attractive forces
(2) Nuclear forces are attractive forces
(3) Electromagnetic forces can be attractive as well as repulsive
(4) All of these

Sol. Answer (4)

38. Choose the correct statement.

(1) Strong nuclear force is 100 times stronger than electrostatic force
(2) Strong nuclear force is 10^{13} times stronger than weak nuclear force
(3) Strong nuclear force is 10^{39} times stronger than gravitational force
(4) All of these

Sol. Answer (4)

39. Choose the correct statement.

    (1) Range of strong nuclear force is ≈ 10^{-15} m

    (2) Range of weak nuclear force is ≈ 10^{-16} m

    (3) Gravitational and electromagnetic force have infinite range

    (4) All of these

Sol. Answer (4)

40. Choose the correct statement.

    (1) Strong nuclear force is mediated by the particle 'π-meson'

    (2) Weak nuclear force is mediated by the particle 'Boson'

    (3) Electromagnetic force is mediated by the particle 'photon' and gravitational force is mediated by the particle 'graviton'

    (4) All of these

Sol. Answer (4)

41. Choose the correct statement.

    (1) Gravitational force is conservative (2) Electromagnetic force is conservative

    (3) Nuclear force is non-conservative (4) All of these

Sol. Answer (4)

42. Choose the correct statement.

    (1) Gravitational force is a central force (2) Electromagnetic force is a central force

    (3) Nuclear force is a non-central force (4) All of these

Sol. Answer (4)

43. Choose the correct statement.

    (1) Gravitational force is not affected by intervening medium

    (2) Electromagnetic force is affected by intervening medium

    (3) Nuclear force does not obey inverse square law

    (4) All of these

Sol. Answer (4)

44. Choose the correct statement.

    (1) Hans Lippershey is associated with the discovery of telescope

    (2) Kepler is associated with the discovery of telescope

    (3) C.V. Raman is associated with the discovery of telescope

    (4) Hubble is associated with the discovery of telescope

Sol. Answer (1)

45. Choose the correct statement.
    (1) C.V. Raman is associated with scattering of light by the molecules
    (2) Neil Bohr is associated with scattering of light by the molecules
    (3) S. Chandrashekhar is associated with scattering of light by the molecules
    (4) Heisenberg is associated with radioactivity

Sol. Answer (1)

46. Choose the correct statement.
    (1) F. Caree is associated with refrigerator
    (2) H. Hertz is associated with electromagnetic waves
    (3) James Chadwick is associated with the discovery of neutron
    (4) All of these

Sol. Answer (4)

47. Choose the correct statement.
    (1) Scientific principle involved in refrigerator is laws of thermodynamics
    (2) Scientific principle involved in steam engine is laws of thermodynamics
    (3) Scientific principle involved in rocket propulsion is Newton's laws of motion
    (4) All of these

Sol. Answer (4)

48. Choose the correct statement.
    (1) Newton unified celestial and terrestrial mechanics
    (2) Maxwell verified experimentally the predictions of the theory of 'electroweak force'
    (3) Glashow showed that electricity and magnetism are inseparable aspects of 'electromagnetism'
    (4) Rubia unified celestial and terrestrial mechanics

Sol. Answer (1)

49. Choose the correct statement.
    (1) Law of conservation of linear momentum is valid in the presence of an external force also
    (2) For angular momentum of a system to remain constant, it is not necessary that external torque acting on it be zero
    (3) Charge can be created and destroyed
    (4) A conservation law cannot be proved

Sol. Answer (4)

50. Choose the correct statement.
    (1) Symmetry of nature w.r.t. translation in time is equivalent to law of conservation of energy
    (2) Symmetry of nature w.r.t. translation in space is equivalent to law of conservation of linear momentum
    (3) Isotropy of space is equivalent to law of conservation of angular momentum
    (4) All of these

Sol. Answer (4)

SECTION - B

Assertion - Reason Type Questions

1. A : Quark-quark force is said to be fundamental force instead of strong nuclear force.

   R : Nucleons consist of more fundamental particles known as quarks.

Sol. Answer (1)

2. A : Gravitational force is the weakest force among all other forces.

   R : Gravitational force between the two masses is independent of the medium in between.

Sol. Answer (2)

3. A : Gravitational force dominates terrestrial phenomena.

   R : Matter is mostly electrically neutral and gravitational force are only of attractive nature.

Sol. Answer (1)

4. A : Gravitational force is always attractive but electromagnetic force can be attractive or repulsive.

   R : Mass comes only in one variety (there is no negative mass) but charge comes in two varieties. (Positive and negative charge)

Sol. Answer (1)

5. A : If m and m_0 are moving mass, rest mass of a body and c is velocity of light, then kinetic energy of the body is $E = (m - m_0)c^2$.

   R : Total energy of a body is sum of kinetic energy and rest mass energy.

Sol. Answer (1)

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Chapter 2

Units and Measurements

Solutions

SECTION - A

Objective Type Questions

1. The base quantity among the following is

(1) Speed (2) Weight (3) Length (4) Area

Sol. Answer (3)

There are seven base quantities,

(i) Mass (ii) Length

(iii) Time (iv) Current

(v) Amount of substance (vi) Luminous intensity

(vii) Temperature

2. Which of the following is not a unit of time?

(1) Second (2) Minute (3) Hour (4) Light year

Sol. Answer (4)

Light year is the unit of distance

1 light year = 9.46×10^{15} m

3. One astronomical unit is a distance equal to

(1) 9.46×10^{15} m (2) 1.496×10^{11} m (3) 3×10^{8} m (4) 3.08×10^{16} m

Sol. Answer (2)

One astronomical unit is the average distance between earth and sun

$$\boxed{1 \text{ astronomical unit (AU)} = 1.496 \times 10^{11} \text{ m}}$$

4. The volume of a cube having sides 1.2 m is appropriately expressed as

(1) 1.728×10^{6} cm^3 (2) 1.7×10^{6} cm^3 (3) 1.8×10^{6} cm^3 (4) 1.73×10^{6} cm^3

Sol. Answer (2)

The volume of cube is l^3

$$v = (1.2 \text{ cm})^3 = 1.728 \times 10^{6} \text{ cm}^3$$

$$\boxed{v \simeq 1.7 \times 10^{6} \text{ cm}^3}$$

Answer should be reported in minimum number of significant figures.

5. Ampere second is a unit of

(1) Current (2) Charge (3) Energy (4) Power

Sol. Answer (2)

Current $I = \frac{q}{t} \Rightarrow q = It$

$\boxed{q = \text{Ampere second}}$

So, ampere second is the unit of charge.

6. The most precise reading of the mass of an object, among the following is

(1) 20 g (2) 20.0 g (3) 20.01 g (4) 20×10^0 g

Sol. Answer (3)

A measurement having more number of decimal places is the one with the most precision.

So, 20.01 g is most precise.

7. The most accurate reading of the length of a 6.28 cm long fibre is

(1) 6 cm (2) 6.5 cm (3) 5.99 cm (4) 6.0 cm

Sol. Answer (2)

Most accurate reading is the one having minimum error.

So, $|6 - 6.28| = 0.28$ cm

$|6.5 - 6.28| = 0.22$ cm

$|5.99 - 6.28| = 0.29$ cm

$|6.0 - 6.28| = 0.28$ cm

So, second reading is most accurate.

8. Which of the following is a unit that of force?

(1) N m (2) mN (3) nm (4) N s

Sol. Answer (2)

Nm → Unit of torque

mN → Milli newton ⇒ 10^{-3} N

nm → Nano metre

Ns → Unit of momentum

9. The value of 60° in radian is

(1) $\frac{\pi}{2}$ (2) $\frac{\pi}{3}$ (3) $\frac{\pi}{4}$ (4) $\frac{\pi}{5}$

Sol. Answer (2)

$180° = \pi$ radian

$$1° = \frac{\pi}{180} \text{ rad}$$

$$60° = \frac{\pi}{180} \times 60 \text{ rad}$$

$$\boxed{60° = \frac{\pi}{3} \text{ rad}}$$

10. The total plane angle subtended by a circle at its centre is

(1) π rad (2) 2π rad (3) $\frac{2\pi}{3}$ rad (4) $\frac{\pi}{2}$ rad

Sol. Answer (2)

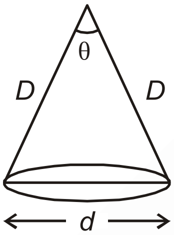
The total plane angle is 360º or 2π rad.

11. A far off planet is estimated to be at a distance *D* from the earth. If its diametrically opposite extremes subtend an angle θ at an observatory situated on the earth, the approximate diameter of the planet is

(1) $\frac{\theta}{D}$ (2) $\frac{D}{\theta}$ (3) $D\theta$ (4) $\frac{1}{D\theta}$

Sol. Answer (3)

$$\theta = \frac{\text{Arc length}}{\text{Radius}}$$



$$\theta = \frac{d}{D}$$

$$\Rightarrow \boxed{d = D\theta}$$

12. One unified atomic mass unit represents a mass of magnitude

(1) 10^{-30} kg (2) 1.66×10^{27} kg (3) 1.66×10^{-27}kg (4) 10^{30} kg

Sol. Answer (3)

$$\boxed{1\text{ amu} = 1.66 \times 10^{-27}\text{ kg}}$$

13. If the average life of a person is taken as 100 s, the age of the universe on this scale is of the order

(1) 10^{10} s (2) 10^{8} s (3) 10^{17} s (4) 10^{9} s

Sol. Answer (1)

Time span of human life = 10^{9} s

Age of universe = 10^{17} s

So, $\frac{\text{Age of universe}}{\text{Time of human}} = \frac{10^{17}}{10^{9}} = 10^{8}$

If, $\frac{\text{Age of universe}}{100} = 10^{8}$

$$\Rightarrow \boxed{\text{Age of universe} = 10^{10}\text{ s}}$$

14. Which of the following is the most precise measurement?

(1) 3×10^{-3} m (2) 0.0030 m (3) 30×10^{-4} m (4) 300×10^{-5} m

Sol. Answer (4)

3×10^{-3}

3.0×10^{-3}

3.0×10^{-3}

3.00×10^{-3}

So, fourth measurement is most precise.

15. The number of significant figures in a pure number 410 is

(1) Two (2) Three (3) One (4) Infinite

Sol. Answer (4)

A pure number has infinite number of significant figures.

16. Thickness of a pencil measured by using a screw gauge (least count .001 cm) comes out to be 0.802 cm. The percentage error in the measurement is

(1) 0.125% (2) 2.43% (3) 4.12% (4) 2.14%

Sol. Answer (1)

The percentage error is $\frac{\Delta L}{L} \times 100\% = \frac{0.001}{0.802} \times 100\% = 0.1246\% \simeq 0.125\%$

17. The percentage error in the measurement of the voltage V is 3% and in the measurement of the current is 2%. The percentage error in the measurement of the resistance is

(1) 3% (2) 2% (3) 1% (4) 5%

Sol. Answer (4)

$V = IR \Rightarrow R = \frac{V}{I}$

$\Rightarrow \left(\frac{\Delta R}{R}\right) \times 100\% = \left(\frac{\Delta V}{V} + \frac{\Delta I}{I}\right) \times 100\%$

$\Rightarrow \frac{\Delta R}{R} \times 100\% = 3\% + 2\% = 5\%$

18. The relative error in the measurement of the side of a cube is 0.027. The relative error in the measurement of its volume is

(1) 0.027 (2) 0.054 (3) 0.081 (4) 0.046

Sol. Answer (3)

Volume of cube, $V = \text{side}^3$

$\frac{\Delta V}{V} = \frac{3\,\Delta\text{side}}{\text{side}}$

$\frac{\Delta V}{V} = 3 \times 0.027 \Rightarrow \boxed{\frac{\Delta V}{V} = 0.081}$

19. Zero error in an instrument introduces

(1) Systematic error (2) Random error (3) Least count error (4) Personal error

Sol. Answer (1)

Zero error is a part of systematic error.

20. A packet contains silver powder of mass 20.23 g ± 0.01 g. Some of the powder of mass 5.75 g ± 0.01 g is taken out from it. The mass of the powder left back is

(1) 14.48 g ± 0.00 g (2) 14.48 ± 0.02 g (3) 14.5 g ± 0.1 g (4) 14.5 g ± 0.2 g

Sol. Answer (2)

$m_1 = 20.23\text{ g} \pm 0.01\text{ g}$

$m_2 = (5.75 \pm 0.01)\text{ g}$

$m_1 - m_2 = [(20.23 - 5.75) \pm 0.02]\text{ g}$

$\boxed{\Delta m = (14.48 \pm 0.02)\text{ g}}$

21. The addition of three masses 1.6 g, 7.32 g and 4.238 g, addressed upto proper decimal places is

(1) 13.158 g (2) 13.2 g (3) 13.16 g (4) 13.15 g

Sol. Answer (2)

$m_1 = 1.6$ g

$m_2 = 7.32$ g

$m_3 = 4.238$ g

$m_1 + m_2 + m_3 = 13.158$ g

but answer should be reported in one decimal place only.

$\therefore \quad \boxed{m = 13.2 \text{ g}}$

22. The area of a sheet of length 10.2 cm and width 6.8 cm addressed upto proper number of significant figures is

(1) 69.36 cm^2 (2) 69.4 cm^2 (3) 69 cm^2 (4) 70 cm^2

Sol. Answer (3)

$l = 10.2$ cm

$w = 6.8$ cm

Area $= lw = 10.2 \times 6.8 = 69.36$

$\Rightarrow$ Area = 69 cm^2

23. The radius of a sphere is (2.6 ± 0.1) cm. The percentage error in its volume is

(1) $\frac{0.1}{2.6}\times 100\,\%$ (2) $3 \times \frac{0.1}{2.6}\times 100\,\%$ (3) $\frac{0.1}{3\times 2.6}\times 100\,\%$ (4) $\frac{0.1}{2.6}\,\%$

Sol. Answer (2)

$r = (2.6 \pm 0.1)$ cm

$$V = \frac{4}{3}\pi r^3$$

$$\frac{\Delta V}{V}\times 100\% = \frac{3\Delta r}{r}\times 100\%$$

$$\boxed{\frac{\Delta V}{V}\times 100\% = \frac{3\times 0.1}{2.6}\times 100\%}$$

24. The uncertain digit in the measurement of a length reported as 41.68 cm is

(1) 4 (2) 1 (3) 6 (4) 8

Sol. Answer (4)

41.68 cm

The rightmost digit is most insignificant and leftmost is most significant.

So, 8 → most insignificant

4 → most significant

25. We can reduce random errors by

(1) Taking large number of observations (2) Corrected zero error

(3) By following proper technique of experiment (4) Both (1) & (3)

Sol. Answer (1)

The only method of reducing random errors is by taking more and more number of observations.

26. The number of significant figures in the measured value 0.0204 is

(1) Five (2) Three (3) Four (4) Two

Sol. Answer (2)

The non-zero digits after the decimal places are significant.

27. The number of significant figures in the measured value 26000 is

(1) Five (2) Two (3) Three (4) Infinite

Sol. Answer (2)

The trailing zeros are not significant.

So, only two digits are significant.

28. The number of significant zeroes present in the measured value 0.020040, is

(1) Five (2) Two (3) One (4) Three

Sol. Answer (4)

Zeores appearing between and after non-zero numbers are significant.

$0.02\underline{00}4\underline{0}$

29. The number of significant figures in the measured value 4.700 m is the same as that in the value

(1) 4700 m (2) 0.047 m (3) 4070 m (4) 470.0 m

Sol. Answer (4)

4.700 ⇒ Four significant figures.

Also, 470.0 m ⇒ four significant figures.

30. If a calculated value 2.7465 g contains only three significant figures, the two insignificant digits in it are

(1) 2 and 7 (2) 7 and 4 (3) 6 and 5 (4) 4 and 6

Sol. Answer (3)

2.7465 g ⇒ Last two digits are most insignificant.

31. An object of mass 4.237 g occupies a volume 1.72 cm^3. The density of the object to appropriate significant figures is

(1) 2.46 g cm^{-3} (2) 2.463 g cm^{-3} (3) 2.5 g cm^{-3} (4) 2.50 g cm^{-3}

Sol. Answer (1)

$m = 4.237$ g

$V = 1.72$ cm^3

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{4.237\text{ g}}{1.72\text{ cm}^3}$$

$$\Rightarrow \boxed{d = 2.46\text{ gcm}^{-3}}$$

32. Round off the value 2.845 to three significant figures.

(1) 2.85 (2) 2.84 (3) 2.80 (4) 2.83

Sol. Answer (2)

2.845 ⇒ 2.84

33. A length 5.997 m rounded off to three significant figures is written as

(1) 6.00 m (2) 5.99 m (3) 5.95 m (4) 5.90 m

Sol. Answer (1)

5.997 ⇒ 6.00 m

34. The order of the magnitude of speed of light in SI unit is

(1) 16 (2) 8 (3) 4 (4) 7

Sol. Answer (2)

Speed of light ⇒ 3×10^8 ms^{-1}

Order of magnitude = 8

35. The values of a number of quantities are used in a mathematical formula. The quantity that should be most precise and accurate in measurement is the one

(1) Having smallest magnitude (2) Having largest magnitude

(3) Used in the numerator (4) Used in the denominator

Sol. Answer (1)

The quantity having smallest magnitude should be measured very precisely as it is likely to contribute the maximum relative error.

36. What are the dimensions of the change in velocity?

(1) $[M^0L^0T^0]$ (2) $[LT^{-1}]$ (3) $[MLT^{-1}]$ (4) $[LT^{-2}]$

Sol. Answer (2)

The dimensions of change in velocity is same as that of velocity $[M^0LT^{-1}]$.

37. The dimensional formula for energy is

(1) $[MLT^{-2}]$ (2) $[ML^2T^{-2}]$ (3) $[M^{-1}L^2T]$ (4) $[M L^2 T]$

Sol. Answer (2)

The dimensional formula is $[ML^2T^{-2}]$

38. The pair of the quantities having same dimensions is

(1) Displacement, velocity (2) Time, frequency

(3) Wavelength, focal length (4) Force, acceleration

Sol. Answer (3)

Wavelength and focal length both are have units of length.

39. The dimensional formula for relative refractive index is

(1) $[M^1L^1 T^1]$ (2) $[M^0L^0T^0]$ (3) $[M^1L^0T^0]$ (4) $[MLT^{-1}]$

Sol. Answer (2)

Refractive index is a pure number, hence dimensionless.

40. The dimensional formula $[ML^{-1}T^{-2}]$ is for the quantity

(1) Force (2) Acceleration (3) Pressure (4) Work

Sol. Answer (3)

The dimensional formula for pressure

$$P = \frac{\text{Force}}{\text{Area}} = \frac{MLT^{-2}}{L^2} \Rightarrow [ML^{-1}T^{-2}]$$

41. If the buoyant force F acting on an object depends on its volume V immersed in a liquid, the density ρ of the liquid and the acceleration due to gravity g. The correct expression for F can be

(1) $V\rho\, g$ (2) $\dfrac{\rho g}{V}$ (3) $\rho\, g V^2$ (4) $\sqrt{\rho g V}$

Sol. Answer (1)

$F \propto V^a \rho^b g^c$

$F = [L^3]^a [ML^{-3}]^b [LT^{-2}]^c$

$[MLT^{-2}] = F = [M^b L^{3a-3b+c} T^{-2c}]$

On comparing,

$\boxed{b=1}$, $-2c = -2$

$\Rightarrow \boxed{c=1}$

$3a - 3b + c = 1$

$\Rightarrow 3a - 3 + 1 = 1$

$\Rightarrow 3a - 2 = 1$

$\Rightarrow 3a = 3 \Rightarrow \boxed{a=1}$

So, on putting all these values,

$\boxed{F = V\rho g}$

42. The dimensionally correct expression for the resistance R among the following is [P = electric power, I = electric current, t = time, V = voltage and E = electric energy]

(1) $R = \sqrt{PI}$ (2) $R = \dfrac{E}{I^2 t}$ (3) $R = V^2 P$ (4) $R = VI$

Sol. Answer (2)

Dimensional formula of power $= \dfrac{W}{t} = \dfrac{ML^2T^{-2}}{T} = [ML^2T^{-3}]$

Current $\rightarrow [A]$

$V = \dfrac{W}{q} = \dfrac{ML^2T^{-2}}{AT} = [ML^2T^{-3}A^{-1}]$

$E = [ML^2T^{-2}]$

So, $R = \dfrac{E}{I^2 t} = \dfrac{ML^2T^{-2}}{A^2T} \Rightarrow [ML^2T^{-3}A^{-2}]$

and $V = IR \Rightarrow R = \dfrac{ML^2T^{-3}A^{-1}}{A} \Rightarrow [ML^2T^{-3}A^{-2}]$

So, (2) is the correct formula.

43. Which of the following does not have dimensions of force?

(1) Weight
(2) Rate of change of momentum
(3) Work per unit length
(4) Work done per unit charge

Sol. Answer (4)

Dimension of $\dfrac{W}{q} = [ML^2A^{-1}T^{-3}]$

which is different from dimension of force $[MLT^{-2}]$

44. The potential energy u of a particle varies with distance x from a fixed origin as $u = \frac{A\sqrt{x}}{x+B}$, where A and B are constants. The dimensions of A and B are respectively

(1) $[ML^{5/2}T^{-2}]$, [L] (2) $[MLT^{-2}]$, $[L^2]$ (3) [L], $[ML^{3/2}T^{-2}]$ (4) $[L^2]$, $[MLT^{-2}]$

Sol. Answer (1)

$$u = \frac{A\sqrt{x}}{x+B}$$

By the principle of homogeneity, $x = B$ (dimensionally)

$$\Rightarrow \boxed{B = [L]}$$

and $[ML^2T^{-2}] = \frac{AL^{1/2}}{L}$

$$[ML^2T^{-2}] = AL^{-1/2}$$

$$\boxed{A = [ML^{3/2}T^{-2}]}$$

45. A physical quantity P is given by the relation. $P = P_0 e^{(-\alpha t^2)}$ If t denotes the time, the dimensions of constant α are

(1) [T] (2) $[T^2]$ (3) $[T^{-1}]$ (4) $[T^{-2}]$

Sol. Answer (4)

$$P = P_0 e^{-\alpha t^2}$$

The power of exponent is dimensionless,

$$\alpha t^2 = [M^0L^0T^0]$$

$$\boxed{\alpha = [T^{-2}]}$$

46. The dimensions of potential energy of an object in mass, length and time are respectively

(1) 2, 2, 1 (2) 1, 2, – 2 (3) –2, 1, 2 (4) 1, – 1, 2

Sol. Answer (2)

The dimensional formula of energy

$$E = [ML^2T^{-2}]$$

So, dimensions of i) Mass → 1 ii) Length → 2 iii) Time → –2

47. Which of the following is a dimensional constant?

(1) Magnification (2) Relative density (3) Gravitational constant (4) Relative error

Sol. Answer (3)

Gravitational constant is a dimensional constant.

$$[G] = [M^{-1}L^3T^{-2}]$$

48. The dimensions of solar constant (energy falling on earth per second per unit area) are

(1) $[M^0L^0T^0]$ (2) $[MLT^{-2}]$ (3) $[ML^2T^{-2}]$ (4) $[MT^{-3}]$

Sol. Answer (4)

Solar constant $[S]$ = $\boxed{\frac{\text{Energy}}{\text{Area} \times \text{Time}}} = \frac{ML^2T^{-2}}{L^2T} \Rightarrow [MT^{-3}]$

49. The amount of heat energy Q, used to heat up a substance depends on its mass m, its specific heat capacity (s) and the change in temperature ΔT of the substance. Using dimensional method, find the expression for s is (Given that $[s] = [L^2T^{-2}K^{-1}]$) is

(1) $Qm\Delta T$ (2) $\frac{Q}{m\Delta T}$ (3) $\frac{Qm}{\Delta T}$ (4) $\frac{m}{Q\Delta T}$

Sol. Answer (2)

$Q = m^a\ s^b\ \theta^c$

$[ML^2T^{-2}] = [M^a][L^{2b}T^{-2b}K^{-b}][K^c]$

$\Rightarrow \boxed{a=1}$, $2b = 2 \Rightarrow \boxed{b=1}$

$-b + c = 0$

$\Rightarrow b = c \Rightarrow \boxed{c=1}$

$Q = ms\Delta T$

$$\Rightarrow \boxed{s = \frac{Q}{m\Delta T}}$$

50. The focal power of a lens has the dimensions

(1) [L] (2) $[ML^2T^{-3}]$ (3) $[L^{-1}]$ (4) $[MLT^{-3}]$

Sol. Answer (3)

Focal length $\Rightarrow f = [L]$

SECTION - B

Objective Type Questions

1. The exchange particles responsible for weak interactions are

(1) Gluons (2) π-mesons (3) Photons (4) W and Z bosons

Sol. Answer (4)

Weak interaction takes place through the exchange of BOSONS → W and Z bosons

2. Maxwell unified

(1) Electricity with gravitation (2) Electricity with magnetism

(3) Electromagnetism with optics (4) Electromagnetism with weak interaction

Sol. Answer (3)

Maxwell unified electromagnetism with optics.

3. Which of the following is not a derived force?

(1) Tension in a string (2) van der Waal forces

(3) Nuclear force between proton-proton (4) Electrostatic force between proton-proton

Sol. Answer (4)

Electrostatic force between proton-proton is a fundamental force.

4. Which one of the following does not experience strong nuclear force?

(1) Leptons (2) Baryons (3) Hadrons (4) Proton

Sol. Answer (1)

Leptons doesn't experience strong nuclear force.

5. Which of the following practical units of length is not correct?

(1) 1 fermi = 10^{-15} m
(2) 1 astronomical unit = 1.496×10^{11} m
(3) 1 parsec = 3.26 light year
(4) 1 light year = 9.46×10^{12} m

Sol. Answer (4)

1 light year = 9.46×10^{15} m

6. The damping force on an oscillator is directly proportional to the velocity. The units of the constant of proportionality are

(1) kgs^{-1} (2) kgs (3) kgms^{-1} (4) kgms^{-2}

Sol. Answer (1)

$$F \propto v \Rightarrow F = bv \Rightarrow b = \frac{F}{v} = \frac{\text{kgms}^{-2}}{\text{ms}^{-1}} = \text{kgs}^{-1}$$

7. The dimensions of $(\mu_0\varepsilon_0)^{-1/2}$ are

(1) $[L^{1/2}T^{-1/2}]$ (2) $[L^{-1}T]$ (3) $[LT^{-1}]$ (4) $[L^{1/2}T^{1/2}]$

Sol. Answer (3)

Speed of light $c = \dfrac{1}{\sqrt{\mu_0\varepsilon_0}} \Rightarrow c = (\mu_0\varepsilon_0)^{-1/2}$

So, dimensional formula of $(\mu_0\varepsilon_0)^{-1/2}$

8. The density of a material in CGS system of units is 4 g/cm³. In a system of units in which unit of length is 10 cm and unit of mass is 100 g, the value of density of material will be

(1) 400 (2) 0.04 (3) 0.4 (4) 40

Sol. Answer (4)

Density, $n_1u_1 = n_2u_2$

$$\Rightarrow \frac{4\text{ g}}{\text{cm}^3} = n_2 \times \frac{100\text{ g}}{10^3\text{ cm}^3} \Rightarrow \boxed{n_2 = 40}$$

9. What is the dimension of surface tension?

(1) $[ML^1T^0]$ (2) $[ML^1T^{-1}]$ (3) $[M^1L^1T^{-2}]$ (4) $[M^1L^0T^{-2}]$

Sol. Answer (4)

$$\text{Surface tension} = \frac{\text{Force}}{\text{Length}} = \frac{\text{MLT}^{-2}}{\text{L}}$$

$$\boxed{\text{Surface tension} = [\text{MT}^{-2}]}$$

10. Which two of the following five physical parameters have the same dimensions?

(a) Energy density
(b) Refractive index
(c) Dielectric constant
(d) Young's modulus
(e) Magnetic field

(1) (a) & (e) (2) (b) & (d) (3) (c) & (e) (4) (a) & (d)

Sol. Answer (4)

Refractive index and dielectric constant are dimensional constant

Energy density = $\dfrac{ML^2T^{-2}}{L^3} = [ML^{-1}T^{-2}]$

Young's modulus = $\dfrac{MLT^{-2}}{L^2} = [ML^{-1}T^{-2}]$

So, (a) & (d)

11. Which of the following has the dimensions of pressure?

(1) $[MLT^{-2}]$
(2) $[ML^{-1}T^{-2}]$
(3) $[ML^{-2}T^{-2}]$
(4) $[M^{-1}L^{-1}]$

Sol. Answer (2)

Pressure = $\dfrac{\text{Force}}{\text{Area}} = \dfrac{MLT^{-2}}{L^2} = [ML^{-1}T^{-2}]$

12. The dimensions of *RC* is

(1) Square of time
(2) Square of inverse time
(3) Time
(4) Inverse time

Sol. Answer (3)

The dimensions of *RC* is time.

13. The dimensions of impulse are equal to that of

(1) Pressure
(2) Linear momentum
(3) Force
(4) Angular momentum

Sol. Answer (2)

Impulse = $F\Delta t \Rightarrow MLT^{-2}\cdot T \Rightarrow [MLT^{-1}]$ is dimensions of *P*.

14. An equation is given here $\left(P + \dfrac{a}{V^2}\right) = b\dfrac{\theta}{V}$ where *P* = Pressure, *V* = Volume and θ = Absolute temperature.

If *a* and *b* are constants, the dimensions of *a* will be

(1) $[ML^{-5}\ T^{-1}]$
(2) $[ML^5\ T^1]$
(3) $[ML^5\ T^{-2}]$
(4) $[M^{-1}\ L^5T^2]$

Sol. Answer (3)

$$\left(P + \frac{a}{V^2}\right) = b\frac{\theta}{V}$$

Dimensionally,

$$P = \frac{a}{V^2}$$

$ML^{-1}T^{-2} \times L^6 = a \Rightarrow \boxed{a = [ML^5T^{-2}]}$

15. Which of the following dimensions will be the same as that of time?

(1) $\dfrac{L}{R}$
(2) $\dfrac{C}{L}$
(3) LC
(4) $\dfrac{R}{L}$

Sol. Answer (1)

$\dfrac{L}{R}$ = Time

16. Which pair do not have equal dimensions?

(1) Energy and torque (2) Force and impulse

(3) Angular momentum and Planck's constant (4) Elastic modulus and pressure

Sol. Answer (2)

Force → $[MLT^{-2}]$

Impulse → $[MLT^{-1}]$

17. The dimensions of Planck's constant equals to that of

(1) Energy (2) Momentum (3) Angular momentum (4) Power

Sol. Answer (3)

$E = h\nu$

$$\frac{ML^2T^{-2}}{T^{-1}} = h \Rightarrow \boxed{h = [ML^2T^{-1}]}$$

18. The dimensions of universal gravitational constant are

(1) $[M^{-1}L^3T^{-2}]$ (2) $[ML^2T^{-1}]$ (3) $[M^{-2}L^3T^{-2}]$ (4) $[M^{-2}L^2T^{-1}]$

Sol. Answer (1)

$$F = \frac{Gm_1m_2}{r^2}$$

$$\Rightarrow G = \frac{Fr^2}{m_1m_2} = \frac{MLT^{-2}\cdot L^2}{M\,M}$$

$$\Rightarrow \boxed{G = [M^{-1}L^3T^{-2}}$$

19. The ratio of the dimensions of Planck's constant and that of moment of inertia is the dimension of

(1) Time (2) Frequency (3) Angular momentum (4) Velocity

Sol. Answer (2)

$$\frac{h}{I} = \frac{ML^2T^{-1}}{ML^2} \Rightarrow [T^{-1}] \rightarrow \text{Frequency}$$

20. The velocity v of a particle at time t is given by $v = at + \frac{b}{t+c}$, where a, b and c are constants. The dimensions of a, b and c are

(1) L, LT and LT^{-2} (2) LT^{-2}, L and T (3) L^2, T and LT^2 (4) LT^2, LT and L

Sol. Answer (2)

$c = t \Rightarrow c = [T]$

$at = LT^{-1}$

$\Rightarrow \boxed{a = [LT^{-2}]}$

$\frac{b}{T} = LT^{-1}$

$\boxed{b = [L]}$

21. Dimensions of resistance in an electrical circuit, in terms of dimension of mass *M*, of length *L*, of time *T* and of current *I*, would be

(1) $[ML^2T^{-2}]$ (2) $[ML^2T^{-1}I^{-1}]$ (3) $[ML^2T^{-3}I^{-2}]$ (4) $[ML^2T^{-3}I^{-1}]$

Sol. Answer (3)

$$R = \frac{V}{I} = \frac{W/q}{I} = \frac{W}{I^2 t}$$

$$R = \frac{ML^2T^{-2}}{I^2T} \Rightarrow [ML^2T^{-3}I^{-2}]$$

$$\boxed{R = [ML^2T^{-3}I^{-2}}$$

22. If the dimensions of a physical quantity are given by $M^aL^bT^c$, then the physical quantity will be

(1) Force if $a = 0$, $b = -1$, $c = -2$ (2) Pressure if $a = 1$, $b = -1$, $c = -2$

(3) Velocity if $a = 1$, $b = 0$, $c = -1$ (4) Acceleration if $a = 1$, $b = 1$, $c = -2$

Sol. Answer (2)

For pressure, $[ML^{-1}T^{-2}]$

$a = 1$, $b = -1$, $c = -2$

23. The dimension of $\frac{1}{2}\varepsilon_0 E^2$, where ε_0 is permittivity of free space and *E* is electric field, is

(1) MLT^{-1} (2) ML^2T^{-2} (3) $ML^{-1}T^{-2}$ (4) ML^2T^{-1}

Sol. Answer (3)

Energy density $= \frac{E}{V} = \frac{1}{2}\varepsilon_0 E^2 \Rightarrow \frac{ML^2T^{-2}}{L^3} \Rightarrow \boxed{[ML^{-1}T^{-2}] = \frac{1}{2}\varepsilon_0 E^2}$

24. If *y* represents pressure and *x* represents velocity gradient, then the dimensions of $\frac{d^2y}{dx^2}$ are

(1) $[ML^{-1}T^{-2}]$ (2) $[M^2L^{-2}T^{-2}]$ (3) $[ML^{-1}T^0]$ (4) $[M^2L^{-2}T^{-4}]$

Sol. Answer (3)

$\frac{d^2y}{dx^2}$ will have dimensions of $\frac{y}{x^2}$

$y \rightarrow$ pressure, $x \rightarrow$ velocity gradient

$$x \rightarrow \frac{V}{L} \Rightarrow \frac{LT^{-1}}{L} \Rightarrow T^{-1}$$

$$\frac{y}{x^2} = \frac{ML^{-1}T^{-2}}{T^{-2}} \Rightarrow [ML^{-1}]$$

25. The unit of length, velocity and force are doubled. Which of the following is the correct change in the other units?

(1) Unit of time is doubled (2) Unit of mass is doubled

(3) Unit of momentum is doubled (4) Unit of energy is doubled

Sol. Answer (3)

$p = F \times t$

$p' = 2F \times t$

$\boxed{p' = 2p}$

26. The dimensions of $\frac{\alpha}{\beta}$ in the equation $F = \frac{\alpha - t^2}{\beta v^2}$, where F is the force, v is velocity and t is time, is

(1) $[MLT^{-1}]$ (2) $[ML^{-1}T^{-2}]$ (3) $[ML^3T^{-4}]$ (4) $[ML^2T^{-4}]$

Sol. Answer (3)

$$F = \frac{\alpha - t^2}{\beta v^2}$$

Dimensionally, $\alpha = [T^2]$

$$[MLT^{-2}] = \frac{[T^2]}{\beta[L^2T^{-2}]}$$

$$\beta = \frac{T^2}{[MLT^{-2} \cdot L^2T^{-2}]}$$

$$\Rightarrow \quad \beta = [M^{-1}L^{-3}T^6]$$

Dimensions of $\frac{\alpha}{\beta} = \frac{T^2}{M^{-1}L^{-3}T^6} = [ML^3T^{-4}]$

27. Even if a physical quantity depends upon three quantities, out of which two are dimensionally same, then the formula cannot be derived by the method of dimensions. This statement

(1) May be true (2) May be false (3) Must be true (4) Must be false

Sol. Answer (3)

This statement is completely correct. If a quantity depends upon two other quantities which are dimensionally same then formula's validity can be checked but it can't be derived by the method of dimensions.

28. The unit of “impulse per unit area” is same as that of

(1) Viscosity (2) Surface tension (3) Bulk modulus (4) Force

Sol. Answer (1)

$$\frac{\text{Impulse}}{\text{Area}} = \frac{MLT^{-1}}{L^2} \Rightarrow [ML^{-1}T^{-1}]$$

Coefficient of viscosity $\Rightarrow \eta = [ML^{-1}T^{-1}]$

So, $\frac{\text{Impulse}}{\text{Area}}$ = coefficient of viscosity

29. In a practical unit if the unit of mass becomes double and that of unit of time becomes half, then 8 joule will be equal to .... unit of work.

(1) 6 (2) 4 (3) 1 (4) 10

Sol. Answer (3)

Work $\rightarrow [ML^2T^{-2}]$

$$n_1v_1 = n_2v_2$$

$$\frac{(8)M_1L_1^2T_1^{-2}}{M_2L_2^2T_2^{-2}} = n_2$$

$$\Rightarrow \quad 8\left[\frac{M_1}{M_2}\right]\left[\frac{L_1}{L_2}\right]^2\left[\frac{T_1}{T_2}\right]^{-2} = n_2$$

$$\Rightarrow \quad 8\left[\frac{M_1}{2M_1}\right]\left[\frac{L_1}{L_1}\right]^2\left[\frac{2T_1}{T_1}\right]^{-2} = n_2$$

$$\Rightarrow \quad 8\times\frac{1}{2}\times\frac{1}{4} = n_2$$

$$\Rightarrow \quad \boxed{n_2 = 1}$$

So, unit of 8 joule = $\boxed{1\times\text{new units}}$

30. In a new system of units energy (E), density (d) and power (P) are taken as fundamental units, then the dimensional formula of universal gravitational constant G will be

(1) $[E^{-1}d^{-2}P^{2}]$ (2) $[E^{-2}d^{-1}P^{2}]$ (3) $[E^{2}d^{-1}P^{-1}]$ (4) $[E^{1}d^{-2}P^{-2}]$

Sol. Answer (2)

$G = [E^a\, d^b\, P^c]$

$E = [ML^2T^{-2}]$

$d = [ML^{-3}]$

$P = [ML^2T^{-3}]$

$G = [M^{-1}L^3T^{-2}]$

$[M^{-1}L^3T^{-2}] = [ML^2T^{-2}]^a\, [ML^{-3}]^b\, [ML^2T^{-3}]^c$

$a + b + c = -1$

$2a - 3b + 2c = 3$

$-2a - 3c = -2 \Rightarrow 2a + 3c = 2$

On solving,

$a = -2$

$b = -1$

$c = 2$

So, $\boxed{G = [E^{-2}d^{-1}P^{2}}$

31. In equation $y = x^2\cos^2 2\pi\dfrac{\beta\gamma}{\alpha}$, the units of x, α, β are m, s^{-1} and $(ms^{-1})^{-1}$ respectively. The units of y and γ are

(1) m^2, ms^{-2} (2) m, ms^{-1} (3) m^2, m (4) m, ms^{-2}

Sol. Answer (1)

$$y = x^2\cos^2 2\pi\left(\frac{\beta\gamma}{\alpha}\right)$$

The argument of a trigonometric ratio is always dimensionless.

$$\frac{\beta\gamma}{\alpha} = [M^0L^0T^0] \text{ or } \beta\gamma = \alpha \Rightarrow \gamma = \frac{T^{-1}}{L^{-1}T} \Rightarrow [LT^{-2}]$$

and $y = x^2 \Rightarrow [L^2]$

$\alpha = s^{-1} \Rightarrow [T^{-1}]$, $\beta = [LT^{-1}]^{-1} \Rightarrow [L^{-1}T]$

$\boxed{y = m^2}$ $\boxed{\gamma = ms^{-2}}$

32. A dimensionally consistent relation for the volume V of a liquid of coefficient of viscosity 'η' flowing per second, through a tube of radius r and length l and having a pressure difference P across its ends, is

(1) $V = \frac{\pi P r^4}{8\eta l}$ (2) $V = \frac{\pi\eta}{8Pr^4}$ (3) $V = \frac{8P\eta}{\pi r^4}$ (4) $V = \frac{\pi P\eta}{8r^4}$

Sol. Answer (1)

On checking the dimensionality the correct relation is

$$V = \frac{\pi P r^4}{8\eta l}$$

33. E, m, J and G denote energy, mass, angular momentum and gravitational constant respectively. The dimensions of $\frac{EJ^2}{m^5G^2}$ are same as of

(1) Angle (2) Length (3) Mass (4) Time

Sol. Answer (1)

$$\frac{EJ^2}{m^5G^2} \Rightarrow \frac{ML^2T^{-2}\cdot(ML^2T^{-1})^2}{M^5\cdot(M^{-1}L^3T^{-2})^2} = \frac{ML^2T^{-2}M^2L^4T^{-2}}{M^5M^{-2}L^6T^{-4}}$$

$\Rightarrow$ $[M^0L^0T^0]$ = Angle (Dimensionless)

34. Let P represent radiation pressure, c represent speed of light and I represent radiation energy striking a unit area per second, then $P^xI^yc^z$ will be dimensionless for

(1) $x = 0,\ y = z$ (2) $x = y = z$ (3) $x = z = -y$ (4) $x = y = -z$

Sol. Answer (3)

$P^xI^yc^z$

$P \rightarrow$ Pressure $\rightarrow [ML^{-1}T^{-2}]$

$I \rightarrow$ Intensity $\rightarrow \frac{E}{AT} \Rightarrow \frac{ML^2T^{-2}}{L^2T} \Rightarrow [MT^{-3}]$

$c \rightarrow$ Speed of light $= [LT^{-1}]$

$[M^0L^0T^0] = [ML^{-1}T^{-2}]^x\,[MT^{-3}]^y\,[LT^{-1}]^z$

$\boxed{x = -y} \Rightarrow x + y = 0,\ -x + z = 0 \Rightarrow \boxed{x = z}$

$\boxed{x = z = -y}$

35. The number of particles crossing per unit area perpendicular to Z axis per unit time is given by $N = -D\frac{(N_2 - N_1)}{(Z_2 - Z_1)}$, where N_2 and N_1 are the number of particles per unit volume at Z_2 and Z_1 respectively. What is the dimensional formula for D?

(1) $[M^0L^{-1}T^2]$ (2) $[M^0L^{-1}T^{-1}]$ (3) $[M^0L^2T^{-1}]$ (4) $[M^0L^2T^2]$

Sol. Answer (3)

$$N = -D\frac{(N_2 - N_1)}{(Z_2 - Z_1)}$$

Dimensionally,

$$D = \frac{N(Z_2 - Z_1)}{(N_2 - N_1)}$$

Given,

$N_2, N_1 \rightarrow$ Number of particles per unit volume.

$$N_2, N_1 \rightarrow \frac{N}{V} \Rightarrow [L^{-3}]$$

$$Z_2 - Z_1 \rightarrow [L]$$

$$N \rightarrow \frac{\text{Number of particles}}{\text{Area} \cdot (T)}$$

$$N \rightarrow [L^{-2}T^{-1}]$$

So, $D = \dfrac{L^{-2}T^{-1} \times L}{L^{-3}} \Rightarrow [L^2T^{-1}]$

36. The frequency of vibrations f of a mass m suspended from a spring of spring constant K is given by a relation of type $f = cm^xK^y$, where c is a dimensionless constant. The values of x and y are

(1) $x = \frac{1}{2},\ y = \frac{1}{2}$

(2) $x = \frac{-1}{2},\ y = \frac{-1}{2}$

(3) $x = \frac{1}{2},\ y = \frac{-1}{2}$

(4) $x = \frac{-1}{2},\ y = \frac{1}{2}$

Sol. Answer (4)

$f \rightarrow$ Frequency $\rightarrow [T^{-1}]$

$m \rightarrow$ Mass $\rightarrow [M]$

$c \rightarrow$ Constant

$$K = \frac{f}{x} = \frac{MLT^{-2}}{L} \Rightarrow [MT^{-2}]$$

$$[M^0L^0T^{-1}] = c[M^x\ M^y\ T^{-2y}]$$

$$x + y = 0, \qquad -2y = -1$$

$$\Rightarrow \boxed{x = \frac{-1}{2}} \qquad \Rightarrow \boxed{y = \frac{1}{2}}$$

37. The equation of a stationary wave is $y = 2A\sin\left(\frac{2\pi ct}{\lambda}\right)\cos\left(\frac{2\pi x}{\lambda}\right)$. Which of the following statements is incorrect?

(1) The unit of ct is same as that of λ

(2) The unit of x is same as that of λ

(3) The unit of $\frac{2\pi c}{\lambda}$ is same as that of $\frac{2\pi x}{\lambda t}$

(4) The unit of $\frac{c}{\lambda}$ is same as that of $\frac{x}{\lambda}$

Sol. Answer (4)

$$y = 2A\sin\left(\frac{2\pi ct}{\lambda}\right)\cos\left(\frac{2\pi x}{\lambda}\right)$$

$$\frac{ct}{\lambda} = \text{dimensionless} \Rightarrow \boxed{ct = \lambda}$$

$$\frac{x}{\lambda} = \text{dimensionless} \Rightarrow \boxed{x = \lambda}$$

38. If energy *E*, velocity *V* and time *T* are taken as fundamental units, the dimensional formula for surface tension is

(1) $[EV^{-2}T^{-2}]$ (2) $[E^{-2}VT^{-2}]$ (3) $[E^{-2}V^{-2}T]$ (4) $[E^{-2}V^{-2}T^{-2}]$

Sol. Answer (1)

Surface tension = $\frac{\text{Force}}{\text{Length}} = \frac{MLT^{-2}}{L} \Rightarrow [MT^{-2}]$

Surface tension = $[MT^{-2}]$

$E \rightarrow [ML^2T^{-2}]$

$V \rightarrow [LT^{-1}]$

$T \rightarrow [T]$

Surface tension = $[E^a V^b T^c]$

$[MT^{-2}] = [ML^2T^{-2}]^a [LT^{-1}]^b [T]^c$

On comparing,

$\boxed{a = 1}$, $2a + b = 0$

$\Rightarrow 2 + b = 0$

$\Rightarrow \boxed{b = -2}$

$-2a - b + c = -2$

$\Rightarrow -2 + 2 + c = -2$

$\Rightarrow \boxed{c = -2}$

Surface tension = $[EV^{-2}T^{-2}]$

39. If force *F*, area *A* and density *D* are taken as the fundamental units, the representation of Young's modulus '*Y*' will be

(1) $[F^{-1}A^{-1}D^{-1}]$ (2) $[FA^{-2}D^2]$ (3) $[FA^{-1}D]$ (4) $[FA^{-1}D^0]$

Sol. Answer (4)

Young's modulus = $\frac{\text{Stress}}{\text{Strain}} = [ML^{-1}T^{-2}]$

$F \rightarrow [MLT^{-2}]$

$A \rightarrow [L^2]$

$D \rightarrow [ML^{-3}]$

$[ML^{-1}T^{-2}] = [MLT^{-2}]^a [L^2]^b [ML^{-3}]^c$

$a + c = 1$, $a + 2b - 3c = -1$

$\Rightarrow \boxed{a = 1 - c}$ $\Rightarrow -2 = -2a - 3c$

$\Rightarrow 2 = 2a + 3c$

$\Rightarrow 2 = 2 - 2c + 3c$

$\Rightarrow 0 = +c \Rightarrow \boxed{c = 0}$

$\therefore \boxed{a = 1}$

$1 + 2b = -1$

$2b = -2$

$\Rightarrow \boxed{b = -1}$

Young's modulus = $[FA^{-1}D^0]$

40. If velocity, time and force (V, T & F) are considered as fundamental quantities, the dimensional formula for mass will be

(1) [FTV] (2) $[F^{-1}TV]$ (3) $[FTV^{-1}]$ (4) $[FT^{-1}V]$

Sol. Answer (3)

$M \rightarrow$ Mass $\rightarrow$ [M]

$V \rightarrow$ Velocity $\rightarrow$ $[LT^{-1}]$

$T \rightarrow$ Time $\rightarrow$ [T]

$F \rightarrow$ Force $\rightarrow$ $[MLT^{-2}]$

$[M] = [MLT^{-2}]^a\,[LT^{-1}]^b\,[T]^c$

$\boxed{a=1}$, $a + b = 0$, $-2a - b + c = 0$

$\Rightarrow \boxed{b=-1}$ $\Rightarrow -2 + 1 + c = 0$

$\Rightarrow \boxed{c=1}$

$\boxed{M=[FV^{-1}T]}$

41. If the error in the measurement of radius of a sphere is 2%, then the error in the determination of volume of the sphere will be

(1) 2% (2) 4% (3) 6% (4) 8%

Sol. Answer (3)

Volume of sphere = $\frac{4}{3}\pi R^3$

$$\Rightarrow \frac{\Delta V}{V}\times 100\% = 3\times\frac{\Delta R}{R}\times 100\%$$

$$= 3 \times 2\%$$

$$\Rightarrow \boxed{\frac{\Delta V}{V}\times 100\% = 6\%}$$

42. Percentage errors in the measurement of mass and speed are 2% and 3% respectively. The error in the estimate of kinetic energy obtained by measuring mass and speed will be

(1) 8% (2) 2% (3) 12% (4) 10%

Sol. Answer (1)

$\text{KE} = \frac{1}{2}MV^2$

$$\Rightarrow \frac{\Delta K}{K}\times 100\% = \frac{\Delta M}{M}\times 100\% + \frac{2\Delta V}{V}\times 100\%$$

$$= 2\% + 2 \times 3\%$$

$$\Rightarrow \boxed{\frac{\Delta K}{K}\times 100\% = 8\%}$$

43. The density of a cube is measured by measuring its mass and length of its sides. If the maximum error in the measurement of mass and lengths are 3% and 2% respectively, the maximum error in the measurement of density would be

(1) 12% (2) 14% (3) 7% (4) 9%

Sol. Answer (4)

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

$$\frac{\Delta d}{d}\times 100\% = \frac{\Delta m}{m}\times 100\% + \frac{3\Delta l}{l}\times 100\%$$

$$= 3\% + 3 \times 2\%$$

$$\boxed{\frac{\Delta d}{d}\times 100\% = 9\%}$$

44. A set of defective observation of weights is used by a student to find the mass of an object using a physical balance. A large number of readings will reduce

(1) Random error
(2) Systematic error
(3) Random as well as systematic error
(4) Neither random nor systematic error

Sol. Answer (1)

Random errors can be reduced by taking a large number of observations.

45. A force F is applied on a square area of side L. If the percentage error in the measurement of L is 2% and that in F is 4%, what is the maximum percentage error in pressure?

(1) 2%
(2) 4%
(3) 6%
(4) 8%

Sol. Answer (4)

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

$$\frac{\Delta P}{P}\times 100\% = \frac{\Delta F}{F}\times 100\% + \frac{2\Delta L}{L}\times 100\%$$

$$= 4\% + 2 \times 2\%$$

$$\boxed{\frac{\Delta P}{P}\times 100\% = 8\%}$$

46. The radius of a sphere is (5.3 ± 0.1) cm. The percentage error in its volume is

(1) $\frac{0.1}{5.3}\times 100$
(2) $3\times\frac{0.1}{5.3}\times 100$
(3) $\frac{3}{2}\times\frac{0.1}{5.3}\times 100$
(4) $6\times\frac{0.1}{0.3}\times 100$

Sol. Answer (2)

$$r = (5.3 \pm 0.1)\text{ cm}$$

$$V = \frac{4}{3}\pi r^3$$

$$\frac{\Delta V}{V}\times 100\% = \frac{3\Delta r}{r}\times 100\%$$

$$\boxed{\frac{\Delta V}{V}\times 100\% = \frac{3\times 0.1}{5.3}\times 100}$$

47. If the percentage error in the measurement of momentum and mass of an object are 2% and 3% respectively, then maximum percentage error in the calculated value of its kinetic energy is

(1) 2% (2) 1% (3) 5% (4) 7%

Sol. Answer (4)

$$\text{KE} = \frac{\text{Momentum}}{\text{Mass}} = \frac{p^2}{2m}$$

$$\frac{\Delta K}{K} \times 100\% = \left(\frac{2\Delta p}{p} \times 100\right)\% + \left(\frac{\Delta m}{m} \times 100\right)\%$$

$$= 2 \times 2\% + 3\%$$

$$\boxed{\frac{\Delta K}{K} \times 100\% \Rightarrow 7\%}$$

48. The acceleration due to gravity is measured on the surface of earth by using a simple pendulum. If α and β are relative errors in the measurement of length and time period respectively, then percentage error in the measurement of acceleration due to gravity is

(1) $\left(\alpha + \frac{1}{2}\beta\right) \times 100$ (2) $(\alpha - 2\beta)$ (3) $(2\alpha + \beta) \times 100$ (4) $(\alpha + 2\beta) \times 100$

Sol. Answer (4)

$$T = 2\pi\sqrt{\frac{L}{g}}$$

$$\Rightarrow \quad T^2 = 4\pi^2 \frac{L}{g}$$

$$\frac{\Delta g}{g} \times 100\% = \frac{\Delta L}{L} \times 100\% + \frac{2\Delta T}{T} \times 100\%$$

$$\boxed{\frac{\Delta g}{g} \times 100\% = (\alpha + 2\beta) \times 100}$$

49. A public park, in the form of a square, has an area of (100 ± 0.2) m^2. The side of park is

(1) (10 ± 0.01) m (2) (10 ± 0.1) m (3) (10 ± 0.02) m (4) (10 ± 0.2) m

Sol. Answer (1)

$$A = (100 \pm 0.2)\ \text{m}^2$$

$$100 = l^2 \Rightarrow \boxed{l = 10\ \text{m}}$$

$$\frac{\Delta A}{A} = \frac{2\Delta l}{l}$$

$$\frac{0.2}{100} = 2 \times \frac{\Delta l}{10}$$

$$\Rightarrow \quad \boxed{\Delta l = 0.01\ \text{m}}$$

So, length = (10 ± 0.01) m

50. A physical quantity is represented by $X = [M^aL^bT^{-c}]$. If percentage error in the measurement of M, L and T are α%, β% and γ% respectively, then maximum percentage error in measurement of X should be (Given that α, β and γ are very small)

(1) $(\alpha a - \beta b + \gamma c)$% (2) $(\alpha a + \beta b + \gamma c)$% (3) $(\alpha a - \beta b - \gamma c)$% (4) $(\alpha a + \beta b - \gamma c)$%

Sol. Answer (2)

$X = [M^aL^bT^{-c}]$

$$\frac{\Delta X}{X}\times 100\% = \frac{a\Delta M}{M}\times 100\% + \frac{b\Delta L}{L}\times 100\% + \frac{c\Delta T}{T}\times 100\%$$

$$\Rightarrow \boxed{\frac{\Delta X}{X}\times 100\% = (a\alpha + b\beta + c\gamma)\%}$$

51. The least count of a stop watch is $\frac{1}{5}$ second. The time of 20 oscillations of a pendulum is measured to be 25 seconds. The maximum percentage error in the measurement of time will be

(1) 0.1% (2) 0.8% (3) 1.8% (4) 8%

Sol. Answer (2)

Least count = $\Delta T = \frac{1}{5}$ s = 0.2 s

$T = 25$ s

Percentage error = $\frac{\Delta T}{T}\times 100\% = \frac{0.2}{25}\times 100\% = 0.8\%$

52. A student measures the distance traversed in free fall of a body, initially at rest in a given time. He uses this data to estimate g, the acceleration due to gravity. If the maximum percentage errors in measurement of the distance and the time are e_1 and e_2 respectively, the maximum percentage error in the estimation of g is

(1) $e_2 - e_1$ (2) $e_1 + 2e_2$ (3) $e_1 + e_2$ (4) $e_1 - 2e_2$

Sol. Answer (2)

$g = LT^{-2}$

$$\frac{\Delta g}{g} = \frac{\Delta L}{L} = \frac{2\Delta T}{T}$$

$$\Rightarrow \boxed{\frac{\Delta g}{g} = e_1 + 2e_2}$$

SECTION - C

Previous Years Questions

1. The pair of quantities having same dimensions is

(1) Young's modulus and Energy (2) Impulse and Surface Tension

(3) Angular momentum and Work (4) Work and Torque

Sol. Answer (4)

Work = Force × Displacement

$$\boxed{W = [ML^2T^{-2}}$$

Torque = Perpendicular distance × Force = $[ML^2T^{-2}]$

2. The damping force on an oscillator is directly proportional to the velocity. The units of the constant of proportionality are

(1) kgs^{-1} (2) kgs (3) $kgms^{-1}$ (4) $kgms^{-2}$

Sol. Answer (1)

$$F \propto v \quad \Rightarrow \quad F = bv$$

$$\Rightarrow \quad b = \frac{F}{v} = \frac{kgms^{-2}}{ms^{-1}} = kgs^{-1}$$

3. The dimensions of $(\mu_0\varepsilon_0)^{-1/2}$ are

(1) $[L^{1/2}T^{-1/2}]$ (2) $[L^{-1}T]$ (3) $[LT^{-1}]$ (4) $[L^{1/2}T^{1/2}]$

Sol. Answer (3)

Speed of light $c = \dfrac{1}{\sqrt{\mu_0\varepsilon_0}}$

$$\Rightarrow \quad c = (\mu_0\varepsilon_0)^{-1/2}$$

So, dimensional formula of $(\mu_0\varepsilon_0)^{-1/2}$

4. The dimensions of μ_0 are

(1) $\left[M^1 L^{-\frac{1}{2}} T^{\frac{1}{2}}\right]$ (2) $\left[M^1 L^{\frac{1}{2}} T^{-\frac{1}{2}}\right]$ (3) $[L^{-1}T]$ (4) $[M^1L^1T^{-2}A^{-2}]$

Sol. Answer (4)

$$\frac{1}{\sqrt{\mu_0\varepsilon_0}} = LT^{-1}$$

$$\Rightarrow \quad \frac{1}{\mu_0\varepsilon_0} = L^2T^{-2}$$

$$\Rightarrow \quad \mu_0 = \frac{1}{L^2T^{-2}\varepsilon_0}$$

$$\Rightarrow \quad \mu_0 = \frac{1}{L^2T^{-2}}[ML^3T^{-4}A^{-2}]$$

$$\Rightarrow \quad \boxed{\mu_0 = [MLT^{-2}A^{-2}}$$

5. The density of a material in CGS system of units is 4 g/cm^3. In a system of units in which unit of length is 10 cm and unit of mass is 100 g, the value of density of material will be

(1) 400 (2) 0.04 (3) 0.4 (4) 40

Sol. Answer (4)

Density, $n_1u_1 = n_2u_2$

$$\Rightarrow \quad \frac{4\ g}{cm^3} = n_2 \times \frac{100\ g}{10^3\ cm^3}$$

$$\Rightarrow \quad \boxed{n_2 = 40}$$

6. What is the dimension of surface tension?

(1) $[ML^1T^0]$ (2) $[ML^1T^{-1}]$ (3) $[ML^0T^{-2}]$ (4) $[M^1L^0T^{-2}]$

Sol. Answer (3, 4)

Surface tension = $\frac{F}{L} = \frac{MLT^{-2}}{L} = [MT^{-2}]$

7. Which two of the following five physical parameters have the same dimensions?

(a) Energy density (b) Refractive index

(c) Dielectric constant (d) Young's modulus

(e) Magnetic field

(1) (a) and (e) (2) (b) and (d) (3) (c) and (e) (4) (a) and (d)

Sol. Answer (4)

Refractive index and dielectric constant are dimensional constant

Energy density = $\frac{ML^2T^{-2}}{L^3} = [ML^{-1}T^{-2}]$

Young's modulus = $\frac{MLT^{-2}}{L^2} = [ML^{-1}T^{-2}]$

So, (d) & (a)

8. In an experiment four quantities a, b, c and d are measured with percentage error 1%, 2%, 3% and 4% respectively. Quantity P is calculated as follows : $P = \frac{a^3b^2}{cd}$

% error in P is

(1) 10% (2) 7% (3) 4% (4) 14%

Sol. Answer (4)

$$P = \frac{a^3b^2}{cd}$$

$$\frac{\Delta P}{P} \times 100\% = \left(\frac{3\Delta a}{a} + \frac{2\Delta b}{b} + \frac{\Delta c}{c} + \frac{\Delta d}{d}\right) \times 100\%$$

$$= 14\%$$

9. If the error in the measurement of radius of a sphere is 2%, then the error in the determination of volume of the sphere will be

(1) 2% (2) 4% (3) 6% (4) 8%

Sol. Answer (3)

Volume of sphere = $\frac{4}{3}\pi R^3$

$$\Rightarrow \frac{\Delta V}{V} \times 100\% = 3 \times \frac{\Delta R}{R} \times 100\% = 3 \times 2\%$$

$$\Rightarrow \boxed{\frac{\Delta V}{V} \times 100\% = 6\%}$$

10. Which of the following has the dimensions of pressure?

(1) $[MLT^{-2}]$ (2) $[ML^{-1}T^{-2}]$ (3) $[ML^{-2}T^{-2}]$ (4) $[M^{-1}L^{-1}]$

Sol. Answer (2)

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}} = \frac{MLT^{-2}}{L^2} \Rightarrow [ML^{-1}T^{-2}]$$

$$\boxed{P = [ML^{-1}T^{-2}}$$

11. Percentage errors in the measurement of mass and speed are 2% and 3% respectively. The error in the estimate of kinetic energy obtained by measuring mass and speed will be

(1) 8% (2) 2% (3) 12% (4) 10%

Sol. Answer (1)

$$\text{KE} = \frac{1}{2}MV^2$$

$$\Rightarrow \frac{\Delta K}{K}\times 100\% = \frac{\Delta M}{M}\times 100\% + \frac{2\Delta V}{V}\times 100\%$$

$$= 2\% + 2 \times 3\%$$

$$\Rightarrow \boxed{\frac{\Delta K}{K}\times 100\% = 8\%}$$

12. Which of the following is a dimensional constant?

(1) Relative density (2) Gravitational constant (3) Refractive index (4) Poisson's ratio

Sol. Answer (2)

Dimensional constant $[G] = [M^{-1}L^3T^{-2}]$

13. The dimensions of *RC* is

(1) Square of time (2) Square of inverse time (3) Time (4) Inverse time

Sol. Answer (3)

RC = Time

14. The dimensions of impulse are equal to that of

(1) Pressure (2) Linear momentum (3) Force (4) Angular momentum

Sol. Answer (2)

Impulse = $\Delta p \Rightarrow [MLT^{-1}]$

15. The density of a cube is measured by measuring its mass and length of its sides. If the maximum error in the measurement of mass and lengths are 3% and 2% respectively, the maximum error in the measurement of density would be

(1) 12% (2) 14% (3) 7% (4) 9%

Sol. Answer (4)

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

$$\frac{\Delta d}{d}\times 100\% = \frac{\Delta m}{m}\times 100\% + \frac{3\Delta l}{l}\times 100\%$$

$$= 3\% + 3 \times 2\%$$

$$\boxed{\frac{\Delta d}{d}\times 100\% = 9\%}$$

16. An equation is given here $\left(P+\frac{a}{V^2}\right)=b\frac{\theta}{V}$ where$P$ = Pressure, V = Volume and θ = Absolute temperature. If a and b are constants, the dimensions of a will be

(1) $[\mathrm{ML}^{-5}\,\mathrm{T}^{-1}]$ (2) $[\mathrm{ML}^{5}\,\mathrm{T}^{1}]$ (3) $[\mathrm{ML}^{5}\,\mathrm{T}^{-2}]$ (4) $[\mathrm{M}^{-1}\,\mathrm{L}^{5}\mathrm{T}^{2}]$

Sol. Answer (3)

$$\left(P+\frac{a}{V^2}\right)=b\frac{\theta}{V}$$

Dimensionally,

$$P=\frac{a}{V^2}$$

$\mathrm{ML}^{-1}\mathrm{T}^{-2}\times\mathrm{L}^6=a$

$\Rightarrow\ \boxed{a=[\mathrm{ML}^5\mathrm{T}^{-2}]}$

17. Which of the following dimensions will be the same as that of time?

(1) $\frac{L}{R}$ (2) $\frac{C}{L}$ (3) LC (4) $\frac{R}{L}$

Sol. Answer (1)

$\frac{L}{R}=\text{Time}$

18. The dimensional formula of magnetic flux is

(1) $[\mathrm{M}^0\mathrm{L}^{-2}\mathrm{T}^2\mathrm{A}^{-2}]$ (2) $[\mathrm{ML}^0\mathrm{T}^{-2}\mathrm{A}^{-2}]$ (3) $[\mathrm{ML}^2\mathrm{T}^{-2}\mathrm{A}^{-1}]$ (4) $[\mathrm{ML}^2\mathrm{T}^{-1}\mathrm{A}^3]$

Sol. Answer (3)

$$\phi = BA = \frac{F}{qv}\times A \qquad [F=qvB]$$

$$= \frac{\mathrm{MLT}^{-2}}{\mathrm{AT}\cdot\mathrm{LT}^{-2}}\times\mathrm{L}^2 = [\mathrm{ML}^2\mathrm{T}^{-2}\mathrm{A}^{-1}]$$

19. Which pair do not have equal dimensions?

(1) Energy and torque (2) Force and impulse

(3) Angular momentum and Planck's constant (4) Elastic modulus and pressure

Sol. Answer (2)

Force = $[\mathrm{MLT}^{-2}]$

Impulse = Force × Time $\Rightarrow [\mathrm{MLT}^{-1}]$

20. The dimensions of Planck's constant equals to that of

(1) Energy (2) Momentum (3) Angular momentum (4) Power

Sol. Answer (3)

$E=h\nu$

$$\frac{\mathrm{ML}^2\mathrm{T}^{-2}}{\mathrm{T}^{-1}}=h\ \Rightarrow\ \boxed{h=[\mathrm{ML}^2\mathrm{T}^{-1}]}$$

Angular momentum $= mvr = \mathrm{MLT}^{-1}\mathrm{L}$

$\boxed{L=[\mathrm{ML}^2\mathrm{T}^{-1}]}$

21. The dimensions of universal gravitational constant are

(1) $[M^{-1}L^{3}T^{-2}]$ (2) $[ML^{2}T^{-1}]$ (3) $[M^{-2}L^{3}T^{-2}]$ (4) $[M^{-2}L^{2}T^{-1}]$

Sol. Answer (1)

Gravitational constant = $[M^{-1}L^{3}T^{-2}]$

22. The ratio of the dimensions of Planck's constant and that of moment of inertia is the dimension of

(1) Time (2) Frequency (3) Angular momentum (4) Velocity

Sol. Answer (2)

$$\frac{h}{I}=\frac{ML^{2}T^{-1}}{ML^{2}} \Rightarrow [T^{-1}] \rightarrow \text{Frequency}$$

23. The velocity v of a particle at time t is given by $v=at+\frac{b}{t+c}$, where a, b and c are constants. The dimensions of a, b and c are

(1) L, LT and LT $^{-2}$ (2) LT $^{-2}$, L and T (3) L^2, T and LT^2 (4) LT^2, LT and L

Sol. Answer (2)

$$v=at+\frac{b}{t+c}$$

By the principle of homogeneity,

$c = t = [T]$

$at = v \Rightarrow a = [LT^{-2}]$

$\frac{b}{T}=LT^{-1} \Rightarrow b = [L]$

24. Dimensions of resistance in an electrical circuit, in terms of dimension of mass M, of length L, of time T and of current I, would be

(1) $[ML^{2}T^{-2}]$ (2) $[ML^{2}T^{-1}I^{-1}]$ (3) $[ML^{2}T^{-3}I^{-2}]$ (4) $[ML^{2}T^{-3}I^{-1}]$

Sol. Answer (3)

$$V = IR \Rightarrow R=\frac{V}{I}=\frac{W}{qI}=\frac{ML^{2}T^{-2}}{AT\cdot A} \Rightarrow \boxed{R=[ML^{2}T^{-3}A^{-2}]}$$

25. If the dimensions of a physical quantity are given by $M^aL^bT^c$, then the physical quantity will be

(1) Force if $a = 0$, $b = -1$, $c = -2$ (2) Pressure if $a = 1$, $b = -1$, $c = -2$

(3) Velocity if $a = 1$, $b = 0$, $c = -1$ (4) Acceleration if $a = 1$, $b = 1$, $c = -2$

Sol. Answer (2)

Pressure = $[ML^{-1}T^{-2}]$

26. The dimension of $\frac{1}{2}\varepsilon_0E^2$, where ε_0 is permittivity of free space and E is electric field, is

(1) MLT^{-1} (2) $ML^{2}T^{-2}$ (3) $ML^{-1}T^{-2}$ (4) $ML^{2}T^{-1}$

Sol. Answer (3)

$$\text{Energy density} = \frac{E}{V} = \frac{1}{2}\varepsilon_0E^2 \Rightarrow \frac{ML^{2}T^{-2}}{L^{3}} \Rightarrow \boxed{[ML^{-1}T^{-2}]=\frac{1}{2}\varepsilon_0E^2}$$

SECTION - D

Assertion-Reason Type Questions

1. A : Shake and light year, both measure time.

   R : Both have dimension of time.

Sol. Answer (4)

Shake → Unit of time

Light year → Unit of length

2. A : Displacement gradient is a dimensionless quantity.

   R : Displacement is dimensionless quantity.

Sol. Answer (3)

Displacement gradient = $\dfrac{\text{Displacement}}{\text{Length}} \Rightarrow$ Dimensionless

But displacement is not dimensionless.

3. A : Absolute error in a physical quantity can be positive, negative or zero.

   R : Absolute error is the difference in measured value and true value of physical quantity.

Sol. Answer (4)

Absolute error is always positive as it is $|\text{true value} - \text{measured value}|$

4. A : A unitless physical quantity must be dimensionless.

   R : A pure number is always dimensionless.

Sol. Answer (2)

If a quantity doesnot have units so definitely it will be dimensionless but reverse is not true.

Pure number → also dimensionless.

5. A : Absolute error is unitless and dimensionless.

   R : All type of errors are unitless and dimensionless.

Sol. Answer (4)

Absolute error is not dimensionless rather it will having dimensions of the measured quantity.

6. A : Higher is the accuracy of measurement, if instrument have smaller least count.

   R : Smaller the percentage error, higher is the accuracy of measurement.

Sol. Answer (2)

Higher accuracy means higher precisions.

So, error will be very smaller.

Low least count means low error and hence high accuracy.

7. A : The maximum possible error in a reading is taken as least count of the measuring instrument.

   R : Error in a measurement cannot be greater than least count of the measuring instrument.

Sol. Answer (3)

The assertion is true as least count is the maximum possible error in the measurement.

But the error can be greater than least count it will depend upon power of quantity.

8. A : In a measurement, two readings obtained are 20.004 and 20.0004. The second measurement is more precise.

   R : Measurement having more decimal places is more precise.

Sol. Answer (1)

The precisions is decided by the more number of decimal places so, 20.0004 is more precise.

9. A : Out of the measurements $A = 20.00$ and $B = 20.000$, B is more accurate.

R : Percentage error in B is less than the percentage error in A.

Sol. Answer (1)

Out of 20.00 and 20.000

The second measurement is more precise and more accurate also. The percentage error in second reading is less.

$$\frac{0.01}{20.00}\times 100 \Rightarrow \frac{1}{20} = 0.05\%$$

$$\frac{0.001}{20.000}\times 100 \Rightarrow 0.0005\%$$

10. A : When we change the unit of a measurement of a quantity, its numerical value changes.

R : The product of numerical value of the physical quantity and unit for a quantity remain constant.

Sol. Answer (1)

Numerical value × Unit = constant

11. A : All physically correct equations are dimensionally correct.

R : All dimensionally correct equations are physically correct.

Sol. Answer (3)

If an equation is physically correct it has to be dimensionally correct also.

But the reverse is not true.

12. A : Physical relations involving addition and subtraction cannot be derived by dimensional analysis.

R : Numerical constants cannot be deduced by the method of dimensions.

Sol. Answer (2)

Those equations carrying multiplication and divisions of physical quantities can be derived but not valid for addition or subtraction.

13. A : If displacement y of a particle executing simple harmonic motion depends upon amplitude a angular frequency ω and time t then the relation $y = a \sin\omega t$ cannot be dimensionally achieved.

R : An equation cannot be achieved by dimensional analysis; if it contains dimensionless expressions.

Sol. Answer (1)

Assertion and reason is correct and correctly explains assertion.

14. A : An exact number has infinite number of significant digits.

R : A number, which is not a measured value has infinite number of significant digits.

Sol. Answer (2)

An exact number contains infinite number of significant figures.

15. A : A dimensionless quantity may have unit.

R : Two physical quantities having same dimensions, may have different units.

Sol. Answer (2)

Dimensionless quantity may have unit. for example, angle.

Also two quantities having same dimensions may have different units.

Work → ML^2T^{-2} → Joule

Torque → ML^2T^{-2} → Nm

❑ ❑ ❑

Chapter 3

Motion in a Straight Line

Solutions

SECTION - A

Objective Type Questions

1. A body in one dimensional motion has zero speed at an instant. At that instant, it must have

(1) Zero velocity (2) Zero acceleration

(3) Non-zero velocity (4) Non-zero acceleration

Sol. Answer (1)

Magnitude of velocity = Speed

So, if the speed is zero then it must have zero velocity also.

2. A particle is moving along a circle such that it completes one revolution in 40 seconds. In 2 minutes 20 seconds, the ratio $\frac{|\text{displacement}|}{\text{distance}}$ is

(1) 0 (2) $\frac{1}{7}$ (3) $\frac{2}{7}$ (4) $\frac{1}{11}$

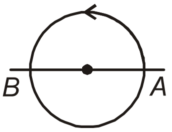
Sol. Answer (4)

$T = 40$ s

If t = 2 minute 20 second

= 2 × 60 + 20

= 140 s



So, it has completed $3\frac{1}{2}$ revolution.

Distance travelled $= 3 \times 2\pi R + \pi R$

$= 7\pi R$

Displacement = $2R$

$$\frac{|\text{Displacement}|}{\text{Distance}} = \frac{2R}{7\pi R} = \frac{2}{7\times\frac{22}{7}} = \frac{1}{11}$$

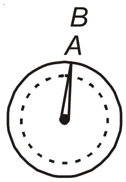
3. Consider the motion of the tip of the second hand of a clock. In one minute (R be the length of second hand), its

(1) Displacement is $2\pi R$ (2) Distance covered is $2R$

(3) Displacement is zero (4) Distance covered is zero

Sol. Answer (3)

The second hand of the clock in minute covers an angle of 360º and the initial and final positions are same.



So, $\boxed{\text{Displacement} = 0}$

4. The position of a body moving along x-axis at time t is given by $x = (t^2 - 4t + 6)$ m. The distance travelled by body in time interval $t = 0$ to $t = 3$ s is

(1) 5 m (2) 7 m (3) 4 m (4) 3 m

Sol. Answer (1)

$x = t^2 - 4t + 6$

$$\frac{dx}{dt} = 2t - 4$$

At $t = 2$ s, particle is at rest and reverses its position so,

$$\left.\begin{array}{l} x|_{t=0} = 6\text{ m} \\ x|_{t=2\text{ s}} = 2\text{ m} \\ x|_{t=3\text{ s}} = 3\text{ m} \end{array}\right. \begin{array}{l} \left.\right] 4\text{ m} \\ \left.\right] 1\text{ m} \end{array}$$

Distance = (4 + 1) m = 5 m

Displacement = 3 m

5. If a particle is moving along straight line with increasing speed, then

(1) Its acceleration is negative (2) Its acceleration may be decreasing

(3) Its acceleration is positive (4) Both (2) & (3)

Sol. Answer (2)

If the speed of body is increasing then acceleration is in the direction of velocity.

It may be positive or negative.

If acceleration is in negative direction then acceleration is increasing but in negative side, so it will be called as decreasing.

6. At any instant, the velocity and acceleration of a particle moving along a straight line are v and a. The speed of the particle is increasing if

(1) $v > 0, a > 0$ (2) $v < 0, a > 0$ (3) $v > 0, a < 0$ (4) $v > 0, a = 0$

Sol. Answer (1)

For increasing speed both velocity (v) and acceleration (a) are in the same direction.

7. A particle moves along x-axis with speed 6 m/s for the first half distance of a journey and the second half distance with a speed 3 m/s. The average speed in the total journey is

(1) 5 m/s (2) 4.5 m/s (3) 4 m/s (4) 2 m/s

Sol. Answer (3)

If a body travels equal distance with speed v_1 and v_2 then average speed is given by

$$v_{av} = \frac{2v_1v_2}{v_1+v_2} = \frac{2\times6\times3}{6+3} = 4 \text{ ms}^{-1}$$

8. If magnitude of average speed and average velocity over a time interval are same, then

(1) The particle must move with zero acceleration

(2) The particle must move with non-zero acceleration

(3) The particle must be at rest

(4) The particle must move in a straight line without turning back

Sol. Answer (4)

The magnitude of average speed and average velocity can only be equal if object moves in a straight line without turning back. In that condition distance will be equal to displacement.

9. If v is the velocity of a body moving along x-axis, then acceleration of body is

(1) $\frac{dv}{dx}$ (2) $v\frac{dv}{dx}$ (3) $x\frac{du}{dx}$ (4) $v\frac{dx}{dv}$

Sol. Answer (2)

$$a = \frac{dv}{dt} = \frac{dv}{dx}\frac{dx}{dt} \qquad \left(\frac{dx}{dt} = \text{velocity}\right)$$

$$\boxed{a = \frac{vdv}{dx}}$$

10. If a body is moving with constant speed, then its acceleration

(1) Must be zero (2) May be variable (3) May be uniform (4) Both (2) & (3)

Sol. Answer (2)

Acceleration is the rate of change of velocity. The magnitude of velocity (*i.e.,* speed) is constant but it may change in direction. So, acceleration may be variable due to change in direction.

11. When the velocity of body is variable, then

(1) Its speed may be constant (2) Its acceleration may be constant

(3) Its average acceleration may be constant (4) All of these

Sol. Answer (4)

If velocity is changing they may change in magnitude or direction or both.

(i) So, if velocity is changing in direction only the magnitude is constant so speed is constant.

(ii) If only direction of velocity is changing and magnitude is constant then acceleration will also be constant in magnitude (in case of uniform circular motion).

(iii) Average acceleration may be constant.

$$a_{av} = \frac{v_2 - v_1}{t_2 - t_1}$$

12. An object is moving with variable speed, then

(1) Its velocity may be zero
(2) Its velocity must be variable
(3) Its acceleration may be zero
(4) Its velocity may be constant

Sol. Answer (2)

If speed is changing then velocity must change.

13. The position of a particle moving along x-axis is given by $x = 10t - 2t^2$. Then the time (t) at which it will momently come to rest is

(1) 0
(2) 2.5 s
(3) 5 s
(4) 10 s

Sol. Answer (2)

$x = 10t - 2t^2$

$$v = \frac{dx}{dt} = 10 - 4t$$

$v = 0$, at the time of coming to rest, so

$10 - 4t = 0$

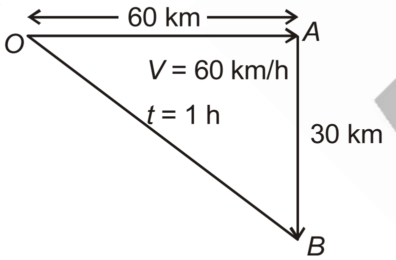
$\boxed{t = 2.5 \text{ s}}$

14. A car moves with speed 60 km/h for 1 hour in east direction and with same speed for 30 min in south direction. The displacement of car from initial position is

(1) 60 km
(2) $30\sqrt{3}$ km
(3) $30\sqrt{5}$ km
(4) $60\sqrt{2}$ km

Sol. Answer (3)

Displacement of car = $\sqrt{60^2 + 30^2} = 30\sqrt{5}$ km



$$\left[\begin{array}{l}\text{Distance } OA = \text{Speed} \times \text{Time} \\ \Rightarrow 60 \times 1 \text{ h} = 60 \text{ km}\end{array}\right]$$

15. A person travels along a straight road for the first $\frac{t}{3}$ time with a speed v_1 and for next $\frac{2t}{3}$ time with a speed v_2. Then the mean speed v is given by

(1) $v = \frac{v_1 + 2v_2}{3}$
(2) $\frac{1}{v} = \frac{1}{3v_1} + \frac{2}{3v_2}$
(3) $v = \frac{1}{3}\sqrt{2v_1 v_2}$
(4) $v = \sqrt{\frac{3v_2}{2v_1}}$

Sol. Answer (1)

$$v_{av} = \frac{\text{Distance}}{\text{Time}} = \frac{\text{Speed} \times \text{Time}}{\text{Time}} = \frac{v_1 \times \frac{t}{3} + v_2 \times \frac{2t}{3}}{\frac{t}{3} + \frac{2t}{3}}$$

$$\Rightarrow \quad v_{av} = \frac{\frac{v_1}{3} + \frac{2v_2}{3}}{1} = \frac{v_1 + 2v_2}{3} \quad \Rightarrow \quad \boxed{v_{av} = \frac{v_1 + 2v_2}{3}}$$

16. If the displacement of a particle varies with time as $\sqrt{x} = t + 7$, then
    (1) Velocity of the particle is inversely proportional to t
    (2) Velocity of the particle is proportional to t^2
    (3) Velocity of the particle is proportional to $\sqrt{t}$
    (4) The particle moves with constant acceleration

Sol. Answer (4)

$$\sqrt{x} = t + 7$$

$$\Rightarrow \quad x = (t+7)^2$$

$$= t^2 + 49 + 14t \qquad \text{(squaring)}$$

$$\frac{dx}{dt} = 2t + 14$$

$$\boxed{v = 2t + 14} \Rightarrow \boxed{v \propto t}$$

Acceleration :

$$a = \frac{dv}{dt}$$

$$\boxed{a = 2\ \text{ms}^{-2}} \rightarrow \text{constant}$$

17. A boat covers certain distance between two spots in a river taking t_1 hrs going downstream and t_2 hrs going upstream. What time will be taken by boat to cover same distance in still water?

(1) $\frac{t_1 + t_2}{2}$ (2) $2(t_2 - t_1)$ (3) $\frac{2t_1t_2}{t_1 + t_2}$ (4) $\sqrt{t_1t_2}$

Sol. Answer (3)

For upstream, Speed ⇒ $v - u$ (where $v \rightarrow$ man and $u \rightarrow$ water)

For downstream, Speed ⇒ $v + u$

$$t_{\text{up}} = \frac{d}{v-u}$$

$$t_2 = \frac{d}{v-u}$$

$$\Rightarrow \quad d = (v-u)t_2 \qquad \text{...(i)}$$

$$t_{\text{down}} = \frac{d}{v+u}$$

$$t_1 = \frac{d}{v+u}$$

$$\Rightarrow \quad d = (v+u)t_1 \qquad \text{...(ii)}$$

$$t_{\text{still}} = \frac{d}{v}$$

$$\boxed{t_{\text{still}} = \frac{2t_1t_2}{t_1 + t_2}}$$

On equating (i) and (ii)

$$(v - u)\, t_2 = (v + u)\, t_1$$

$$\Rightarrow \quad vt_2 - ut_2 = vt_1 + ut_1$$

$$\Rightarrow \quad v(t_2 - t_1) = u(t_1 + t_2)$$

$$\Rightarrow \quad u = \frac{v(t_2 - t_1)}{t_2 + t_1}$$

So, $d = \left(v - \frac{v(t_2 - t_1)}{t_1 + t_2}\right)t_2 = vt_2\left(\frac{t_1 + t_2 - t_2 + t_1}{t_1 + t_2}\right)$

$$\boxed{\frac{d}{v} = \frac{2t_1t_2}{t_1 + t_2}} \rightarrow \textbf{Remember as shortcut}$$

18. A particle starts moving with acceleration 2 m/s^2. Distance travelled by it in 5th half second is

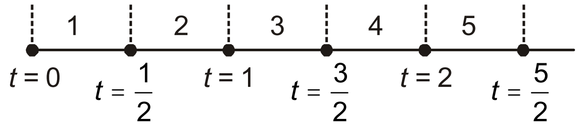
(1) 1.25 m (2) 2.25 m (3) 6.25 m (4) 30.25 m

Sol. Answer (2)

$S_{2.5} - S_2 = ?$ (distance travelled in 5th half second)

$$S_{2.5} = ut + \frac{1}{2}at^2$$

$a = 2\text{ ms}^{-2}$



$$\Rightarrow \quad S_{2.5} = \frac{1}{2} \times 2 \times (2.5)^2 = 6.25\text{ m} \quad (\because\ u = 0)$$

$$S_2 = \frac{1}{2} \times 2 \times 4 = 4\text{ m}$$

So, $\boxed{S_{2.5} - S_2 = 2.25\text{ m}}$

19. The two ends of a train moving with constant acceleration pass a certain point with velocities *u* and 3*u*. The velocity with which the middle point of the train passes the same point is

(1) $2u$ (2) $\frac{3}{2}u$ (3) $\sqrt{5}\,u$ (4) $\sqrt{10}\,u$

Sol. Answer (3)

$$\text{Velocity at the mid-point} = \sqrt{\frac{\overset{\text{Final velocity}}{v^2} + \overset{\text{Initial velocity}}{u^2}}{2}}$$

(When acceleration is constant)

Given, $v = 3u$, $u = u$

$$\text{So, } v_{\text{mid}} = \sqrt{\frac{9u^2 + u^2}{2}} = \sqrt{\frac{10u^2}{2}}$$

$$v_{\text{mid}} = \sqrt{5u^2} = \boxed{\sqrt{5}u = v_{\text{mid}}}$$

20. The initial velocity of a particle is *u* (at $t = 0$) and the acceleration *a* is given by $\alpha t^{3/2}$. Which of the following relations is valid?

(1) $v = u + \alpha t^{3/2}$ (2) $v = u + \frac{3\alpha t^3}{2}$ (3) $v = u + \frac{2}{5}\alpha t^{5/2}$ (4) $v = u + \alpha t^{5/2}$

Sol. Answer (3)

$a = \alpha t^{3/2}$ (acceleration is a function of time)

$$\int_u^v dv = \int_0^t a\,dt$$

$$\Rightarrow \quad \int_u^v dv = \int_0^t \alpha t^{3/2} dt$$

$$\Rightarrow \quad v\Big|_u^v = \alpha \left.\frac{t^{3/2}+1}{\frac{3}{2}+1}\right|_0^t$$

$$\Rightarrow \quad (v-u) = \alpha \times \frac{2}{5} \qquad \left(t^{5/2}-0\right)$$

$$\Rightarrow \quad v-u = \frac{2}{5}\alpha t^{5/2}$$

$$\Rightarrow \quad \boxed{v = u+\frac{2}{5}\alpha t^{5/2}}$$

Note : *The equations of kinematics are valid only for constant acceleration, here a is a function of 't' so we didn't apply those equations.*

21. A train starts from rest from a station with acceleration 0.2 m/s^2 on a straight track and then comes to rest after attaining maximum speed on another station due to retardation 0.4 m/s^2. If total time spent is half an hour, then distance between two stations is [Neglect length of train]

(1) 216 km (2) 512 km (3) 728 km (4) 1296 km

Sol. Answer (1)

Shortcut : $S = \frac{1}{2}\frac{\alpha\beta}{\alpha+\beta}T^2$

$\alpha \rightarrow$ Acceleration

$\beta \rightarrow$ Deceleration (magnitude only)

$T \rightarrow$ Time of journey

$S \rightarrow$ Distance travelled

Given, α = 0.2 ms^{-2}

β = 0.4 ms^{-2}

T = half an hour = 30 × 60 s = 1800 s

$$S = \frac{1}{2}\times\left(\frac{0.2\times 0.4}{0.2+0.4}\right)\times(1800)^2$$

$\Rightarrow$ S = 216000 m

$$\Rightarrow \quad \boxed{S = 216\text{ km}}$$

22. The position x of particle moving along x-axis varies with time t as $x = A\sin(\omega t)$ where A and ω are positive constants. The acceleration a of particle varies with its position (x) as

(1) $a = Ax$ (2) $a = -\omega^2 x$ (3) $a = A\omega x$ (4) $a = \omega^2 x A$

Sol. Answer (2)

$x = A\sin\omega t$

$$\frac{dx}{dt} = A\omega\cos\omega t$$

$$\Rightarrow \quad \frac{d^2x}{dt^2} = -A\omega^2\sin\omega t$$

$$\Rightarrow \quad \boxed{a = -\omega^2 x} \qquad (\because\ A\sin\omega t = x)$$

23. A particle moves in a straight line and its position x at time t is given by $x^2 = 2 + t$. Its acceleration is given by

(1) $\frac{-2}{x^3}$ (2) $-\frac{1}{4x^3}$ (3) $-\frac{1}{4x^2}$ (4) $\frac{1}{x^2}$

Sol. Answer (2)

$$x^2 = t + 2 \Rightarrow \boxed{\frac{1}{x^2} = \frac{1}{t+2}} \qquad \text{....(i)}$$

$$\Rightarrow \quad x = \sqrt{t+2}$$

$$\Rightarrow \quad \frac{dx}{dt} = \frac{1}{2}(t+2)^{\frac{1}{2}-1}$$

$$\Rightarrow \quad \frac{dx}{dt} = \frac{1}{2}(t+2)^{-\frac{1}{2}}$$

$$\Rightarrow \quad \frac{d^2x}{dt^2} = \frac{1}{2}\left(-\frac{1}{2}\right)(t+2)^{-\frac{1}{2}-1}$$

$$\Rightarrow \quad a = -\frac{1}{4}(t+2)^{-\frac{3}{2}} = -\frac{1}{4(t+2)} \times \frac{1}{(t+2)^{\frac{1}{2}}} = -\frac{1}{4} \times \frac{1}{x^2} \times \frac{1}{x}$$

$$\Rightarrow \quad \boxed{a = -\frac{1}{4x^3}}$$

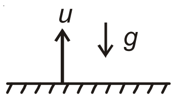
24. A body is projected vertically upward direction from the surface of earth. If upward direction is taken as positive, then acceleration of body during its upward and downward journey are respectively

(1) Positive, negative (2) Negative, negative (3) Positive, positive (4) Negative, positive

Sol. Answer (2)

Whether body move upwards or downwards the earth tries to pull it downwards only. Hence during both the motion g will negative.

So, negative, negative



25. A particle start moving from rest state along a straight line under the action of a constant force and travel distance x in first 5 seconds. The distance travelled by it in next five seconds will be

(1) x (2) $2x$ (3) $3x$ (4) $4x$

Sol. Answer (3)

Body starts from rest and moves with a constant acceleration, then the distance travelled in equal time intervals will be in the ratio of odd number. (Galileo's law of odd number)

$x_1 : x_2 \Rightarrow 1 : 3$

$x : x_2 \Rightarrow 1 : 3$

$$\Rightarrow \quad \frac{x}{x_2} = \frac{1}{3}$$

$$\Rightarrow \quad \boxed{x_2 = 3x}$$

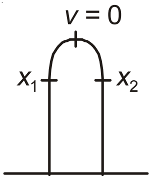
26. A body is projected vertically upward with speed 40 m/s. The distance travelled by body in the last second of upward journey is [take g = 9.8 m/s^2 and neglect effect of air resistance]

(1) 4.9 m (2) 9.8 m (3) 12.4 m (4) 19.6 m

Sol. Answer (1)

As the motion under gravity is symmetric, so distance travelled in last second of ascent is equal to first second of descent.

t = 1 s (1st second)



$$-x_2 = ut - \frac{1}{2}g \times 1^2$$

$$x_2 = \frac{1}{2} \times 9.8 \times 1^2 \quad (\because\ u = 0)$$

$$\Rightarrow \boxed{x_2 = 4.9\text{ m}}$$

This distance is constant for every body thrown with any speed.

27. A body is moving with variable acceleration (a) along a straight line. The average acceleration of body in time interval t_1 to t_2 is

(1) $\dfrac{a[t_2 + t_1]}{2}$ (2) $\dfrac{a[t_2 - t_1]}{2}$ (3) $\dfrac{\int_{t_1}^{t_2} a\,dt}{t_2 + t_1}$ (4) $\dfrac{\int_{t_1}^{t_2} a\,dt}{t_2 - t_1}$

Sol. Answer (4)

$$\text{Average acceleration} = \frac{\text{Change in velocity}}{\text{Time}} \Rightarrow \boxed{a_{\text{av}} = \frac{\int_{t_1}^{t_2} a\,dt}{t_2 - t_1}}$$

28. A body is projected vertically upward with speed 10 m/s and other at same time with same speed in downward direction from the top of a tower. The magnitude of acceleration of first body w.r.t. second is {take g = 10 m/s^2}

(1) Zero (2) 10 m/s^2 (3) 5 m/s^2 (4) 20 m/s^2

Sol. Answer (1)

The acceleration of first body

a_1 = 10 ms^{-2}

a_2 = 10 ms^{-2}

$a_{\text{rel}} = a_1 - a_2$ = 10 ms^{-2} – 10 ms^{-2} = 0

29. The position of a particle moving along x-axis given by $x = (-2t^3 + 3t^2 + 5)$m. The acceleration of particle at the instant its velocity becomes zero is

(1) 12 m/s^2 (2) –12 m/s^2 (3) –6 m/s^2 (4) Zero

Sol. Answer (3)

$$x = (-2t^3 + 3t^2 + 5)\text{ m}$$

$$\Rightarrow \frac{dx}{dt} = -6t^2 + 6t = v$$

$$\Rightarrow \frac{d^2x}{dt^2} = -12t + 6 \qquad (\text{for } v = 0,\ 6t = 6t^2 \Rightarrow t = 1\text{ s})$$

$$a|_{t=1\text{ s}} = -12 + 6 = -6\text{ ms}^{-2}$$

30. A car travelling at a speed of 30 km/h is brought to rest in a distance of 8 m by applying brakes. If the same car is moving at a speed of 60 km/h then it can be brought to rest with same brakes in

(1) 64 m (2) 32 m (3) 16 m (4) 4 m

Sol. Answer (2)

$$d_s = \frac{u^2}{2a} \Rightarrow d_s \propto u^2$$

$$u' = 2u$$

$$\frac{d'}{d} = \frac{(2u)^2}{u^2}$$

$$\Rightarrow \frac{d'}{8} = 4$$

$$\Rightarrow d' = 32$$

31. A particle is thrown with any velocity vertically upward, the distance travelled by the particle in first second of its decent is

(1) g (2) $\frac{g}{2}$ (3) $\frac{g}{4}$ (4) Cannot be calculated

Sol. Answer (2)

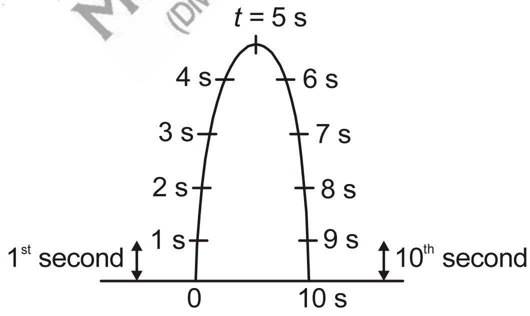
$$s = \frac{1}{2} g \times 1^2 \Rightarrow \boxed{s = \frac{g}{2}}$$

32. A body is thrown vertically upwards and takes 5 seconds to reach maximum height. The distance travelled by the body will be same in

(1) 1st and 10th second (2) 2nd and 8th second (3) 4th and 6th second (4) Both (2) & (3)

Sol. Answer (1)

The motion under gravity is a symmetric motion and the time taken to go up is same as time taken to come back to the initial position.



So, clearly the distance travelled in 1st second is same as that travelled in 10th second.

33. A ball is dropped from a bridge of 122.5 metre above a river. After the ball has been falling for two seconds, a second ball is thrown straight down after it. Initial velocity of second ball so that both hit the water at the same time is

(1) 49 m/s (2) 55.5 m/s (3) 26.1 m/s (4) 9.8 m/s

Sol. Answer (3)

$-h = -\frac{1}{2}gt^2$ 1st ball

$\Rightarrow \; 122.5 = \frac{1}{2}\times 9.8\,t^2$

$\Rightarrow \; t^2 = 25 \Rightarrow \boxed{t = 5\text{ s}}$

Another ball is dropped after 2 second so it took only (5 – 2) = 3 s

$-122.5 = -u(3) - \frac{1}{2}\times 9.8\times 3^2$

$\Rightarrow \; 122.5 = 3u + 4.9 \times 9$

$\Rightarrow \; 3u = 78.4$

$\Rightarrow \; \boxed{u = 26.1\text{ s}}$

34. A balloon starts rising from ground from rest with an upward acceleration 2 m/s**2**. Just after 1 s, a stone is dropped from it. The time taken by stone to strike the ground is nearly

(1) 0.3 s (2) 0.7 s (3) 1 s (4) 1.4 s

Sol. Answer (2)

$u = 0,\; a = 2\text{ ms}^{-2}$

The velocity of object after one second

$v = u + at$

$\Rightarrow \; \boxed{v = 2\text{ ms}^{-1}}$

$s = \frac{1}{2}\times 2\times 1^2 = 1\text{ m}$

Now after separating from the balloon it will move under the effect of gravity alone.

$-h = vt - \frac{1}{2}\times 9.8\times t^2$

$\Rightarrow \; -1 = 2t - 4.9t^2$

$\Rightarrow \; 4.9t^2 - 2t - 1 = 0$

$\Rightarrow \; \boxed{t = 0.7\text{ s}}$

35. A boy throws a ball into air after 2 second. The next ball is thrown when the velocity of first ball is zero. How high do the ball rise above his hand? [Take $g = 9.8\text{ m/s}^2$]

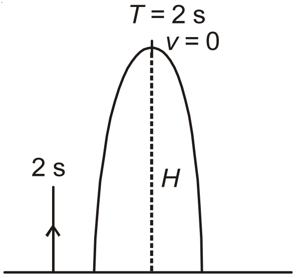
(1) 4.9 m (2) 9.8 m (3) 19.6 m (4) 29.4 m

Sol. Answer (3)

$2T = \frac{2u}{g} \Rightarrow 2 = \frac{u}{9.8} \Rightarrow u = 19.6$

$H = \frac{u^2}{2g} = \frac{19.6\times 19.6}{2\times 9.8}$

$\Rightarrow \; \boxed{H = 19.6\text{ m}}$



36. A ball projected from ground vertically upward is at same height at time t_1 and t_2. The speed of projection of ball is [Neglect the effect of air resistance]

(1) $g[t_2 - t_1]$ (2) $\frac{g[t_1 + t_2]}{2}$ (3) $\frac{g[t_2 - t_1]}{2}$ (4) $g[t_1 + t_2]$

Sol. Answer (2)

$t_1 + t_2$ = total time of flight

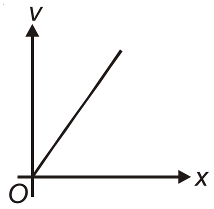
$t_1 + t_2 = 2T$

$T = \frac{t_1 + t_2}{2}$, also $T = \frac{u}{g}$

$$\frac{u}{g} = \frac{t_1 + t_2}{2} \Rightarrow \boxed{u = \frac{1}{2} g\,(t_1 + t_2)}$$

37. For a body moving with uniform acceleration along straight line, the variation of its velocity (v) with position (x) is best represented by

(1)



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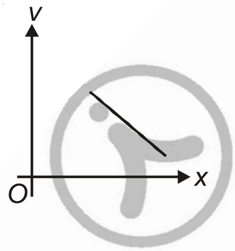

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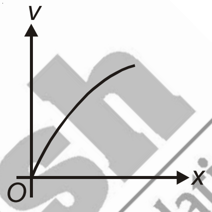

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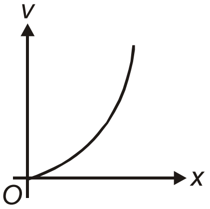
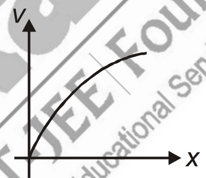


Sol. Answer (3)

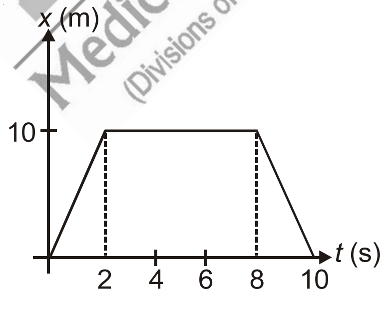
For uniform acceleration, $a \rightarrow$ constant

$v^2 = u^2 + 2as$

$\Rightarrow \boxed{v^2 \propto x}$ ($\because$ u = rest)



38. The position-time graph for a particle moving along a straight line is shown in figure. The total distance travelled by it in time t = 0 to t = 10 s is



(1) Zero (2) 10 m (3) 20 m (4) 80 m

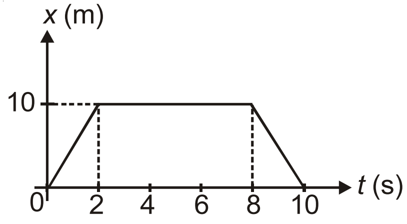
Sol. Answer (3)

The total distance travelled from 0 to 2 s is 10 m

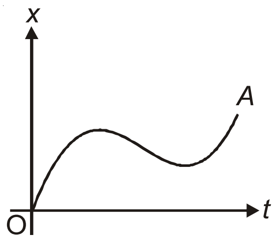
2 s to 8 s → Zero distance

and from 8 s to 10 s → 10 m

So, distance = 10 + 0 + 10 = 20 m



39. The position-time graph for a body moving along a straight line between O and A is shown in figure. During its motion between O and A, how many times body comes to rest?



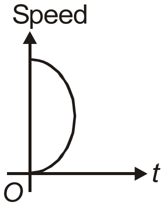
(1) Zero (2) 1 time (3) 2 times (4) 3 times

Sol. Answer (3)

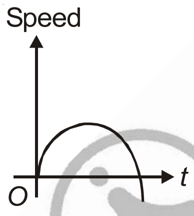
As there are two extremes in the graph one is maxima and other is minima. At both maxima and minima the slope is zero. So, it comes to rest twice.

40. Which one of the following graph for a body moving along a straight line is possible?

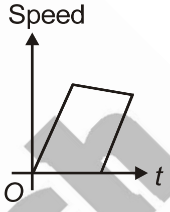
(1)



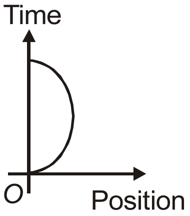
(2)



(3)



(4)

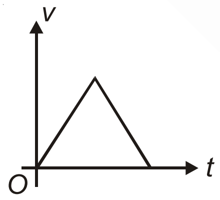


Sol. Answer (4)

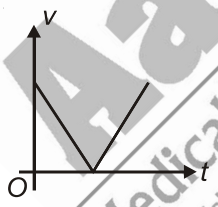
This graph is possible.

41. A body is projected vertically upward from ground. If we neglect the effect of air, then which one of the following is the best representation of variation of speed (v) with time (t)?

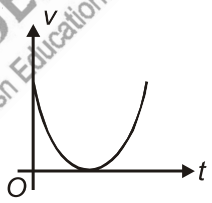
(1)



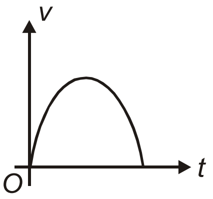
(2)



(3)



(4)

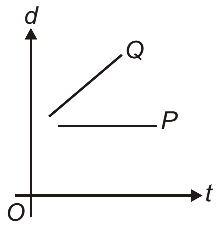


Sol. Answer (2)

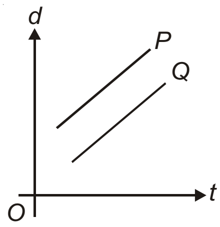
The speed of an object is directly proportional to time $\boxed{v \propto t}$.

42. Which one of the following time-displacement graph represents two moving objects P and Q with zero relative velocity?

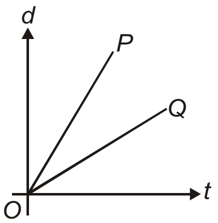
(1)



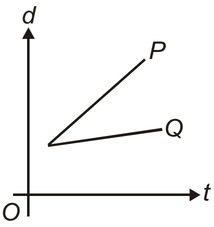
(2)



(3)



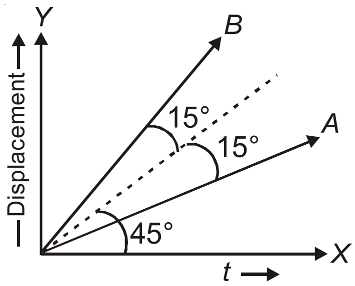
(4)



Sol. Answer (2)

Zero relative velocity means that both of them have same slope.

43. The displacement-time graph for two particles A and B is as follows. The ratio $\frac{v_A}{v_B}$ is

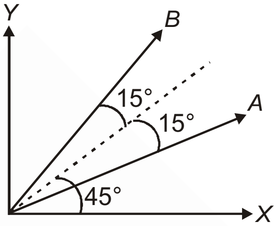


(1) 1 : 2 (2) $1:\sqrt{3}$ (3) $\sqrt{3}:1$ (4) 1 : 3

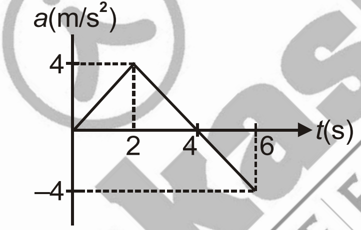
Sol. Answer (4)

The slope of line A is tan30º and B = tan60º

$$\frac{v_A}{v_B}=\frac{\tan 30^o}{\tan 60^o}=\frac{\frac{1}{\sqrt{3}}}{\sqrt{3}}=\frac{1}{3}\Rightarrow \boxed{v_A:v_B=1:3}$$



44. For the acceleration-time (a-t) graph shown in figure, the change in velocity of particle from t = 0 to t = 6 s is



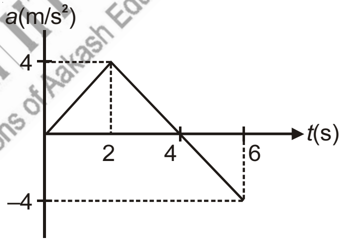
(1) 10 m/s (2) 4 m/s (3) 12 m/s (4) 8 m/s

Sol. Answer (2)

Area under a-t graph gives change in velocity.

So, $\Delta v=\frac{1}{2}\times 4\times 4-\frac{1}{2}\times 2\times 4=8-4$

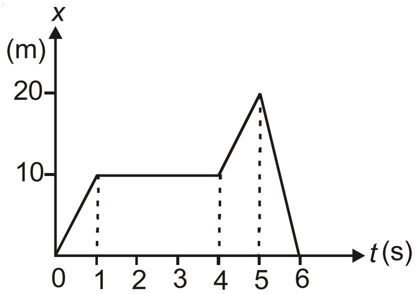
$\boxed{\Delta v=4\ \text{ms}^{-1}}$



45. Figure shows the graph of x-coordinate of a particle moving along x-axis as a function of time. Average velocity during t = 0 to 6 s and instantaneous velocity at t = 3 s respectively, will be

(1) 10 m/s, 0 (2) 60 m/s, 0

(3) 0, 0 (4) 0, 10 m/s



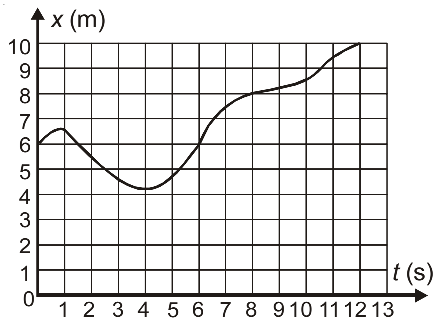
Sol. Answer (3)

From 0 to 6 s → Displacement = 0

so, average velocity = 0

at t = 3 s, the displacement = 0, so v = 0

46. Position-time graph for a particle is shown in figure. Starting from $t = 0$, at what time t, the average velocity is zero?



(1) 1 s (2) 3 s (3) 6 s (4) 7 s

Sol. Answer (3)

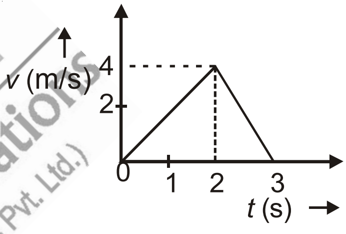
If we look at the graph very carefully at $t = 0$, $x = 6$ m

The average velocity will be zero if it comes back to the initial position.

It is evident that at $t = 6$ s, $x = 6$ m

So, v_{av} at $t = 6$ s is zero.

47. The velocity versus time graph of a body moving in a straight line is as shown in the figure below



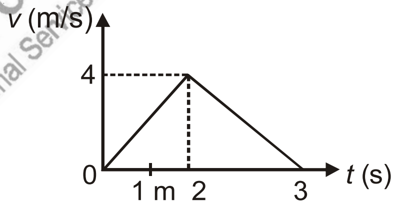
(1) The distance covered by the body in 0 to 2s is 8m

(2) The acceleration of the body in 0 to 2s is 4 ms^{-2}

(3) The acceleration of the body in 2 to 3s is 4 ms^{-2}

(4) The distance moved by the body during 0 to 3 s is 6 m

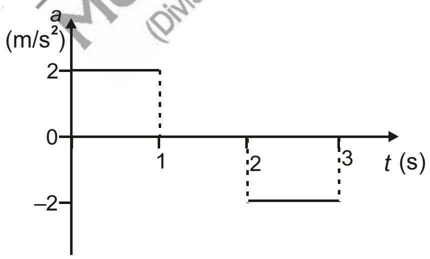
Sol. Answer (4)



Distance covered = Area under v-t graph $= \frac{1}{2} \times 3 \times 4 = 6$ m

$$\text{Acceleration}\big|_{t=0 \text{ to } 2\text{ s}} = \frac{4-0}{2} = 2\ \text{ms}^{-2}$$

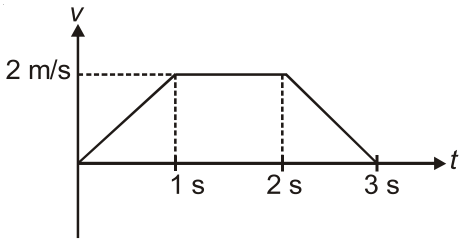
48. Acceleration-time graph for a particle is given in figure. If it starts motion at $t = 0$, distance travelled in 3 s will be



(1) 4 m (2) 2 m (3) 0 (4) 6 m

Sol. Answer (1)

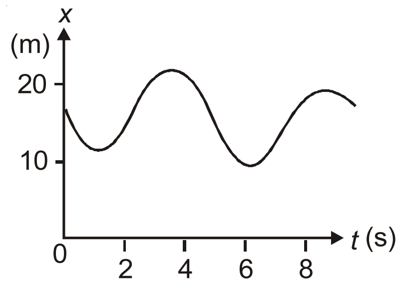
Draw the v-t graph from a-t graph.



Area under v-t graph $= \frac{1}{2} \times 2 \times (3+1)$

$= 4$ m

49. Figure shows the position of a particle moving on the x-axis as a function of time



(1) The particle has come to rest 4 times

(2) The velocity at t = 8 s is negative

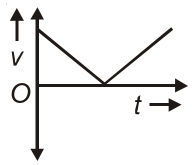
(3) The velocity remains positive for t = 2 s to t = 6 s

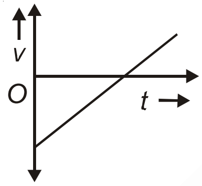
(4) The particle moves with a constant velocity

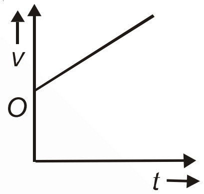
Sol. Answer (1)

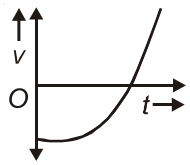
The particle has come to rest four times.

50. A particle moves along x-axis in such a way that its x-co-ordinate varies with time according to the equation $x = 4 - 2t + t^2$. The speed of the particle will vary with time as

(1)


(2)


(3)


(4)


Sol. Answer (1)

$x = 4 - 2t + t^2 \Rightarrow \frac{dx}{dt} = -2 + 2t$

$v = 2t - 2 \rightarrow$ Straight line

Slope $\rightarrow$ Positive

Intercept $\rightarrow$ Negative

51. Two balls are projected upward simultaneously with speeds 40 m/s and 60 m/s. Relative position (x) of second ball w.r.t. first ball at time t = 5 s is [Neglect air resistance].

(1) 20 m (2) 80 m (3) 100 m (4) 120 m

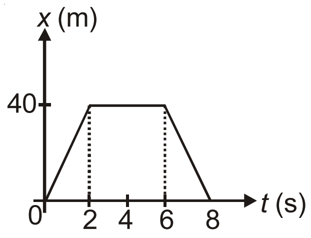
Sol. Answer (3)

$$S_{\text{rel}} = U_{\text{rel}}\, t + \frac{1}{2} a_{\text{rel}}\, t^2$$

$\Rightarrow \; S_{\text{rel}} = (60 - 40)\, 5 \qquad (a_{\text{rel}} = 0)$

$\Rightarrow \; \boxed{S_{\text{rel}} = 100 \text{ m}}$

52. The position (x) of a particle moving along x-axis varies with time (t) as shown in figure. The average acceleration of particle in time interval t = 0 to t = 8 s is



(1) 3 m/s^2 (2) –5 m/s^2

(3) –4 m/s^2 (4) 2.5 m/s^2

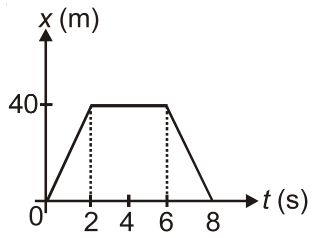
Sol. Answer (2)

t = 0 to t = 2 t = 6 to t = 8

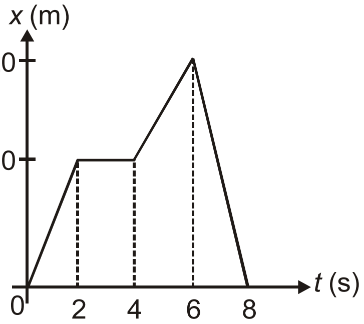
v = 20 m/s v = – 20 m/s

$$a_{\text{avg}} = \frac{\Delta v}{\Delta t} = \frac{-20-20}{8} = \frac{-40}{8} = -5 \text{ ms}^{-2}$$

$\boxed{a_{\text{avg}} = -5 \text{ ms}^{-2}}$



53. The position (x)-time (t) graph for a particle moving along a straight line is shown in figure. The average speed of particle in time interval $t = 0$ to $t = 8$ s is



(1) Zero (2) 5 m/s (3) 7.5 m/s (4) 9.7 m/s

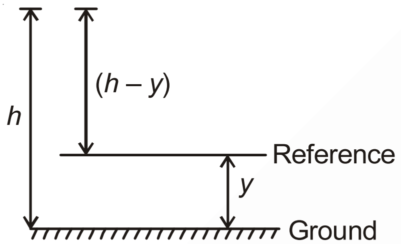
Sol. Answer (2)

$$v = \frac{\text{Distance}}{\text{Time}} = \frac{40}{8} = 5 \text{ ms}^{-1}$$

54. A ball is dropped from a height h above ground. Neglect the air resistance, its velocity (v) varies with its height above the ground as

(1) $\sqrt{2g(h-y)}$ (2) $\sqrt{2gh}$ (3) $\sqrt{2gy}$ (4) $\sqrt{2g(h+y)}$

Sol. Answer (1)

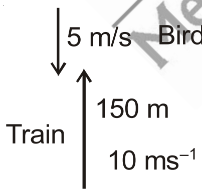


$$\boxed{v = \sqrt{2g(h-y)}}$$

55. A train of 150 m length is going towards North at a speed of 10 m/s. A bird is flying at 5 m/s parallel to the track towards South. The time taken by the bird to cross the train is

(1) 10 s (2) 15 s (3) 30 s (4) 12 s

Sol. Answer (1)



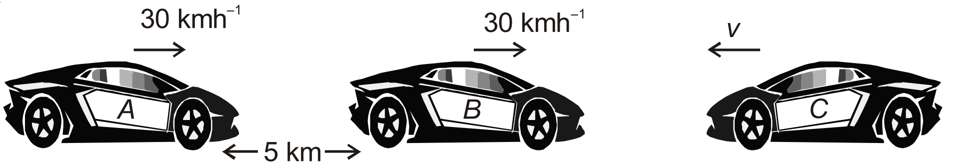
$$\text{Time} = \frac{150}{10+5} = \frac{150}{15}$$

$$\Rightarrow \boxed{T = 10 \text{ s}}$$

56. Two cars are moving in the same direction with a speed of 30 km/h. They are separated from each other by 5 km. Third car moving in the opposite direction meets the two cars after an interval of 4 minutes. The speed of the third car is

(1) 30 km/h (2) 25 km/h (3) 40 km/h (4) 45 km/h

Sol. Answer (4)



The distance of 5 km is in between *A* and *B* is covered by *C* in 4 minute with relative velocity (v + 30).

So, $d_{\text{rel}} = v_{\text{rel}} \times t$

$\Rightarrow$ $5\text{ km} = (v+30)\times\dfrac{4}{60}$

$\Rightarrow$ $75\text{ kmh}^{-1} = v + 30$

$\Rightarrow$ $\boxed{v = 45\text{ kmh}^{-1}}$

57. Two cars *A* and *B* are moving in same direction with velocities 30 m/s and 20 m/s. When car *A* is at a distance *d* behind the car *B*, the driver of the car *A* applies brakes producing uniform retardation of 2 m/s**²**. There will be no collision when

(1) $d < 2.5$ m (2) $d > 125$ m (3) $d > 25$ m (4) $d < 125$ m

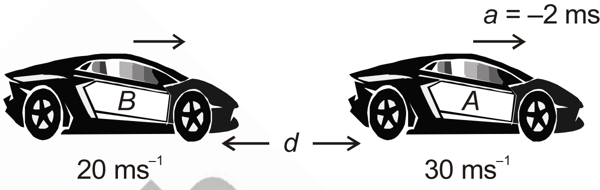
Sol. Answer (3)

$v^2 = u^2 + 2ad$

$\Rightarrow$ $0 = (10)^2 - 2 \times 2 \times d_{\text{rel}}$

$\Rightarrow$ $\dfrac{100}{4} \le d_{\text{rel}}$

$\Rightarrow$ $\boxed{d_{\text{rel}} \ge 25\text{ m}}$



58. Two trains each of length 100 m moving parallel towards each other at speed 72 km/h and 36 km/h respectively. In how much time will they cross each other?

(1) 4.5 s (2) 6.67 s (3) 3.5 s (4) 7.25 s

Sol. Answer (2)

When two trains are moving in opposite direction then

$v_{\text{rel}} = (20+10) = 30\text{ ms}^{-1}$

$t = \dfrac{200}{30} = 6.67\text{ s}$

59. A ball is dropped from the top of a building of height 80 m. At same instant another ball is thrown upwards with speed 50 m/s from the bottom of the building. The time at which balls will meet is

(1) 1.6 s (2) 5 s (3) 8 s (4) 10 s

Sol. Answer (1)

$t = \dfrac{h}{v_{\text{rel}}} = \dfrac{80}{50}$

$\Rightarrow$ $\boxed{t = 1.6\text{ s}}$

60. A particle move with velocity v_1 for time t_1 and v_2 for time t_2 along a straight line. The magnitude of its average acceleration is

(1) $\dfrac{v_2 - v_1}{t_1 - t_2}$ (2) $\dfrac{v_2 - v_1}{t_1 + t_2}$ (3) $\dfrac{v_2 - v_1}{t_2 - t_1}$ (4) $\dfrac{v_1 + v_2}{t_1 - t_2}$

Sol. Answer (2)

$$\boxed{a_{\text{avg}} = \frac{v_2 - v_1}{t_1 + t_2}} = \frac{\text{Change in velocity}}{\text{Time interval}}$$

SECTION - B

Objective Type Questions

1. If average velocity of particle moving on a straight line is zero in a time interval, then

(1) Acceleration of particle may be zero

(2) Velocity of particle must be zero at an instant

(3) Velocity of particle may be never zero in the interval

(4) Average speed of particle may be zero in the interval

Sol. Answer (2)

If average velocity = zero, then displacement is zero it means particle takes a turn in the opposite direction and at the time of turning back velocity has to be zero.

2. A car moving with speed v on a straight road can be stopped with in distance d on applying brakes. If same car is moving with speed $3v$ and brakes provide half retardation, then car will stop after travelling distance

(1) 6 d (2) 3 d (3) 9 d (4) 18 d

Sol. Answer (3)

$$d_s = \frac{u^2}{2a}$$

$$d_s \propto u^2 \Rightarrow \frac{d_s}{d_s'} - \frac{u^2}{u'^2}$$

$u' = 3v$

$u = v$

So, $\frac{d_s}{d_s'} = \frac{v^2}{9v^2}$

$\Rightarrow \quad d_s' = 9d_s$

$\Rightarrow \quad \boxed{d_s' = 9d}$

3. The initial velocity of a particle moving along x-axis is u (at $t = 0$ and $x = 0$) and its acceleration a is given by $a = kx$. Which of the following equation is correct between its velocity (v) and position (x)?

(1) $v^2 - u^2 = 2kx$ (2) $v^2 = u^2 + 2kx^2$ (3) $v^2 = u^2 + kx^2$ (4) $v^2 + u^2 = 2kx$

Sol. Answer (3)

$a = kx$ and $\frac{vdv}{dx} = a$

$$\Rightarrow \quad \int_u^v vdv = \int_0^x adx = \int_0^x kxdx$$

$$\Rightarrow \quad \left.\frac{v^2}{2}\right|_u^v = \left.\frac{kx^2}{2}\right|_0^x$$

$\Rightarrow \quad v^2 - u^2 = kx^2 \Rightarrow \boxed{v^2 = u^2 + kx^2}$

4. The velocity v of a body moving along a straight line varies with time t as $v = 2t^2 e^{-t}$, where v is in m/s and t is in second. The acceleration of body is zero at t =

(1) 0 (2) 2 s (3) 3 (4) Both (1) & (2)

Sol. Answer (2)

$v = 2t^2 e^{-t}$

$$\frac{dv}{dt} = 2[t^2e^{-t} \times (-1) + e^{-t} \times 2t]$$

Put, $a = 0$,

$$-2t^2e^{-t} + 4te^{-t} = 0$$

$$\Rightarrow \quad -2t^2 + 4t = 0 \ \Rightarrow \ t^2 = 2t \Rightarrow \boxed{t = 2\text{ s}}$$

5. The relation between position (x) and time (t) are given below for a particle moving along a straight line. Which of the following equation represents uniformly accelerated motion? [where α and β are positive constants]

(1) $\beta x = \alpha t + \alpha\beta$ (2) $\alpha x = \beta + t$ (3) $xt = \alpha\beta$ (4) $\alpha t = \sqrt{\beta + x}$

Sol. Answer (4)

For uniformly accelerated motion,

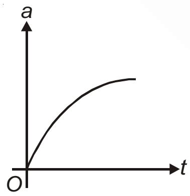
$$\underset{\text{Constant}}{\underset{\downarrow}{v^2}} = u^2 + 2as \quad \text{or} \quad \underset{\text{Constant}}{\underset{\downarrow}{s}} = ut + \frac{1}{2}at^2$$

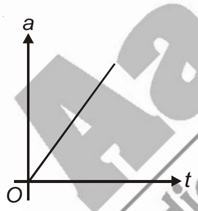
$$x = \frac{1}{2}at^2 + ut$$

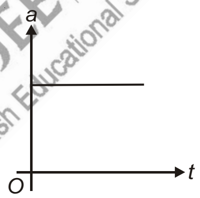
Or the maximum power of t has to be two.

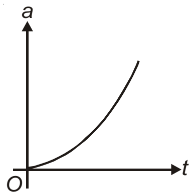
So, $\boxed{4}$.

6. The velocity v of a particle moving along x-axis varies with its position (x) as $v = \alpha\sqrt{x}$; where α is a constant. Which of the following graph represents the variation of its acceleration (a) with time (t)?

(1)


(2)


(3)


(4)


Sol. Answer (3)

$v = \alpha\sqrt{x}$

Squaring both sides $v^2 = \alpha^2 x$

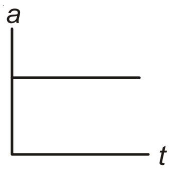
Comparing above equation with 3rd equation of kinematics.

$$v^2 = u^2 + 2ax$$

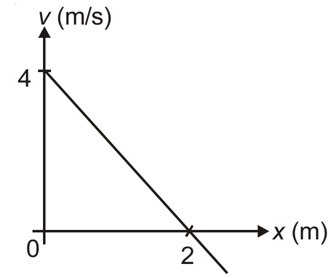
$$\alpha^2 x = 2ax$$

$$\Rightarrow \boxed{\underset{\downarrow}{a} = \frac{\alpha^2}{2}}$$

Constant → not a function of time

So,


7. The velocity (v) of a particle moving along x-axis varies with its position x as shown in figure. The acceleration (a) of particle varies with position (x) as



(1) $a^2 = x + 3$ (2) $a = 2x^2 + 4$ (3) $2a = 3x + 5$ (4) $a = 4x - 8$

Sol. Answer (4)

$$a = \frac{vdv}{dx}$$

$$\frac{dv}{dx} \rightarrow \text{ slope}$$

So, $\frac{-4}{2} = -2$

Intercept = + 4

$a \rightarrow$ Negative

So, $a = \frac{vdv}{dx}$

Relation between v and x

$$\Rightarrow \quad \frac{v-4}{x-0} = \frac{0-4}{2-0}$$

$$\Rightarrow \quad \frac{v-u}{x} = \frac{-4}{2}$$

$$\Rightarrow \quad v - 4 = -2x$$

$$\Rightarrow \quad v = -2x + 4$$

$$\Rightarrow \quad \frac{dv}{dx} = -2$$

$$\Rightarrow \quad a = \frac{vdv}{dx} = (-2x+4)(-2)$$

$$\Rightarrow \quad \boxed{a = 4x - 8}$$

8. A ball is dropped from an elevator moving upward with acceleration 'a' by a boy standing in it. The acceleration of ball with respect to [Take upward direction positive]

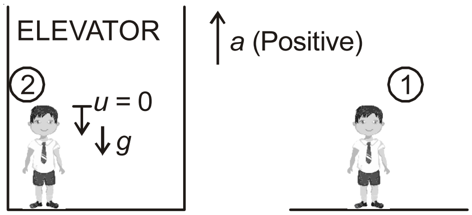
(1) Boy is $-g$ (2) Boy is $-(g + a)$ (3) Ground is $-g$ (4) Both (2) & (3)

Sol. Answer (4)

Upward direction → Positive

Negative direction → Negative

If a person is observing from ground then, for him the acceleration of ball is in the downward direction.



$$a_{\text{ball } G} = a_{\text{ball}} - a_{\text{ground}} = -g - 0$$

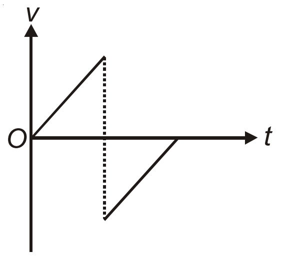
$$\boxed{a_{bG} = -g}$$

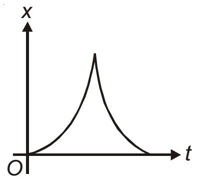
a_{bG} = Acceleration of ball w.r.t. ground.

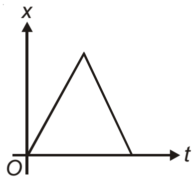
$$a_{\text{ball boy}} = a_{\text{ball}} - a_{\text{boy}} = -g - a$$

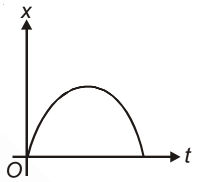
$\boxed{a_{bb} = -(g + a)}$, a_{bb} = Acceleration of ball w.r.t. boy.

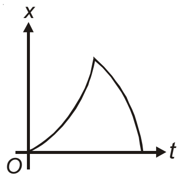
9. The velocity (v)-time (t) graph for a particle moving along x-axis is shown in the figure. The corresponding position (x)- time (t) is best represented by



(1) 

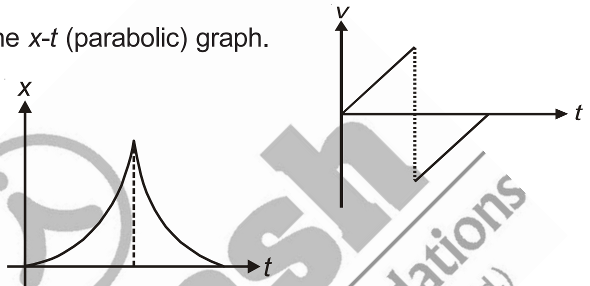
(2) 

(3) 

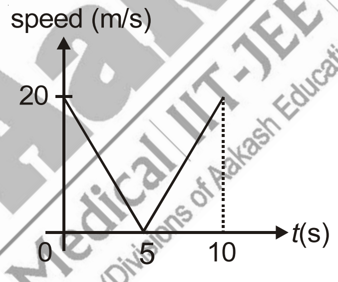
(4) 

Sol. Answer (1)

The graph of v-t can be converted into the x-t (parabolic) graph.



10. The speed-time graph for a body moving along a straight line is shown in figure. The average acceleration of body may be

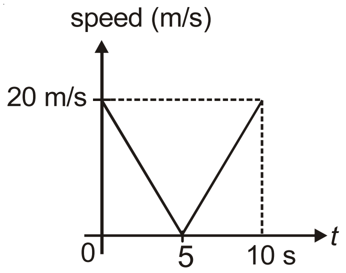


(1) 0 (2) 4 m/s^2 (3) – 4 m/s^2 (4) All of these

Sol. Answer (4)

The acceleration from zero to 5 s is

$$a = \frac{0-20}{5-0} = \frac{-20}{5} = -4 \text{ ms}^{-2}$$



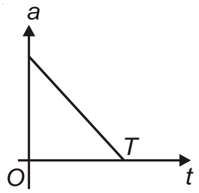
From 5 s to 10 s

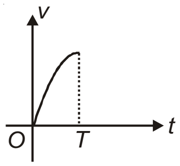
$$a = \frac{20-0}{10-5} = 4 \text{ ms}^{-2}$$

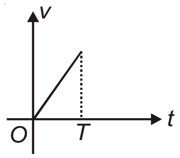
$$a = \frac{\text{Total change in velocity}}{\text{Time}}$$

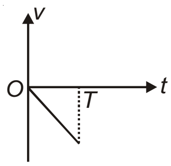
$$= \frac{20-20}{10-0} = 0 \text{ ms}^{-2}$$

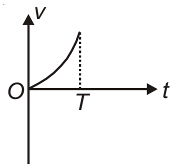
11. The acceleration (a)-time (t) graph for a particle moving along a straight starting from rest is shown in figure. Which of the following graph is the best representation of variation of its velocity (v) with time (t)?



(1)


(2)


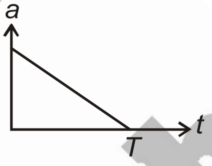
(3)


(4)


Sol. Answer (1)

From the graph it is evident that the acceleration is decreasing with time.

Also, $a \propto -t$



$\Rightarrow$ $a = -kt$ (decreasing with time)

To find velocity,

$$\frac{dv}{dt} = -kt$$

$$\int dv = \int -kt\,dt$$

$v \propto -t^2$ or graph of velocity should be parabolic with a decreasing slope.

12. A ball is thrown upward with speed 10 m/s from the top of the tower reaches the ground with a speed 20 m/s. The height of the tower is [Take $g = 10$ m/s^2]

(1) 10 m (2) 15 m (3) 20 m (4) 25 m

Sol. Answer (2)

$$v = \sqrt{u^2 + 2gh}$$

$$\Rightarrow (-20)^2 = 10^2 + 2 \times 10 \times h$$

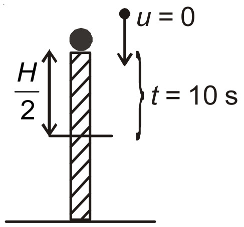
$$\Rightarrow \frac{300}{2 \times 10} = h \Rightarrow \boxed{h = 15\text{ m}}$$

13. A ball dropped from the top of tower falls first half height of tower in 10 s. The total time spend by ball in air is [Take g = 10 m/s^2]

(1) 14.14 s (2) 15.25 s (3) 12.36 s (4) 17.36 s

Sol. Answer (1)

$$\frac{-H}{2} = ut - \frac{1}{2} g \times 10^2$$



$$\Rightarrow H = g \times 10^2$$

$$\Rightarrow -H = -\frac{1}{2} g t^2 \quad \text{(Full journey)}$$

$$g \times 10^2 = \frac{1}{2}gt^2$$

$\Rightarrow$ $t^2 = 200$

$\Rightarrow$ $t = 10\sqrt{2}$ s

$\Rightarrow$ $t = 10 \times 1.414$ s

$= \boxed{14.14 \text{ s} = t}$

14. An object thrown vertically up from the ground passes the height 5 m twice in an interval of 10 s. What is its time of flight?

(1) $\sqrt{28}$ s	(2) $\sqrt{86}$ s	(3) $\sqrt{104}$ s	(4) $\sqrt{72}$ s

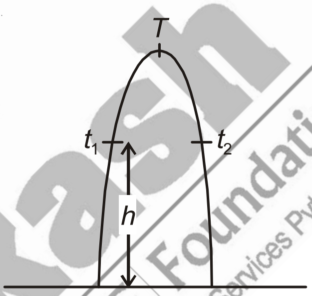
Sol. Answer (3)

$h = 5$ m (given)

$t_2 - t_1 = 10$ s

$T \rightarrow$ Time taken to reach the highest point.

$$t_1 = T - \sqrt{T^2 - \frac{2h}{g}}, \quad t_2 = T + \sqrt{T^2 - \frac{2h}{g}}$$



$$t_2 - t_1 = T + \sqrt{T^2 - \frac{2h}{g}} - T + \sqrt{T^2 - \frac{2h}{g}}$$

$$\Rightarrow \quad 10 = 2\sqrt{T^2 - \frac{2 \times 5}{10}}$$

$\Rightarrow$ $5 = \sqrt{T^2 - 1}$ $\Rightarrow$ $25 = T^2 - 1$

$T^2 = 26$

$\Rightarrow$ $\boxed{T = \sqrt{26}}$

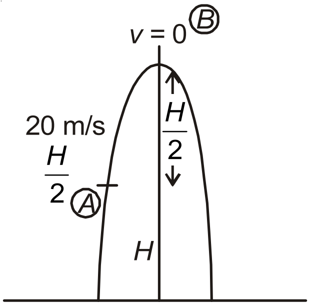
Total time of flight $\Rightarrow$ $2T = 2\sqrt{26} = \sqrt{4 \times 26} = \sqrt{104}$ s

15. A ball is projected vertically upwards. Its speed at half of maximum height is 20 m/s. The maximum height attained by it is [Take $g = 10$ ms^2]

(1) 35 m	(2) 15 m	(3) 25 m	(4) 40 m

Sol. Answer (4)

$$v_B^2 - v_A^2 = -2g\left(\frac{H}{2}\right)$$



$$\Rightarrow \quad 0 - 400 = -2 \times 10 \times \frac{H}{2}$$

$\Rightarrow$ $\boxed{40 \text{ m} = H}$

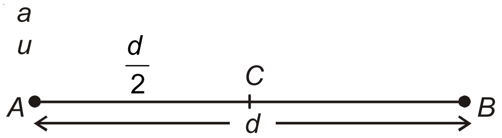
16. A particle starts with initial speed u and retardation a to come to rest in time T. The time taken to cover first half of the total path travelled is

(1) $\frac{T}{\sqrt{2}}$ (2) $T\left(1-\frac{1}{\sqrt{2}}\right)$ (3) $\frac{T}{2}$ (4) $\frac{3T}{4}$

Sol. Answer (2)

Retardation → a

Initial velocity → u



Time = T

(I) **For total journey**

$$v = u + at$$

$$0 = u - aT$$

$$\Rightarrow u = aT \qquad \text{...(i)}$$

$$d = uT - \frac{1}{2}aT^2$$

Dividing by 2 on both sides

$$\frac{d}{2} = \frac{uT}{2} - \frac{1}{2}\frac{aT^2}{2} \qquad \text{....(ii)}$$

(II) **For half journey**

$$\frac{d}{2} = ut - \frac{1}{2}at^2 \qquad \text{...(iii)}$$

On comparing equation (i) & (iii)

$$\frac{uT}{2} - \frac{1}{2}\frac{aT^2}{2} = ut - \frac{1}{2}at^2$$

Put $u = aT$

$$\Rightarrow \frac{aT^2}{2} - \frac{aT^2}{4} = aTt - \frac{1}{2}at^2$$

$$\Rightarrow \frac{T^2}{4} = Tt - \frac{t^2}{2}$$

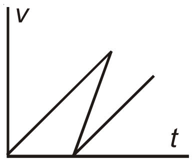
Multiplying by 4 on both sides

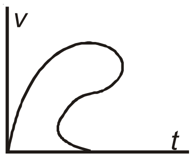
$$T^2 = 4Tt - 2t^2 \Rightarrow 2t^2 - 4Tt + T^2 = 0$$

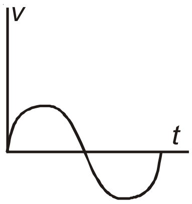
On solving this quadratic equation,

$$t = T - \frac{T}{\sqrt{2}} \Rightarrow \boxed{t = T\left(1-\frac{1}{\sqrt{2}}\right)}$$

17. Which of the following speed-time (v-t) graphs is physically not possible?

(1)


(2)


(3)


(4) All of these

Sol. Answer (4)

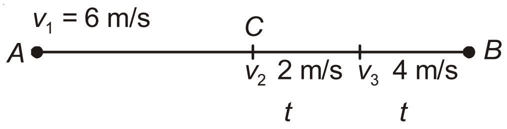
None of the graph is physically possible.

18. A particle travels half of the distance of a straight journey with a speed 6 m/s. The remaining part of the distance is covered with speed 2 m/s for half of the time of remaining journey and with speed 4 m/s for the other half of time. The average speed of the particle is

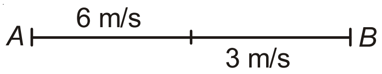
(1) 3 m/s (2) 4 m/s (3) 3/4 m/s (4) 5 m/s

Sol. Answer (2)

From C to B the time interval of travelling is same.



So, $v_{av} = \frac{v_2 + v_3}{2} = \frac{2+4}{2} = 3$ m/s

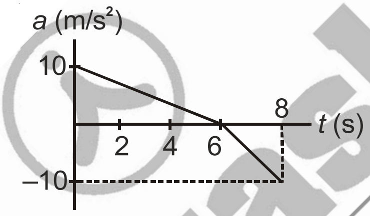
Now, 

Now, first half is covered with 6 ms^{-1} and second half with 3 ms^{-1}. So when distances are same.

$$v_{av} = \frac{2v_1v_2}{v_1 + v_2} = \frac{2 \times 6 \times 3}{6+3} = 4\ ms^{-1}$$

$$\boxed{v_{av} = 4\ ms^{-1}}$$

19. The acceleration-time graph for a particle moving along x-axis is shown in figure. If the initial velocity of particle is –5 m/s, the velocity at t = 8 s is



(1) +15 m/s (2) +20 m/s (3) –15 m/s (4) –20 m/s

Sol. Answer (1)

The area under a-t graph gives change in velocity.

Given, u = – 5 m/s

$\Rightarrow$ Area on positive side = $\frac{1}{2} \times 6 \times 10$ = 30 ms^{-1}

$\Rightarrow$ Area on negative side = $\frac{1}{2} \times 2 \times 10$ = 10 ms^{-1}

Net area = 30 – 10 = 20 ms^{-1}

Δv = Area

$v - (-5) = 20$

$\Rightarrow$ $\boxed{v = 15\ ms^{-1}}$

20. A body thrown vertically up with initial velocity 52 m/s from the ground passes twice a point at h height above at an interval of 10 s. The height h is (g = 10 m/s²)

(1) 22 m (2) 10.2 m (3) 11.2 m (4) 15 m

Sol. Answer (2)

Given, $t_2 - t_1$ = 10 s

$$t_2 + t_1 = \frac{2u}{g} = \frac{2 \times 52}{10} = 10.4$$

$\Rightarrow\ 2t_2 = 20.4$

$\Rightarrow\ t_2 = 10.2$ s

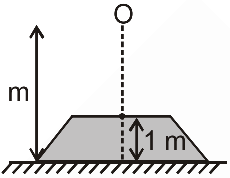
$t_1 = 0.2$ s

So, $t_1 t_2 = \dfrac{2h}{g}$

$$0.2 \times 10.2 = \frac{2 \times h}{10}$$

$\Rightarrow\ 1 \times 10.2 = h \Rightarrow \boxed{10.2\text{ m} = h}$

21. A body falling from a vertical height of 10 m pierces through a distance of 1 m in sand. It faces an average retardation in sand equal to (g = acceleration due to gravity)



(1) g (2) $9\,g$ (3) $100\,g$ (4) $1000\,g$

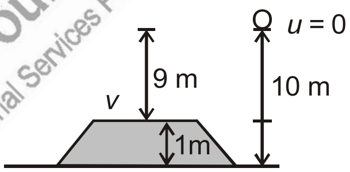
Sol. Answer (2)

If the ball is dropped then $x = 0$, the velocity with which it will hit the sand will be given by

$v^2 - u^2 = 2(-g)\,(-9)$

$v^2 - 0 = 18\,g$

$\boxed{v^2 = 18\,g}$ ...(i)



Now on striking sand, the body penetrates into sand for 1 m and comes to rest. So, $v \rightarrow$ initial for sand and final velocity = 0

$$v'^2 - v^2 = 2(a) \times (-1)$$

$\Rightarrow\ -18\,g = -2\,a$

$\Rightarrow\ \boxed{a = 9\,g}$

22. When a particle is thrown verticaly upwards, its velocity at one third of its maximum height is $10\sqrt{2}$ m/s. The maximum height attained by it is

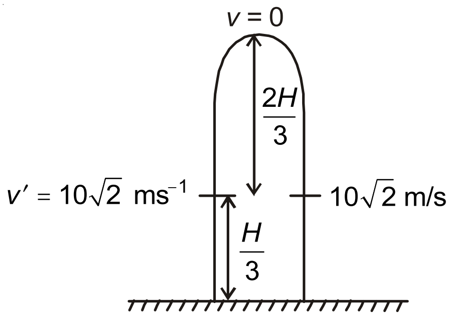
(1) $20\sqrt{2}$ m (2) 30 m (3) 15 m (4) 12.8 m

Sol. Answer (3)

$$v^2 - u^2 = -2g \times \frac{2H}{3}$$

$$\Rightarrow\ -100 \times 2 = -2 \times 10 \times \frac{2H}{3}$$

$\Rightarrow\ \boxed{H = 15\text{ m}}$



23. A body is dropped from a height H. The time taken to cover second half of the journey is

(1) $2\sqrt{\frac{2H}{g}}$ (2) $\sqrt{\frac{H}{g}}$ (3) $\sqrt{\frac{H}{g}}\left(\sqrt{2}-1\right)$ (4) $\sqrt{\frac{2H}{g}}\times\frac{1}{(\sqrt{2}-1)}$

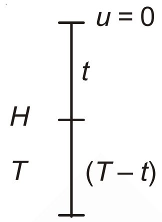
Sol. Answer (3)

The total time of journey

$$-s = ut - \frac{1}{2}gt^2$$

$$\Rightarrow \quad H = \frac{1}{2}gT^2 \qquad \text{...(i)}$$

$$\frac{-H}{2} = ut - \frac{1}{2}gt^2 \;\Rightarrow\; T = \sqrt{\frac{2H}{g}}$$



$$\Rightarrow \quad \frac{H}{2} = \frac{1}{2}gt^2$$

$$\Rightarrow \quad \frac{1}{2}gT^2 = gt^2 \qquad (\because\; ut = 0)$$

$$\Rightarrow \quad t = \frac{T}{\sqrt{2}}$$

$$\Rightarrow \quad \text{Second half time} = T - t = T - \frac{T}{\sqrt{2}} = T\left(1-\frac{1}{\sqrt{2}}\right) = \sqrt{\frac{2H}{g}}\left(1-\frac{1}{\sqrt{2}}\right) = \sqrt{\frac{H}{g}}\left(\sqrt{2}-1\right)$$

24. A stone dropped from the top of a tower is found to travel $\left(\frac{5}{9}\right)$ of the height of the tower during the last second of its fall. The time of fall is

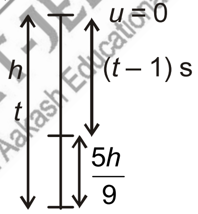
(1) 2 s (2) 3 s (3) 4 s (4) 5 s

Sol. Answer (2)

Let the total height of tower = H

Total time of journey = t

Time taken to cover the $\frac{5h}{9}$ is = last second



So, $s_t - s_{t-1} = \frac{5h}{9}$

$$\Rightarrow \quad \frac{1}{2}gt^2 - \frac{1}{2}g(t-1)^2 = \frac{5}{9}\times\frac{1}{2}gt^2 \qquad \left[\because\; h = \frac{1}{2}gt^2\right]$$

$$\Rightarrow \quad \frac{1}{2}g(t^2 - t^2 - 1 + 2t) = \frac{1}{2}gt^2\times\frac{5}{9}$$

$$\Rightarrow \quad (2t-1) = \frac{5}{9}t^2$$

$\Rightarrow$ $18t - 9 = 5t^2$

$\Rightarrow$ $5t^2 - 18t + 9 = 0$

$\Rightarrow$ $5t^2 - 15t - 3t + 9 = 0$

$\Rightarrow$ $5t(t - 3) - 3(t - 3) = 0$

$\Rightarrow$ $(5t - 3)(t - 3) = 0$

$t = \frac{3}{5}$, $\boxed{t = 3\text{ s}}$ ($t = \frac{3}{5}$, doesn't satisfy the given criterion, so we neglect it)

25. The velocity of a body depends on time according to the equation $v = \dfrac{t^2}{10} + 20$. The body is undergoing

(1) Uniform acceleration (2) Uniform retardation

(3) Non-uniform acceleration (4) Zero acceleration

Sol. Answer (3)

$$v = \frac{t^2}{10} + 20$$

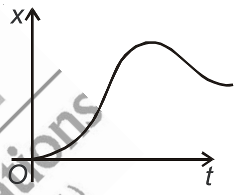
To find acceleration find $\dfrac{dv}{dt}$

So, $a = \dfrac{dv}{dt} = \dfrac{2t}{10} + 0$

$\Rightarrow \quad a = \dfrac{t}{5} \Rightarrow \boxed{a \propto t}$

$\because$ a is a function of time so it is not constant, rather it is non-uniform.

26. The displacement (x) - time (t) graph of a particle is shown in figure. Which of the following is correct?



(1) Particle starts with zero velocity and variable acceleration

(2) Particle starts with non-zero velocity and variable acceleration

(3) Particle starts with zero velocity and uniform acceleration

(4) Particle starts with non-zero velocity and uniform acceleration

Sol. Answer (1)

From the graph it is clear that the x is a function of time and speed/velocity is also changing. So, if velocity is changing then definitely the acceleration also changes with time. So, at t = 0, x = 0, so v = 0 but it is function of time and hence non-uniform.

27. A stone thrown upward with a speed u from the top of a tower reaches the ground with a velocity $4u$. The height of the tower is

(1) $\dfrac{15u^2}{2g}$ (2) $\dfrac{7u^2}{2g}$ (3) $\dfrac{16u^2}{g}$ (4) Zero

Sol. Answer (1)

$$v = \sqrt{u^2 + 2gh}$$

$$(4u)^2 = u^2 + 2gh$$

$$\frac{16u^2 - u^2}{2g} = h \Rightarrow \boxed{h = \frac{15u^2}{2g}}$$

28. If magnitude of average speed and average velocity over an interval of time are same, then

(1) Particle must move with zero acceleration

(2) Particle must move with uniform acceleration

(3) Particle must be at rest

(4) Particle must move in a straight line without turning back

Sol. Answer (4)

Particle should have same distance and displacement in order to have final average speed and average velocity which is only possible only in case of an object moving on a straight line without turning back.

29. A body is dropped from a certain height h (h is very large) and second body is thrown downward with velocity of 5 m/s simultaneouly. What will be difference in heights of the two bodies after 3s?

(1) 5 m (2) 10 m (3) 15 m (4) 20 m

Sol. Answer (3)

$$u_{\text{rel}} = u_1 - u_2 = 0 - (-5) = 5 \text{ ms}^{-1}$$

t = 3 s

$$a_{\text{rel}} = a_1 - a_2 = -g - (-g) = 0 \text{ ms}^{-2}$$

$$s_{\text{rel}} = u_{\text{rel}}\, t + \frac{1}{2} a_{\text{rel}}\, t^2$$

$$\Rightarrow \quad s_{\text{rel}} = 5 \times 3 = 15 \text{ m} \qquad (\because\ a_{\text{rel}} = 0)$$

So, $\boxed{s_{\text{rel}} = 15 \text{ m}}$

30. Ball A is thrown up vertically with speed 10 m/s. At the same instant another ball B is released from rest at height h. At time t, the speed of A relative to B is

(1) 10 m/s (2) $10 - 2\,gt$ (3) $\sqrt{10^2 - 2gh}$ (4) $10 - gt$

Sol. Answer (1)

$$v_A = 10 \text{ ms}^{-1} - 10t$$

$$v_B = 0 - 10t$$

$$v_{AB} = v_A - v_B = 10 - (10t) - (-10t) = 10 - 10t + 10t \ = 0$$

$$\Rightarrow \quad \boxed{v_{AB} = 10 \text{ ms}^{-1}}$$

31. A man moves in an open field such that after moving 10 m on a straight line, he makes a sharp turn of 60º to his left. The total displacement after 8 such turn is equal to

(1) 12 m (2) 15 m (3) 17.32 m (4) 14.14 m

Sol. Answer (3)

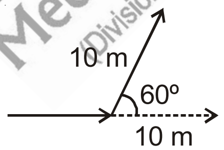
After 8 such turns object is at 'B'.

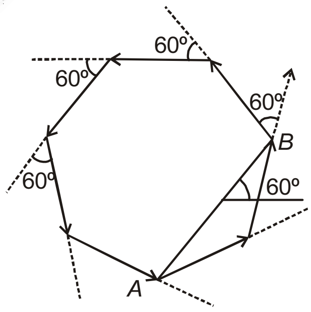
Displacement = AB

Two vectors are at 60º

$$\sqrt{10^2 + 10^2 + 2 \times 10^2 \times \frac{1}{2}} \ = 10\sqrt{3} \text{ m}$$

$$\Rightarrow \quad \boxed{17.32 \text{ m} = AB}$$





32. A body starts from origin and moves along x-axis so that its position at any instant is $x = 4t^2 - 12t$ where t is in second and v in m/s. What is the acceleration of particle?

(1) 4 m/s^2 (2) 8 m/s^2 (3) 24 m/s^2 (4) 0 m/s^2

Sol. Answer (2)

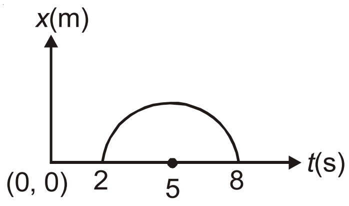
$$x = 4t^2 - 12t$$

$$v = \frac{dx}{dt} = 8t - 12$$

$$a = \frac{d^2x}{dt^2} = 8$$

$$\Rightarrow \boxed{a = 8 \text{ ms}^{-2}}$$

33. Position time graph of a particle moving along straight line is shown which is in the form of semi-circle starting from $t = 2$ to $t = 8$ s. Select correct statement



(1) Velocity of particle between $t = 0$ to $t = 2$ s is positive

(2) Velocity of particle is opposite to acceleration between $t = 2$ to $t = 5$ s

(3) Velocity of particle is opposite to acceleration between $t = 5$ to $t = 8$ s

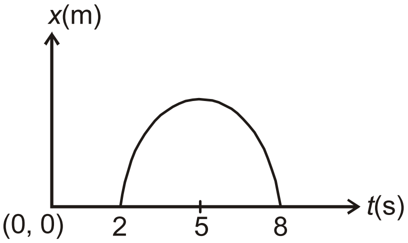
(4) Acceleration of particle is positive between $t_1 = 2$ s to $t_2 = 5$ s while it is negative between $t_1 = 5$ s to $t_2 = 8$ s

Sol. Answer (2)

(i) From 0 to 2 s the velocity = 0 as displacement is zero.

(ii) From 2 to 5 s velocity is decreasing but nature is positive, but acceleration is negative.

So, v and a have opposite nature.



34. Two bodies starts moving from same point along a straight line with velocities $v_1 = 6$ m/s and $v_2 = 10$ m/s, simultaneously. After what time their separation becomes 40 m?

(1) 6 s (2) 8 s (3) 12 s (4) 10 s

Sol. Answer (4)

$$s_{\text{rel}} = u_{\text{rel}}\,t + \frac{1}{2}a_{\text{rel}}\,t^2$$

$a_{\text{rel}} = 0$,

$$\Rightarrow \quad 40 = (10-6)\times t$$

$$\Rightarrow \quad \frac{40}{4} = t \quad \Rightarrow \quad \boxed{t = 10\text{ s}}$$

SECTION - C

Previous Years Questions

1. The displacement 'x' (in meter) of a particle of mass 'm' (in kg) moving in one dimension under the action of a force, is related to time 't' (in sec) by $t = \sqrt{x} + 3$. The displacement of the particle when its velocity is zero, will be

(1) 2 m (2) 4 m (3) 0 m (zero) (4) 6 m

Sol. Answer (3)

$$t = \sqrt{x} + 3$$

$$(t-3) = \sqrt{x} \quad \Rightarrow \quad x = (t-3)^2 = t^2 + 9 - 6t$$

$$\Rightarrow \quad v = \frac{dx}{dt} = 2t - 6$$

If $v = 0$, $\quad 2t - 6 = 0$

$$\Rightarrow \quad \boxed{t = 3\text{ s}}$$

At, $t = 3$ s, $\quad x = ?$

$$\Rightarrow \quad x = (t-3)^2 = (3-3)^2$$

$$\boxed{x = 0}$$

2. The motion of a particle along a straight line is described by equation

$x = 8 + 12t - t^3$

where x is in metre and t in second. The retardation of the particle when its velocity becomes zero, is

(1) 6 ms^{-2} (2) 12 ms^{-2} (3) 24 ms^{-2} (4) Zero

Sol. Answer (2)

$x = 8 + 12t - t^3$

$$\frac{dx}{dt} = 12 - 3t^2$$

If $v = 0$, then $12 - 3t^2 = 0$

$$\Rightarrow 4 = t^2 \Rightarrow \boxed{t = 2\text{ s}}$$

$$a = \frac{d^2x}{dt^2} = -6t$$

$$a\big|_{t=2\text{ s}} \Rightarrow -12\text{ ms}^{-2}$$

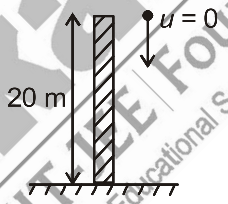
$$\boxed{|a| = 12\text{ ms}^{-2}}$$

3. A boy standing at the top of a tower of 20 m height drops a stone. Assuming $g = 10\text{ ms}^{-2}$, the velocity with which it hits the ground is

(1) 5.0 m/s (2) 10.0 m/s (3) 20.0 m/s (4) 40.0 m/s

Sol. Answer (3)

$$-s = ut - \frac{1}{2}gt^2$$



$$\Rightarrow \quad -20 = -\frac{1}{2} \times 10 \times t^2 \qquad (\because\ u = 0)$$

$$\Rightarrow \quad 40 = 10t^2$$

$$\Rightarrow \quad \boxed{t = 2\text{ s}}$$

$$v = u - gt$$

$$\Rightarrow \quad \boxed{v = -20\text{ ms}^{-1}} \qquad (\because\ u = 0)$$

$$\Rightarrow \quad \boxed{|v| = 20\text{ ms}^{-1}}$$

4. A particle covers half of its total distance with speed v_1 and the rest half distance with speed v_2. Its average speed during the complete journey is

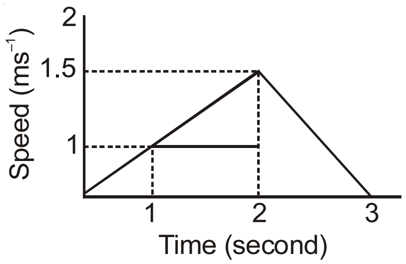
(1) $\dfrac{v_1^2 v_2^2}{v_1^2 + v_2^2}$ (2) $\dfrac{v_1 + v_2}{2}$ (3) $\dfrac{v_1 v_2}{v_1 + v_2}$ (4) $\dfrac{2v_1 v_2}{v_1 + v_2}$

Sol. Answer (4)

As the distances are same so,

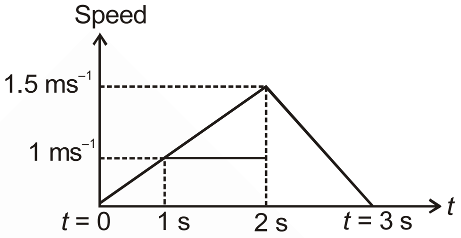
$$\boxed{v_{av} = \frac{2v_1 v_2}{v_1 + v_2}}$$

5. The speed-time graph of a particle moving along a solid curve is shown below. The distance traversed by the particle from $t = 0$ to $t = 3$ is



(1) $\frac{9}{2}$ m (2) $\frac{9}{4}$ m (3) $\frac{10}{3}$ m (4) $\frac{10}{5}$ m

Sol. Answer (2)



Area under the speed-time graph gives distance.

$$\text{Area} = \frac{1}{2}\times 3\times 1.5 \Rightarrow \frac{9}{4}\text{ m}$$

6. The distance travelled by a particle starting from rest and moving with an acceleration $\frac{4}{3}$ ms^{-2}, in the third second is

(1) $\frac{19}{3}$m (2) 6 m (3) 4 m (4) $\frac{10}{3}$m

Sol. Answer (4)

$$S_{n^{\text{th}}} = u + \frac{a}{2}(2n-1)$$

$n = 3$, (given), $a = \frac{4}{3}$ ms^{-2}

$$S_{n^{\text{th}}} = u + \frac{a}{2}(2n-1)$$

$$\Rightarrow \quad S_{n^{\text{th}}} = 0 + \frac{4}{3}\times\frac{1}{2}(2\times 3 - 1)$$

$$= \frac{2}{3}\times 5$$

$$\Rightarrow \quad \boxed{\frac{10}{3}\text{ m} = S_{3^{\text{rd}}}}$$

7. A student measures the distance traversed in free fall of a body, initially at rest in a given time. He uses this data to estimate g, the acceleration due to gravity. If the maximum percentage errors in measurement of the distance and the time are e_1 and e_2 respectively, the percentage error in the estimation of g is

(1) $e_2 - e_1$ (2) $e_1 + 2e_2$ (3) $e_1 + e_2$ (4) $e_1 - 2e_2$

Sol. Answer (2)

Repeated.

8. A particle moves in a straight line with a constant acceleration. It changes its velocity from 10 ms^{-1} to 20 ms^{-1} while passing through a distance 135 m in *t* second. The value of *t* is

(1) 9 (2) 10 (3) 1.8 (4) 12

Sol. Answer (1)

Using 3rd equation, we first find acceleration,

$v^2 - u^2 = 2as$

$20^2 - 10^2 = 2a \times 135$

$$\Rightarrow \frac{300}{2\times135} = a \quad \Rightarrow a = \frac{20}{18} \Rightarrow \boxed{\frac{10}{9}\ \text{ms}^{-2} = a}$$

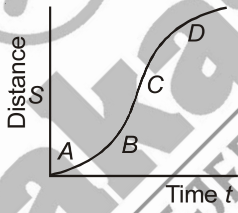
$\Rightarrow v = u + at$

$$\Rightarrow 20 = 10 + \frac{10}{9}\times t$$

$$\Rightarrow 10 = \frac{10}{9}t$$

$$\Rightarrow \boxed{t = 9\ \text{s}}$$

9. A particle shows distance-time curve as given in this figure. The maximum instantaneous velocity of the particle is around the point



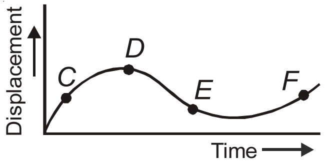
(1) *A* (2) *B* (3) *C* (4) *D*

Sol. Answer (3)

Maximum instantaneous velocity will be at that point which has maximum slope.

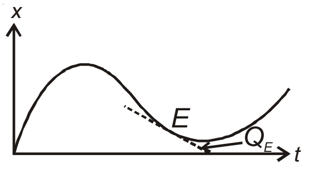
As clear from the graph '*C*' has maximum slope.

10. The displacement-time graph of a moving particle is shown below. The instantaneous velocity of the particle is negative at the point



(1) *E* (2) *F* (3) *C* (4) *D*

Sol. Answer (1)



The angle made by the tangent at point '*C*' is obtuse hence

tan Q_E = negative, so slope = negative

hence, velocity is also negative.

11. The displacement x of a particle varies with time t as $x = ae^{-\alpha t} + be^{\beta t}$, where a, b, α and β are positive constants. The velocity of the particle will

(1) Be independent of β (2) Drop to zero when $\alpha = \beta$

(3) Go on decreasing with time (4) Go on increasing with time

Sol. Answer (4)

$$x = ae^{-\alpha t} + be^{\beta t}$$

$$\frac{dx}{dt} = a(-\alpha)e^{-\alpha t} + b(\beta)e^{\beta t}$$

$$v = b\beta e^{\beta t} - a\alpha e^{-\alpha t}$$

As we increase time $e^{\beta t}$ increases and $e^{-\alpha t}$ decreases.

So, v keeps on increasing with time.

12. A particle moves along a straight line OX. At a time t (in seconds) the distance x (in metres) of the particle from O is given by $x = 40 + 12t - t^3$. How long would the particle travel before coming to rest?

(1) 16 m (2) 24 m (3) 40 m (4) 56 m

Sol. Answer (1)

$$\boxed{x = 40 + 12t - t^3}$$

The particle will come to rest when $v = 0$,

$$v = \frac{dx}{dt} = 12 - 3t^2$$

$$\Rightarrow \quad v = 0 \quad \Rightarrow \quad 12 = 3t^2$$

$$\Rightarrow \quad t^2 = 4 \;\Rightarrow\; \boxed{t = 2\text{ s}}$$

So, the distance travelled by object is 2 s.

$$x|_{t=0} = 40\text{ m},$$

$$x|_{t=2\text{s}} = 40 + 12 \times 2 - 8 = 40 + 24 - 8 = 40 + 16 \Rightarrow 56\text{ m}$$

Distance travelled = (56 – 40) = 16 m

13. Two bodies A (of mass 1 kg) and B (of mass 3 kg) are dropped from heights of 16 m and 25 m, respectively. The ratio of the time taken by them to reach the ground is

(1) $\frac{4}{5}$ (2) $\frac{5}{4}$ (3) $\frac{12}{5}$ (4) $\frac{5}{12}$

Sol. Answer (1)

$$T = \sqrt{\frac{2H}{g}} \Rightarrow T \propto \sqrt{H}$$

$$\Rightarrow \quad \frac{T_1}{T_2} = \sqrt{\frac{H_1}{H_2}}$$

$$\Rightarrow \quad \frac{T_1}{T_2} = \sqrt{\frac{16}{25}} = \frac{4}{5} \qquad (\text{Given, } H_1 = 16\text{ m}, H_2 = 25\text{ m})$$

$$\Rightarrow \quad \boxed{\frac{T_1}{T_2} = \frac{4}{5}}$$

14. The position x of a particle with respect to time t along x-axis is given by $x = 9t^2 - t^3$, where x is in metres and t in seconds. What will be the position of this particle when it achieves maximum speed along the $+x$ direction?

(1) 54 m (2) 81 m (3) 24 m (4) 32 m

Sol. Answer (1)

$x = 9t^2 - t^3$

$$\frac{dx}{dt} = 18t - 3t^2$$

$\Rightarrow$ $v = 18t - 3t^2$

To find the maxima of speed,

$$\frac{dv}{dt} = 18 - 6t$$

Put, $\frac{dv}{dt} = 0$ $\Rightarrow$ $18 - 6t = 0$

$\Rightarrow$ $\boxed{t = 3\text{ s}}$

So, the positions of particle at $t = 3$ = ?

$$x|_{t=3\text{ s}} = 9(3^2) - 3^3$$

$$\boxed{x = 54\text{ m}}$$

15. A car moves from X to Y with a uniform speed v_u and returns to X with a uniform speed v_d. The average speed for this round trip is

(1) $\sqrt{v_u v_d}$ (2) $\frac{v_d v_u}{v_d + v_u}$ (3) $\frac{v_u + v_d}{2}$ (4) $\frac{2v_d v_u}{v_d + v_u}$

Sol. Answer (4)

Repeated.

16. A particle moving along x-axis has acceleration f at time t given by $f = f_0\left(1 - \frac{t}{T}\right)$, where f_0 and T are constants. The particle at $t = 0$ has zero velocity. In the time interval between $t = 0$ and the instant when $f = 0$, the particle's velocity (v_x) is

(1) $\frac{1}{2}f_0T^2$ (2) f_0T^2 (3) $\frac{1}{2}f_0T$ (4) f_0T

Sol. Answer (3)

$$f = f_0\left(1 - \frac{t}{T}\right)$$

$f \rightarrow$ Acceleration

$f_0 \rightarrow$ Initial acceleration

Initial/lower limit of time = 0, $u = 0$

Upper limit of time = T, v = ?

$$a = \frac{dv}{dt} \Rightarrow \int_0^{v_x} dv = \int_0^t a dt$$

$$\int_0^{v_x} dv = \int_0^T f_0\left(1 - \frac{t}{T}\right) dt$$

$$v\Big|_0^{v_x} = f_0\, t\Big|_0^T - \frac{f_0}{T}\frac{t^2}{2}\Big|_0^T$$

$$v_x - 0 = f_0(T-0) - \frac{f_0}{2T}(T^2 - 0)$$

$$\Rightarrow \quad v_x = f_0 T - \frac{1}{2} f_0 T$$

$$\Rightarrow \quad \boxed{v_x = \frac{1}{2} f_0 T}$$

17. A particle starts its motion from rest under the action of a constant force. If the distance covered in first 10 seconds is S_1 and that covered in the first 20 seconds is S_2, then

(1) $S_2 = S_1$ (2) $S_2 = 2S_1$ (3) $S_2 = 3S_1$ (4) $S_2 = 4S_1$

Sol. Answer (4)

$u = 0$, $a \rightarrow$ Constant

$$S_1 = \frac{1}{2}a(10)^2, \; S_2 = \frac{1}{2}a(20)^2$$

$$\frac{S_1}{S_2} = \frac{10^2}{(20)^2} = \frac{100}{400}$$

$$\boxed{S_2 = 4S_1}$$

18. A bus is moving with a speed of 10 ms^{-1} on a straight road. A scooterist wishes to overtake the bus in 100 s. If the bus is at a distance of 1 km from the scooterist, with what speed should the scooterist chase the bus?

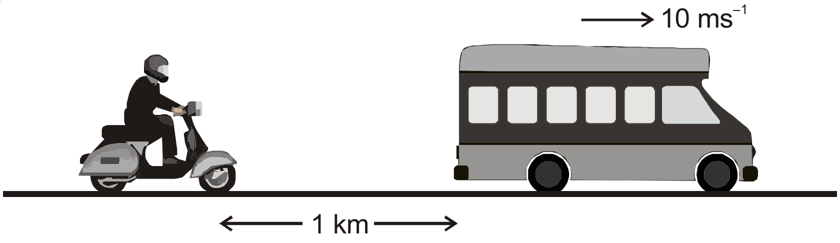
(1) 10 ms^{-1} (2) 20 ms^{-1} (3) 40 ms^{-1} (4) 25 ms^{-1}

Sol. Answer (2)

$T = 100$ s

$S_{rel} = 1000$ m

$S_{rel} = U_{rel}\, t \qquad (\because a_{rel} = 0)$



$1000 = (v - 10) \times 100$

$$\boxed{v = 20 \text{ ms}^{-1}}$$

19. A particle moves a distance x in time t according to equation $x = (t + 5)^{-1}$. The acceleration of particle is proportional to

(1) $(\text{Velocity})^{2/3}$ (2) $(\text{Velocity})^{3/2}$ (3) $(\text{Distance})^2$ (4) $(\text{Distance})^{-2}$

Sol. Answer (2)

$x = (t + 5)^{-1}$

$$v = \frac{dx}{dt} = (-1)(t+5)^{-2} \qquad \left[\because \frac{d}{dx}(x^n) = nx^{n-1}\right]$$

$v = -(t + 5)^{-2}$

$$a = \frac{dv}{dt} = (-1)(-2)(t+5)^{-3}$$

$$a = 2(t+5)^{-3} - 2(t+5)^{-2} \times (t+5)^{-1} \qquad \left[\because v \propto \frac{1}{(t+5)^2} \Rightarrow v^{\frac{1}{2}} \propto \frac{1}{t+5}\right]$$

$$\propto 2(v) \times v^{\frac{1}{2}}$$

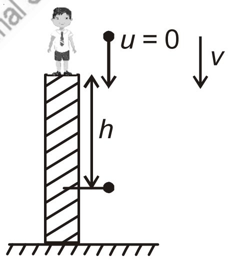
$$a \propto 2v^{\frac{3}{2}}$$

$$\boxed{a \propto (\text{velocity})^{\frac{3}{2}}}$$

20. A ball is dropped from a high rise platform at $t = 0$ starting from rest. After 6 seconds another ball is thrown downwards from the same platform with a speed v. The two balls meet at $t = 18$ s. What is the value of v? (Take $g = 10$ m/s^2)

(1) 60 m/s (2) 75 m/s (3) 55 m/s (4) 40 m/s

Sol. Answer (2)



As the ball meet at $t = 18$ s

So, it means both of them covered the same distance 'h'.

But the time of travel is different

1st body → t

2nd body → $(t - 6)$ → as theorem after 6 s.

1st body

$$-h = -\frac{1}{2}gt^2$$

$$h = \frac{1}{2}gt^2 \qquad \text{...(i)}$$

2nd body

$$-h = -v(t-6) - \frac{1}{2}g(t-6)^2$$

$$h = v(t-2) + \frac{1}{2}(t-2)^2 \qquad \text{...(ii)}$$

Equating (i) and (ii), we get

$v = 75$ m/s

For fitst body, $t = 18$ s

For second body, $t = (18 - 6) = 12$ s

$$h = \frac{1}{2} \times 10 \times (18)^2 = 5 \times 324$$

$h = 1620$ m

For second body

$1600 = v \times (18 - 6) + \frac{1}{2} \times 10\ (18 - 6)^2$

$1620 = v \times 12 + 5 \times 144$

$\frac{1620 - 720}{12} = v$

$\frac{900}{12} = v \Rightarrow \boxed{v = 75\ \text{ms}^{-1}}$

21. The velocity of train increases uniformly from 20 km/h to 60 km/h in 4 hour. The distance travelled by the train during this period is

(1) 160 km (2) 180 km (3) 100 km (4) 120 km

Sol. Answer (1)

$v^2 - u^2 = 2as$

$v = u + at$

$60 = 20 + a \times 4$

$40 = 4a$

$\boxed{a = 10\ \text{km/h}^{-2}}$

$60^2 - 20^2 = 2 \times 10 \times s$

$\frac{3600 - 400}{20} = s \Rightarrow \boxed{s = 160\ \text{km}}$

22. A particle moves along a straight line suchthat its displacement at any time t is given by$s = (t^3 - 6t^2 - 3t + 4)$ metres. The velocity when the acceleration is zero is

(1) 3 m/s (2) 42 m/s (3) –9 m/s (4) –15 m/s

Sol. Answer (4)

$s = t^3 - 6t - 3t + 4$

$v = \frac{ds}{dt} = 3t^2 - 12t - 3$

$a = \frac{dv}{dt} = 6t - 12$

Put $a = 0 \Rightarrow 6t - 12 = 0$

$\boxed{t = 2\ \text{s}}$

$v|_{t=2\ \text{s}} = 3(2)^2 - 12(2) - 3$

$= 12 - 24 - 3$

$= -12 - 3$

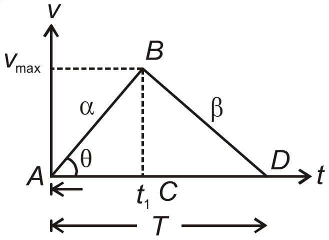
$\boxed{v = -15\ \text{ms}^{-1}}$

23. A car accelerates from rest at a constant rate α for some time after which it decelerates at a constant rate β and comes to rest. If total time elapsed is *t,* then maximum velocity acquired by car will be

(1) $\frac{(\alpha^2-\beta^2)t}{\alpha\beta}$ (2) $\frac{(\alpha^2+\beta^2)t}{\alpha\beta}$ (3) $\frac{(\alpha+\beta)t}{\alpha\beta}$ (4) $\frac{\alpha\beta t}{\alpha+\beta}$

Sol. Answer (4)

$$\boxed{v_{\max} = \frac{\alpha\beta t}{\alpha+\beta}}$$



In ΔABC, $\tan\theta = \text{slope} = \frac{v_{\max}}{t_1}$

In ΔBCD, $1-\beta = \frac{-v_{\max}}{T-t_1}$

$$\alpha t_1 = \beta T - \beta t_1$$

$$\Rightarrow \quad t_1 = \frac{\beta T}{\alpha+\beta}$$

$$v_{\max} = \alpha \times t_1$$

$$\boxed{v_{\max} = \frac{\alpha\beta T}{\alpha+\beta}}$$

24. A stone falls freely under gravity. It covers distances h_1, h_2 and h_3 in the first 5 seconds, the next 5 seconds and the next 5 seconds respectively. The relation between h_1, h_2 and h_3 is

(1) $h_1 = \frac{h_2}{3} = \frac{h_3}{5}$ (2) $h_2 = 3h_1$ and $h_3 = 3h_2$ (3) $h_1 = h_2 = h_3$ (4) $h_1 = 2h_2 = 3h_3$

Sol. Answer (1)

When a body starts from rest and under the effect of constant acceleration then the distance travelled by the body in final time intervals is in the ratio of odd number *i.e.*, 1 : 3 : 5 : 7

So, $h_1 : h_2 : h_3 \Rightarrow 1 : 3 : 5$

$$\frac{h_1}{h_2} = \frac{1}{3}, \quad \frac{h_1}{h_3} = \frac{1}{5}$$

$$\Rightarrow \quad h_1 = \frac{h_2}{3}, \quad h_1 = \frac{h_3}{5}$$

So, $h_1 = \frac{h_2}{3} = \frac{h_3}{5}$

25. The water drops fall at regular intervals from a tap 5 m above the ground. The third drop is leaving the tap at instant the first drop touches the ground. How far above the ground is the second drop at that instant? (Take g = 10 ms^{-2})

(1) 3.75 m (2) 4. 00 m (3) 1.25 m (4) 2.50 m

Sol. Answer (1)

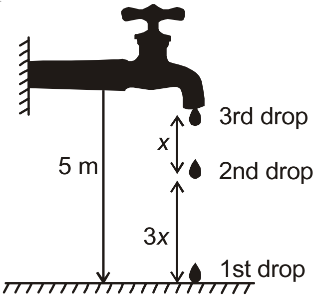
$x = 3x = 5$ m

$\Rightarrow \quad 4x = 5$ m

$\boxed{x = 1.25 \text{ m}}$

So, second drop is at $3x$

$\Rightarrow 3 \times 1.25 = 3.75$ m above ground.



26. The acceleration of a particle is increasing linearly with time t as bt. The particle starts from origin with an initial velocity v_0. The distance travelled by the particle in time t will be

(1) $v_0t + \frac{1}{3}bt^2$ (2) $v_0t + \frac{1}{2}bt^2$ (3) $v_0t + \frac{1}{6}bt^3$ (4) $v_0t + \frac{1}{3}bt^3$

Sol. Answer (3)

$a = bt$

$u = v_0$

$$a = \frac{dv}{dt}$$

$$\int_{v_0}^{v} dv = \int_0^t a\,dt$$

$$\int_{v_0}^{v} dv = \int bt\,dt$$

$$v - v_0 = \left.\frac{bt^2}{2}\right|_0^t$$

$$v - v_0 = \frac{b}{2}(t^2 - 0)$$

$$v = v_0 + \frac{1}{2}bt^2$$

Now, $v = \frac{dx}{dt}$

$$\Rightarrow \int_0^x dx = \int_0^t v\,dt$$

$$\int_0^x dx = \int_0^t \left(v_0 + \frac{1}{2}bt^2\right) dt$$

$$\boxed{x = v_0t + \frac{1}{6}bt^3}$$

27. If a car at rest accelerates uniformly to a speed of144 km/h in 20 s, it covers a distance of

(1) 1440 cm (2) 2980 cm (3) 20 m (4) 400 m

Sol. Answer (4)

$u = 0$, $a \rightarrow$ constant

$v = 144$ km/h^{-1} = $144 \times \frac{5}{18}$ = 40 ms^{-1}

$t = 20$ s

$v = u + at$

$40 = a \times 20$

$\boxed{a = 2\ \text{ms}^2}$

$$s = \frac{1}{2}at^2 = \frac{1}{2} \times 2 \times 400$$

$\boxed{s = 400\ \text{m}}$

28. The position x of a particle varies with time, (t) as $x = at^2 - bt^3$. The acceleration will be zero at time t equal to

(1) $\frac{a}{3b}$ (2) Zero (3) $\frac{2a}{3b}$ (4) $\frac{a}{b}$

Sol. Answer (1)

$x = at^2 - bt^3$

$$v = \frac{dx}{dt} = 2at - 3bt^2$$

$$a = \frac{dv}{dt} = 2a - 6bt$$

Put a = 0, to find 't'

$2a = 6bt$

$$\boxed{t = \frac{a}{3b}}$$

29. Motion of a particle is given by equation

$s = (3t^3 + 7t^2 + 14t + 8)$ m

The value of acceleration of the particle at t = 1 s is

(1) 10 m/s^2 (2) 32 m/s^2 (3) 23 m/s^2 (4) 16 m/s^2

Sol. Answer (2)

$s = 3t^3 + 7t^2 + 14t + 8$

$$v = \frac{ds}{dt} = 9t^2 + 14t + 14$$

$$a = \frac{d^2s}{dt^2} = 18t + 14$$

$$a|_{t=1\text{ s}} = 18 + 14$$

$$\boxed{a|_{t=1\text{ s}} = 32\text{ ms}^{-2}}$$

30. A particle is thrown vertically upward. Its velocity at half of the height is 10 m/s, then the maximum height attained by it is (g = 10 m/s^2)

(1) 8 m (2) 20 m (3) 10 m (4) 16 m

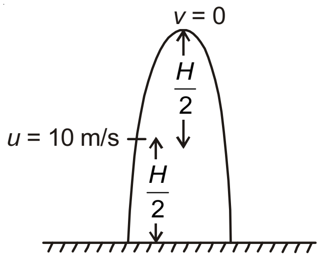
Sol. Answer (3)

$v^2 - u^2 = 2as$

$$0 - 10^2 = 2 \times (-10) \times \frac{H}{2}$$

$100 = 10H$

$$\boxed{H = 10\text{ m}}$$



31. A particle *A* is dropped from a height and another particle *B* is projected in horizontal direction with speed of 5 m/s from the same height then correct statement is

(1) Particle *A* will reach at ground first with respect to particle *B*

(2) Particle *B* will reach at ground first with respect to particle *A*

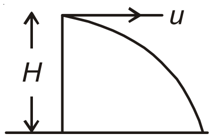
(3) Both particles will reach at ground simultaneously

(4) Both particles will reach at ground with same speed

Sol. Answer (3)

Time taken will be same in both the cases

Horizontal projection



$U_y = \sin\theta$

$\theta = 0$

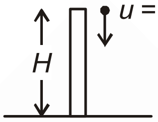
$\boxed{U_y = 0}$

$$S_y = U_y T + \frac{1}{2} a_y T^2$$

$$-H = -\frac{1}{2} g T^2$$

$$T = \sqrt{\frac{2H}{g}}$$

Dropping a body



$$S = ut + \frac{1}{2} at$$

$$-H = -\frac{1}{2} g T^2$$

$$T = \sqrt{\frac{2H}{g}}$$

32. If a ball is thrown vertically upwards with speed *u*, the distance covered during the last *t* seconds of its ascent is

(1) ut (2) $\frac{1}{2} g t^2$ (3) $ut - \frac{1}{2} g t^2$ (4) $(u + gt)t$

Sol. Answer (2)

As the motion is symmetric the distances covered during the last *t* seconds of ascent is same as that travelled during 1st *t* seconds of descent.

At highest point, $v = 0$

$$-s = -\frac{1}{2} g t^2 \Rightarrow \boxed{s = \frac{1}{2} g t^2}$$

33. A man throws balls with the same speed vertically upwards one after the other at an interval of 2 second. What should be the speed of the throw so that more than two balls are in the sky at any time? (Given $g = 9.8$ m/s^2)

(1) More than 19.6 m/s

(2) At least 9.8 m/s

(3) Any speed less than 19.6 m/s

(4) Only with speed 19.6 m/s

Sol. Answer (1)

For move than two ball in air, time of flight should be

Total time of flight $\leq \dfrac{2u}{g}$

$4 \leq \dfrac{2u}{g}$

$2 \times 9.8 \leq u$

$\boxed{u \geq 19.6 \text{ ms}^{-1}}$

SECTION - D

Assertion - Reason Type Questions

1. A : It is not possible to have constant velocity and variable acceleration.

   R : Accelerated body cannot have constant velocity.

Sol. Answer (1)

2. A : The direction of velocity of an object can be reversed with constant acceleration.

   R : A ball projected upward reverse its direction under the effect of gravity.

Sol. Answer (2)

3. A : When the velocity of an object is zero at an instant, the acceleration need not be zero at that instant.

   R : In motion under gravity, the velocity of body is zero at the top-most point.

Sol. Answer (2)

4. A : A body moving with decreasing speed may have increasing acceleration.

   R : The speed of body decreases, when acceleration of body is opposite to velocity.

Sol. Answer (1)

5. A : For a moving particle distance can never be negative or zero.

   R : Distance is a scalar quantity and never decreases with time for moving object.

Sol. Answer (1)

6. A : if speed of a particle is never zero than it may have zero average speed.

   R : The average speed of a moving object in a closed path is zero.

Sol. Answer (4)

7. A : The magnitude of average velocity in an interval can never be greater than average speed in that interval.

   R : For a moving object distance travelled ≥ | Displacement |

Sol. Answer (1)

8. A : The area under acceleration-time graph is equal to velocity of object.

R : For an object moving with constant acceleration, position-time graph is a straight line.

Sol. Answer (4)

9. A : The motion of body projected under the effect of gravity without air resistance is uniformly accelerated motion.

R : If a body is projected upwards or downwards, then the direction of acceleration is downward.

Sol. Answer (2)

10. A : The relative acceleration of two objects moving under the effect of gravity ,only is always zero, irrespective of direction of motion.

R : The acceleration of object moving under the effect of gravity have acceleration always in downward direction and is independent from size and mass of object

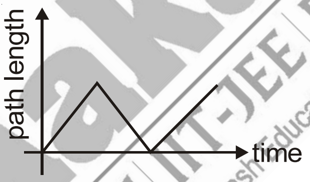
Sol. Answer (1)

11. A : In the presence of air resistance, if the ball is thrown vertically upwards then time of ascent is less than the time of descent.

R : Force due to air friction always acts opposite to the motion of the body.

Sol. Answer (1)

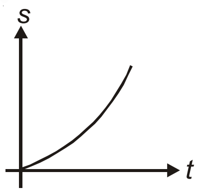
12. A : The following graph can't exist actually



R : Total path length never decreases with time.

Sol. Answer (1)

13. A : The displacement (s) time graph shown in the figure represents an accelerated motion.



R : Slope of graph increases with time.

Sol. Answer (1)

14. A : Average velocity can be zero, but average speed of a moving body can not be zero in any finite time interval.

R : For a moving body displacement can be zero but distance can never be zero.

Sol. Answer (1)

15. A : For a particle moving in a straight line, its acceleration must be either parallel or antiparallel to velocity.

R : A body moving along a curved path may have constant acceleration.

Sol. Answer (2)

❑ ❑ ❑

Chapter 4

Motion in a Plane

Solutions

SECTION - A

Objective Type Questions

1. Which of the following is a vector?

(1) Current (2) Time (3) Acceleration (4) Volume

Sol. Answer (3)

Acceleration is a vector quantity.

2. The change in a vector may occur due to

(1) Rotation of frame of reference (2) Translation of frame of reference

(3) Rotation of vector (4) Both (1) & (3)

Sol. Answer (3)

Change in a vector may occur due to rotation of vector and not due to rotation of frame of reference.

3. Which one of the following pair cannot be the rectangular components of force vector of 10 N?

(1) 6 N & 8 N (2) 7 N & $\sqrt{51}$ N (3) $6\sqrt{2}$ N & $2\sqrt{7}$ N (4) 9 N & 1 N

Sol. Answer (4)

The vector magnitude = $\sqrt{A_{x^2} + A_{y^2}}$

Vector magnitude = 10

But (4) option gives the magnitude

$\Rightarrow \sqrt{9^2 + 1^2} = \sqrt{82} \neq 10$ [by trial method check options]

4. The resultant of two vectors at an angle 150° is 10 units and is perpendicular to one vector. The magnitude of the smaller vector is

(1) 10 units (2) $10\sqrt{3}$ units (3) $10\sqrt{2}$ units (4) $5\sqrt{3}$ units

Sol. Answer (2)

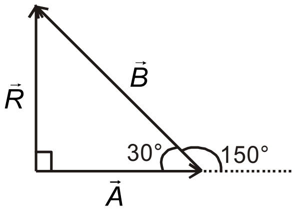
$\Rightarrow\ R^2 + A^2 = B^2$ .....(1)

$R = 10$

Also $\tan 30^\circ = \dfrac{\text{Perpendicular}}{\text{Base}}$

$\dfrac{1}{\sqrt{3}} = \dfrac{R}{A}$

From equation (1) $A = 10\sqrt{3}$



$(10)^2 + (10\sqrt{3})^2 = B^2$

$B = 20$

5. Two vectors, each of magnitude A have a resultant of same magnitude A. The angle between the two vectors is

(1) 30° (2) 60° (3) 120° (4) 150°

Sol. Answer (3)

$|\vec{A}| = |\vec{B}| = |\vec{R}|$

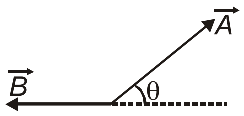
$R = \sqrt{A^2 + B^2 + 2AB\cos\theta}$

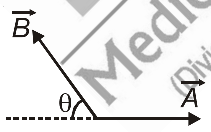
$A^2 = A^2 + A^2 + 2A^2\cos\theta$

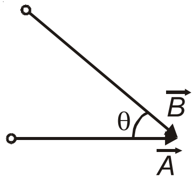
$-A^2 = 2A^2\cos\theta$

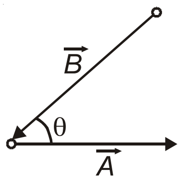
$\cos\theta = -\dfrac{1}{2} \Rightarrow \theta = 120^\circ$

6. Let θ be the angle between vectors $\vec{A}$ and $\vec{B}$. Which of the following figures correctly represents the angle θ?

(1)


(2)


(3)


(4)


Sol. Answer (3)

To find angle between vectors, they will be joined either head to head or tail to tail.

7. $\vec{A}$ is a vector of magnitude 2.7 units due east. What is the magnitude and direction of vector $4\vec{A}$?

(1) 4 units due east (2) 4 units due west (3) 2.7 units due east (4) 10.8 units due east

Sol. Answer (4)

$\vec{A} = 2.7\,\hat{i}$

Vector $4\vec{A}$

$\Rightarrow\ 4(2.7\hat{i}) = 10.8\hat{i}$ or 10.8 units due east.

8. Two forces of magnitude 8 N and 15 N respectively act at a point. If the resultant force is 17 N, the angle between the forces has to be

(1) 60° (2) 45° (3) 90° (4) 30°

Sol. Answer (4)

$R = \sqrt{A^2 + B^2 + 2AB\cos\theta}$

$A = 8,\ B = 15,\ R = 17$

$17^2 = 8^2 + 15^2 + 2 \times 8 \times 15 \times \cos\theta$

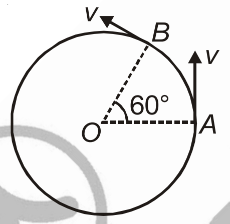
$289 = 64 + 225 + 240\cos\theta$

$\Rightarrow\ 289 = 289 + 24\cos\theta$

$24\cos\theta = 0$

$\cos\theta = 0 \Rightarrow \theta = 90^o$

9. A particle is moving in a circle of radius *r* having centre at *O*, with a constant speed *v*. The magnitude of change in velocity in moving from *A* to *B* is



(1) 2*v* (2) 0 (3) $\sqrt{3}\,v$ (4) *v*

Sol. Answer (4)

$[\Delta\vec{V}] = 2V\sin\frac{\theta}{2} = 2\times V\times\sin\left(\frac{60^o}{2}\right) = 2\times V\times\frac{1}{2} \Rightarrow V = |\Delta\vec{V}|$

10. Two forces of 10 N and 6 N act upon a body. The direction of the forces are unknown. The resultant force on the body may be

(1) 15 N (2) 3 N (3) 17 N (4) 2 N

Sol. Answer (1)

The resultant of two vectors always lie between (*A* + *B*) & (*A* – *B*).

So the resultant of 10 N & 6 N should lie between 16 N & 4 N.

So answer is 15 N.

11. The vector $\overrightarrow{OA}$ where *O* is origin is given by $\overrightarrow{OA} = 2\hat{i} + 2\hat{j}$. Now it is rotated by 45° anticlockwise about *O*. What will be the new vector?

(1) $2\sqrt{2}\ \hat{j}$ (2) $2\ \hat{j}$ (3) $2\ \hat{i}$ (4) $2\sqrt{2}\ \hat{i}$

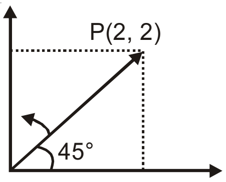
Sol. Answer (1)

$\overrightarrow{OA} = 2\hat{i} + 2\hat{j}$

$|\overrightarrow{OA}| = \sqrt{4+4}\ \Rightarrow\ 2\sqrt{2}$

On rotating by an angle of 45° anticlockwise it will lie along y-axis.

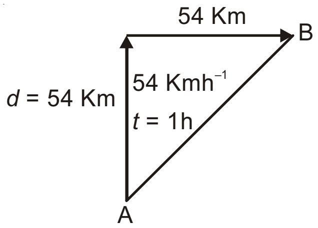
So $\vec{A} = 2\sqrt{2}\ \hat{j}$

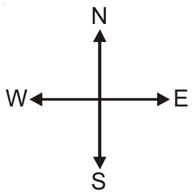


12. A car moves towards north at a speed of 54 km/h for 1 h. Then it moves eastward with same speed for same duration. The average speed and velocity of car for complete journey is

(1) 54 km/h, 0 (2) 15 m/s, $\frac{15}{\sqrt{2}}$ m/s (3) 0, 0 (4) 0, $\frac{54}{\sqrt{2}}$ km/h

Sol. Answer (2)





$$\text{Displacement} = \frac{54\sqrt{2}}{\text{Km}}$$

Distance = 2 × 54 = 108 Km

$$\text{Average speed} = \frac{108}{2} = 54\ \text{Kmh}^{-1} \times \frac{5}{18} = 15\ \text{ms}^{-1}$$

$$\text{Average velocity} = \frac{\text{disp.}}{\text{time}} = \frac{54\sqrt{2}}{2} \Rightarrow 27\sqrt{2} \times \frac{5}{18} \Rightarrow \frac{15}{\sqrt{2}}\ \text{m/s}$$

13. If the sum of two unit vectors is also a unit vector, then magnitude of their difference and angle between the two given unit vectors is

(1) $\sqrt{3}, 60°$ (2) $\sqrt{3}, 120°$ (3) $\sqrt{2}, 60°$ (4) $\sqrt{2}, 120°$

Sol. Answer (2)

$$|\vec{R}| = |\vec{A} + \vec{B}| = \sqrt{A^2 + B^2 + 2AB\cos\theta}$$

$$|\vec{A}| = |\vec{B}| = |\vec{R}| = 1$$

1 = 1 + 1 + 2 × 1 × 1 × cos θ

$$\cos\theta = -\frac{1}{2} \Rightarrow \theta = 120^\circ$$

$$|\vec{R}| = |\vec{A} - \vec{B}| = \sqrt{A^2 + B^2 - 2AB\cos 120^\circ}$$

$$= \sqrt{1^2 + 1^2 - 2\times1\times1\times\left(-\frac{1}{2}\right)} = \sqrt{3} = |\vec{A} - \vec{B}|$$

14. A vector, $\vec{A}$ points vertically upwards and $\vec{B}$ towards north. The vector product $\vec{A} \times \vec{B}$ is

(1) Zero (2) Along east (3) Along west (4) Vertically downward

Sol. Answer (3)

$\vec{A} \times \vec{B} = \vec{C}$ along west. (Using right hand thumb rule)

15. If vectors $\vec{A} = 2\hat{i} + 3\hat{j} + p\hat{k}$ and $\vec{B} = 3\hat{i} - 8\hat{j} + 2\hat{k}$ are perpendicular to each other, then value of p is

(1) 2 (2) –8 (3) –9 (4) 9

Sol. Answer (4)

If two vectors $\vec{A}$ and $\vec{B}$, ⊥ to each other then, $\vec{A}.\vec{B} = 0$

$(2\hat{i} + 3\hat{j} + p\hat{k}).(3\hat{i} - 8\hat{j} + 2\hat{k}) = 0$

$6 - 24 + 2p = 0$

$-18 + 2p = 0$

$p = 9$

16. If $\vec{A} = \hat{i} + 2\hat{k}$ and $\vec{B} = \hat{i} + \hat{j} - \hat{k}$ then $\vec{A} \times \vec{B}$ is equal to

(1) $2\hat{i} - \hat{j} - \hat{k}$ (2) $-2\hat{i} + \hat{j} + \hat{k}$ (3) $-2\hat{i} + 3\hat{j} + \hat{k}$ (4) $-\hat{i} + \hat{j} + \hat{k}$

Sol. Answer (3)

$$\vec{A} \times \vec{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 1 & 0 & 2 \\ 1 & 1 & -1 \end{vmatrix}$$

$= \hat{i}(0-2) - \hat{j}(-1-2) + \hat{k}(1-0)$

$\Rightarrow -2\hat{i} + 3\hat{j} + \hat{k}$

17. What is the angle between $(\hat{i} + \hat{j})$ and $(\hat{k} + \hat{j})$?

(1) 45°′ (2) 60° (3) 90° (4) 180°

Sol. Answer (2)

$\vec{A} = \hat{i} + \hat{j},\ \vec{B} = \hat{k} + \hat{j}$

We know

$\vec{A}.\vec{B} = AB\cos\theta$

$(\hat{i} + \hat{j}).(\hat{k} + \hat{j}) = \sqrt{2} \times \sqrt{2}\cos\theta$

$1 = 2\cos\theta$

$\cos\theta = \frac{1}{2}$

$\theta = 60^\circ$

18. If resultant of two vectors having magnitude 3 and 4 is 5. The magnitude of their cross product is

(1) Zero (2) 12 (3) 15 (4) 20

Sol. Answer (2)

We know for two vector $\vec{A}$ & $\vec{B}$, makes an angle θ then

$|\vec{A} \times \vec{B}| = AB\sin\theta$ and,

$|\vec{A} + \vec{B}| = \sqrt{A^2 + B^2 + 2AB\cos\theta}$

$$5=\sqrt{3^2+4^2+2\times3\times4\cos\theta}$$

$$25=9+16+24\cos\theta$$

$$24\cos\theta=0\Rightarrow\theta=90^\circ$$

So, $|\vec{A}\times\vec{B}|=AB\sin90^\circ$

$= 3 \times 4 \times 1$

$= 12$ units

19. If $\sqrt{3}\,|\vec{A}\times\vec{B}|=\vec{A}\cdot\vec{B}$, then value of $|\vec{A}+\vec{B}|$ is

(1) $[A^2+B^2+AB]^{1/2}$ (2) $[A^2+B^2+\sqrt{3}\,AB]^{1/2}$ (3) $[A^2+B^2-AB]^{1/2}$ (4) $[A^2+B^2]^{1/2}$

Sol. Answer (1)

$$\sqrt{3}|\vec{A}\times\vec{B}|=\vec{A}.\vec{B}$$

$$\sqrt{3}AB\sin\theta=AB\cos\theta$$

$$\tan\theta=\sqrt{3}$$

$$\Rightarrow\ \theta=60^\circ$$

$$|\vec{A}+\vec{B}|=\sqrt{A^2+B^2+2AB\cos\theta}$$

$$=\sqrt{A^2+B^2+2AB\times\cos60^\circ}$$

$$=\left(A^2+B^2+2AB\times\frac{1}{2}\right)^{\frac{1}{2}}$$

20. The area of the parallelogram whose sides are represented by the vectors $\hat{i}+2\hat{k}$ and $\hat{i}+\hat{j}-\hat{k}$ is

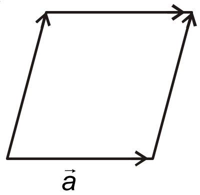
(1) $3\sqrt{5}$ units (2) $2\sqrt{5}$ units (3) $\sqrt{17}$ units (4) $\sqrt{14}$ units

Sol. Answer (4)

$\vec{a}=(\hat{i}+2\hat{k}),(\hat{i}+j-\hat{k})=\vec{b}$

Then

Area = $|\vec{a}\times\vec{b}|$



Area = $|\vec{a}\times\vec{b}|$

$$\text{Area }=\begin{vmatrix}\hat{i}&\hat{j}&\hat{k}\\1&0&2\\1&1&-1\end{vmatrix}$$

$$=\ \hat{i}(0-2)-\hat{j}(-1-2)+\hat{k}(1-0)$$

$$=\ -2\hat{i}+3\hat{j}+\hat{k}$$

So, area $=\sqrt{4+9+1}\Rightarrow\sqrt{14}$ units .

21. A particle projected from origin moves in *x*-*y* plane with a velocity $\vec{v} = 3\hat{i} + 6x\hat{j}$, where $\hat{i}$ and $\hat{j}$ are the unit vectors along *x* and *y* axis. Find the equation of path followed by the particle

(1) $y = x^2$ (2) $y = \frac{1}{x^2}$ (3) $y = 2x^2$ (4) $y = \frac{1}{x}$

Sol. Answer (3)

Method 1:

$$\vec{V} = 3\hat{i} + 6x\hat{j}$$

also $\vec{V} = \frac{dx}{dt}\hat{i} + \frac{dy}{dt}\hat{j}$

$$\Rightarrow \frac{dx}{dt} = 3,$$

$$\int dx = \int 3dt$$

$$x = 3t$$

$$\frac{dy}{dt} = 6x$$

$$dy = 6x \times dt$$

$$\int dy = \int 6 \times 3tdt$$

$$= 18\int tdt \Rightarrow 18 \times \frac{t^2}{2}$$

$$y = 9t^2$$

$$= 9 \times \frac{x^2}{9}$$

$$y = x^2$$

Method 2:

$$V_x\hat{i} + V_y\hat{j} = \vec{V}$$

$$V_x = 3$$

$$V_y = 6x$$

We know

$$\frac{d_y}{d_x} = \tan\theta = \frac{V_y}{V_x}$$

$$\frac{d_y}{d_x} = \frac{6x}{3x}$$

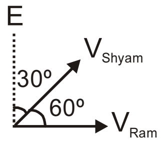
$$\int_0 dy = \int_0 2xdx$$

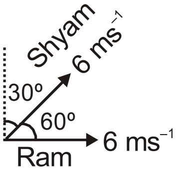
$$y = x^2$$

22. Ram moves in east direction at a speed of 6 m/s and Shyam moves 30° east of north at a speed of 6 m/s. The magnitude of their relative velocity is

(1) 3 m/s (2) 6 m/s (3) $6\sqrt{3}$ m/s (4) $6\sqrt{2}$ m/s

Sol. Answer (2)

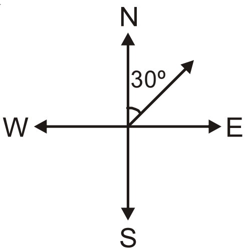




$$|\vec{V}_{RS}| = \sqrt{V_R^2 + V_S^2 - 2V_RV_S\cos\theta}$$

$$= \sqrt{6^2 + 6^2 - 2 \times 6^2 \times \frac{1}{2}}$$

$= 6$ ms^{-1}



23. A train is running at a constant speed of 90 km/h on a straight track. A person standing at the top of a boggey moves in the direction of motion of the train such that he covers 1 meters on the train each second. The speed of the person with respect to ground is

(1) 25 m/s (2) 91 km/h (3) 26 km/h (4) 26 m/s

Sol. Answer (3)

$V_T = 90 \text{ Kmh}^{-1} = 90\times\frac{5}{18} = 25 \text{ ms}^{-1}$

$V_m = ?$

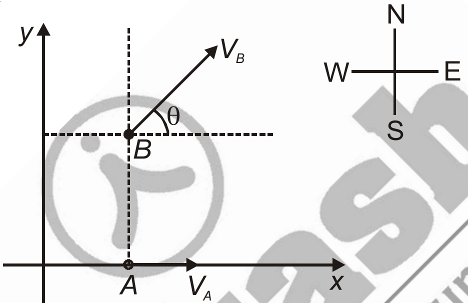
d = speed × time

$d_{\text{net}} = V_{\text{net}} \times t$

$1 = (V_m - 25) \times 1$

$V_m = 26 \text{ ms}^{-1}$

24 . Figure shows two ships moving in x-y plane with velocities V_A and V_B. The ships move such that B always remains north of A. The ratio $\frac{V_A}{V_B}$ is equal to



(1) cosθ (2) sinθ (3) secθ (4) cosecθ

Sol. Answer (1)

If ship B is always north of ship A then, their horizontal component should be equal, so,

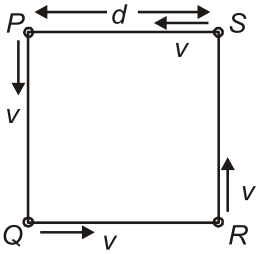
$V_A = V_B \cos\theta$

$\Rightarrow \frac{V_A}{V_B} = \cos\theta$

25. Four persons P, Q, R and S are initially at the four corners of a square of side d. Each person now moves with a constant speed v in such a way that P always moves directly towards Q, Q towards R, R towards S, and S towards P. The four persons will meet after time

(1) $\frac{d}{2v}$ (2) $\frac{d}{v}$ (3) $\frac{3d}{2v}$ (4) They will never meet

Sol. Answer (2)



$T = \frac{d}{v_{rel}}$

$v_{rel} = v - v\cos 90^\circ$

$= v - 0$

$= v$

$T = \frac{d}{v}$

26. A person, reaches a point directly opposite on the other bank of a flowing river, while swimming at a speed of 5 m/s at an angle of 120° with the flow. The speed of the flow must be

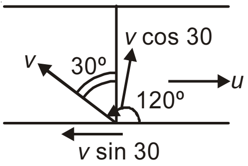
(1) 2.5 m/s (2) 3 m/s (3) 4 m/s (4) 1.5 m/s

Sol. Answer (1)

For drift to be zero

$u = v \sin 30^\circ$

$= 5 \times \frac{1}{2} = 2.5\ \text{ms}^{-1}$



27. A body of mass 1 kg is projected from ground at an angle 30º with horizontal on a level ground at a speed 50 m/s. The magnitude of change in momentum of the body during its flight is (g = 10 m/s^2)

(1) 50 kg ms^{-1} (2) 100 kg ms^{-1} (3) 25 kg ms^{-1} (4) Zero

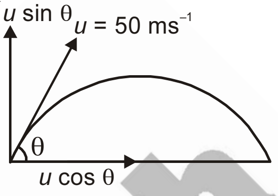
Sol. Answer (1)

$\Rightarrow$ The change in momentum = $-2mu\sin\theta\hat{j}$

$|\Delta\vec{p}| = 2mu\sin\theta$

$= 2 \times 1 \times 50 \times \sin 30^\circ$

$|\Delta\vec{p}|$ = 50 Kg ms^{-1}



28. A boat which has a speed of 5 km/hr in still water crosses a river of width 1 km along the shortest possible path in 15 minutes. The velocity of the river water (in km/hr) is

(1) 1 (2) 3 (3) 4 (4) 40

Sol. Answer (2)

For the shortest possible path

$t = \frac{d}{\sqrt{v^2 - u^2}}$

$v \Rightarrow$ Velocity of boat

$u \Rightarrow$ Velocity of river

$\frac{1}{4} = \frac{1}{\sqrt{v^2 - u^2}}$

$v^2 - u^2 = 16$

$u^2 = 5^2 - 16$

$v^2 = 9$

$u^2 = 3\ \text{Kmh}^{-1}$

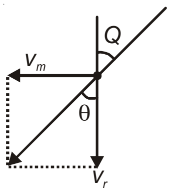
29. A car with a vertical windshield moves in a rain storm at a speed of 40 km/hr. The rain drops fall vertically with constant speed of 20 m/s. The angle at which rain drops strike the windshield is

(1) $\tan^{-1}\frac{5}{9}$ (2) $\tan^{-1}\frac{9}{5}$ (3) $\tan^{-1}\frac{3}{2}$ (4) $\tan^{-1}\frac{2}{3}$

Sol. Answer (2)

$$\tan\theta = \frac{v_m}{v_r} = \frac{\frac{20\times 5}{9}}{20}$$

$$\theta = \tan^{-1}\left(\frac{5}{9}\right)$$



30. Two projectiles are projected at angles $\left(\frac{\pi}{4}+\theta\right)$ and $\left(\frac{\pi}{4}-\theta\right)$ with the horizontal, where $\theta < \frac{\pi}{4}$, with same speed. The ratio of horizontal ranges described by them is

(1) $\tan\theta : 1$ (2) $1 : \tan^2\theta$ (3) $1 : 1$ (4) $1 : \sqrt{3}$

Sol. Answer (3)

The horizontal range is same when the angles of projection are complimentary to each other.

31. A shell is fired vertically upwards with a velocity v_1 from a trolley moving horizontally with velocity v_2. A person on the ground observes the motion of the shell as a parabola, whose horizontal range is

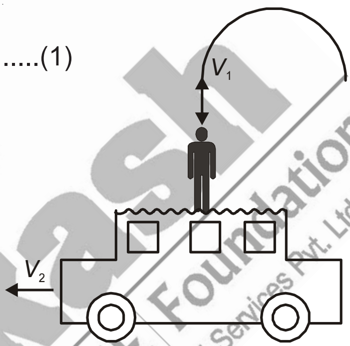
(1) $\frac{2v_1^2 v_2}{g}$ (2) $\frac{2v_1^2}{g}$ (3) $\frac{2v_2^2}{g}$ (4) $\frac{2v_1 v_2}{g}$

Sol. Answer (4)

There is no acceleration in the horizontal direction.

$$S_x = U_x T + \frac{1}{2}a_0 \times T^2$$

$$R = U_x T \qquad .....(1)$$



$$S_y = U_y T + \frac{1}{2}g_y T^2$$

$$O = V_1 T - \frac{1}{2}gT^2$$

$$\Rightarrow V_1 T = \frac{1}{2}gT$$

$$T = \frac{2V_1}{g}$$

We know (R) range = (Horizontal velocity 4*x*) × flight + time (T)

i.e. $R = 4x \times T$

$$R = V_2 \times \frac{2V_1}{g} \Rightarrow \frac{2V_1V_2}{g}$$

32. The position coordinates of a projectile projected from ground on a certain planet (with no atmosphere) are given by $y = (4t - 2t^2)$m and $x = (3t)$ metre, where t is in second and point of projection is taken as origin. The angle of projection of projectile with vertical is

(1) 30° (2) 37° (3) 45° (4) 60°

Sol. Answer (2)

$y = 4t - 2t^2$

$x = 3t$

$$V = V_{x\hat{i}} + V_{y\hat{j}}$$

$$V_x = \frac{dx}{dt},\ V_y = \frac{dy}{dt}$$

$V_x = 3,\ V_y = 4 - 4t$

for $t = 0$, $V_y = 4$

$$\tan\theta = \frac{V_y}{V_x} = \frac{4}{3}$$

$\theta = 53^\circ$ with horizontal

With vertical

$\theta = 37^\circ$

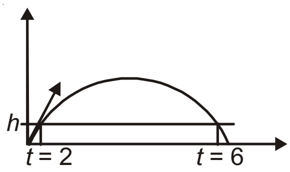
33. A particle is projected from ground with speed 80 m/s at an angle 30° with horizontal from ground. The magnitude of average velocity of particle in time interval $t = 2$ s to $t = 6$ s is [Take $g = 10$ m/s^2]

(1) $40\sqrt{2}$ m/s (2) 40 m/s (3) Zero (4) $40\sqrt{3}$ m/s

Sol. Answer (2)

Average velocity of the projectile when it is at the same vertical height is : $u\cos\theta$.

$\Rightarrow 80 \times \cos 30^\circ \Rightarrow 40\ \text{ms}^{-1}$.



34. A stone projected from ground with certain speed at an angle θ with horizontal attains maximum height h_1. When it is projected with same speed at an angle θ with vertical attains height h_2. The horizontal range of projectile is

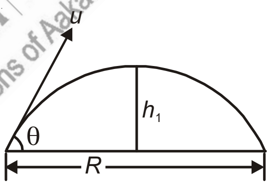
(1) $\frac{h_1 + h_2}{2}$ (2) $2h_1h_2$ (3) $4\sqrt{h_1h_2}$ (4) $h_1 + h_2$

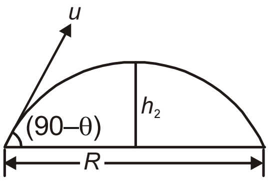
Sol. Answer (3)

When the angles are complimentary the range is same,

$$h_1 = \frac{u^2\sin^2\theta}{2g},$$

$$h_2 = \frac{u^2\sin^2(90-\theta)}{2g}$$





$$h_1 = \frac{u^2\sin^2\theta}{2g}$$

$$h_2 = \frac{u^2\cos^2\theta}{2g}$$

$$h_1h_2 = \frac{u^4\sin^2\theta\cos^2\theta}{4g^2} \Rightarrow \left(\frac{2u\sin\theta\cos\theta}{g}\right)^2 \times \frac{1}{4g} \times \frac{1}{4}$$

$$h_1h_2 = R^2\frac{1}{16}$$

$$\Rightarrow R^2 = 16\,h_1h_2$$

$$R = 4(\sqrt{h_1h_2})$$

35. Two objects are thrown up at angles of 45° and 60° respectively, with the horizontal. If both objects attain same vertical height, then the ratio of magnitude of velocities with which these are projected is

(1) $\sqrt{\dfrac{5}{3}}$ (2) $\sqrt{\dfrac{3}{5}}$ (3) $\sqrt{\dfrac{2}{3}}$ (4) $\sqrt{\dfrac{3}{2}}$

Sol. Answer (4)

$h_1 = h_2$

$$\frac{u_1^2 \sin^2 45^o}{2g} = \frac{V_2^2 \sin^2 60^o}{2g}$$

$$\frac{u_1^2}{V_2^2} = \frac{\frac{\sqrt{3}}{2} \times \frac{\sqrt{3}}{2}}{\frac{1}{2}} = \frac{3}{2}$$

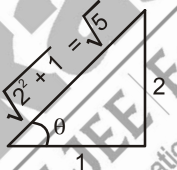
$$\frac{V_1}{V_2} = \sqrt{\frac{3}{2}}$$

36. For an object projected from ground with speed u horizontal range is two times the maximum height attained by it. The horizontal range of object is

(1) $\dfrac{2u^2}{3g}$ (2) $\dfrac{3u^2}{4g}$ (3) $\dfrac{3u^2}{2g}$ (4) $\dfrac{4u^2}{5g}$

Sol. Answer (4)

$R = 24$ also, $\dfrac{H}{R} = \dfrac{1}{4}\tan\theta$



$$\frac{H}{R} = \frac{1}{2} \Rightarrow \frac{1}{2} = \frac{1}{4}\tan\theta$$

$$\tan\theta = 2 = \frac{P}{B}$$

$$R = \frac{2u^2 \sin\theta\cos\theta}{g}$$

$$R = \frac{2u^2}{g}.\frac{2}{\sqrt{5}} \times \frac{1}{\sqrt{5}}$$

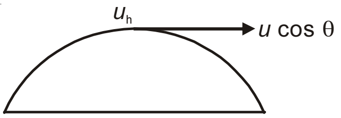
$$R = \frac{4u^2}{5g}$$

37. The velocity at the maximum height of a projectile is $\dfrac{\sqrt{3}}{2}$ times its initial velocity of projection (u). Its range on the horizontal plane is

(1) $\dfrac{\sqrt{3}u^2}{2g}$ (2) $\dfrac{3u^2}{2g}$ (3) $\dfrac{3u^2}{g}$ (4) $\dfrac{u^2}{2g}$

Sol. Answer (1)

$u_h = u\cos\theta$



$$\frac{\sqrt{3}}{2}u = u\cos\theta$$

$$\Rightarrow \cos\theta = \frac{\sqrt{3}}{2}$$

$\theta = 30^\circ$

$$R = \frac{u^2 \sin 2\theta}{g}$$

$$= \frac{u^2 \sin 60^\circ}{g} \Rightarrow \frac{\sqrt{3}u^2}{2g} = R$$

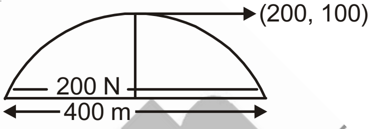
38. A projectile is thrown into space so as to have a maximum possible horizontal range of 400 metres. Taking the point of projection as the origin, the co-ordinates of the point where the velocity of the projectile is minimum are

(1) (400, 100) (2) (200, 100) (3) (400, 200) (4) (200, 200)

Sol. Answer (2)

$R_{max} = 400$ m

The velocity is minimum at the highest point



$$\Rightarrow H \rightarrow \frac{R}{2}$$

$R = 4H$

$400 = 4 \times H$

$H = 100$ m

39. If the time of flight of a bullet over a horizontal range R is T, then the angle of projection with horizontal is

(1) $\tan^{-1}\left(\frac{gT^2}{2R}\right)$ (2) $\tan^{-1}\left(\frac{2R^2}{gT}\right)$ (3) $\tan^{-1}\left(\frac{2R}{g^2T}\right)$ (4) $\tan^{-1}\left(\frac{2R}{gT}\right)$

Sol. Answer (1)

$$T = \frac{2u\sin\theta}{g} \Rightarrow u = \frac{gT}{2\sin\theta}$$

$$R = \frac{2u^2 \sin\theta\cos\theta}{g}$$

$$R = \frac{2u\sin\theta}{g} \times u\cos\theta$$

$R = T \times u \cos\theta$

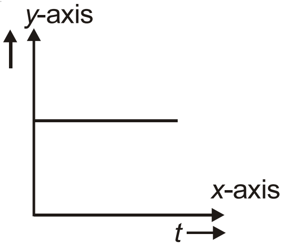
$$R = T \times \frac{gT\cos\theta}{2\sin\theta}$$

$$R = \frac{gT^2}{2}\frac{1}{\tan\theta}$$

$$\tan\theta = \frac{gT^2}{2R}$$

$$\theta = \tan^{-1}\left(\frac{gT^2}{2R}\right)$$

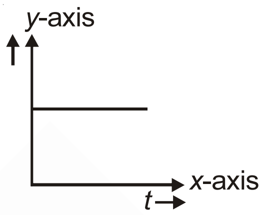
40. In the graph shown in figure, which quantity associated with projectile motion is plotted along *y*-axis



(1) Kinetic energy (2) Momentum (3) Horizontal velocity (4) None of these

Sol. Answer (3)

It is the horizontal component of velocity that remains constant throughout the motion as there is no acceleration in that direction $a_x = 0$, u_x = constant



41. The equation of a projectile is $y = ax - bx^2$. Its horizontal range is

(1) $\frac{a}{b}$ (2) $\frac{b}{a}$ (3) $a + b$ (4) $b - a$

Sol. Answer (1)

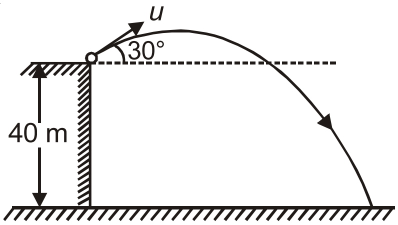
$y = ax - bx^2$

When the body lands then $y = 0$, $x = R$, $0 = aR - bR^2$

$aR = bR$

$R = \frac{a}{b}$

42. Figure shows a projectile thrown with speed u = 20 m/s at an angle 30° with horizontal from the top of a building 40 m high. Then the horizontal range of projectile is



(1) $20\sqrt{3}$ m (2) $40\sqrt{3}$ m

(3) 40 m (4) 20 m

Sol. Answer (2)

$S_y = u_y T + \frac{1}{2} g_y T^2$

$-40 = 4 \sin 30 T - \frac{1}{2} g T^2$

$-40 = 20 \times \frac{1}{2} T - 5T^2$

$-8 = 2T - T^2$

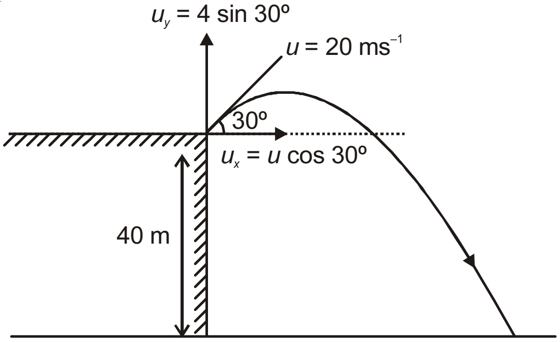
$T^2 - 2T - 8 = 0$

$T^2 - 4T + 2T - 8 = 0$

$T = -2, 4$

$R = u \cos\theta T = 20 \times \frac{\sqrt{3}}{2} \times 4$

$R = 40\sqrt{3}$ m



43. When a particle is projected at some angle to the horizontal, it has a range R and time of flight t_1. If the same particle is projected with the same speed at some other angle to have the same range, its time of flight is t_2, then

(1) $t_1 + t_2 = \frac{2R}{g}$ (2) $t_1 - t_2 = \frac{R}{g}$ (3) $t_1 t_2 = \frac{2R}{g}$ (4) $t_1 t_2 = \frac{R}{g}$

Sol. Answer (3)

The angles has to be complimentary *i.e.,* if $\theta_1 \to \theta,\ \theta_2 \to (90 - \theta)$

$$t_1 = \frac{2u\sin\theta}{g},\ t_2 = \frac{2u\sin(90-\theta)}{g}$$

$$t_2 = \frac{2u\cos\theta}{g}$$

$$t_1 t_2 = \frac{2u\sin\theta}{g} \times \frac{2u\cos\theta}{g}$$

$$t_1 t_2 = \frac{2R}{g}$$

44. A projectile is thrown with velocity v at an angle θ with horizontal. When the projectile is at a height equal to half of the maximum height, the vertical component of the velocity of projectile is

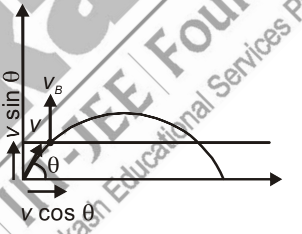
(1) $v \sin\theta \times 3$ (2) $\frac{v\sin\theta}{3}$ (3) $\frac{v\sin\theta}{\sqrt{2}}$ (4) $\frac{v\sin\theta}{\sqrt{3}}$

Sol. Answer (3)

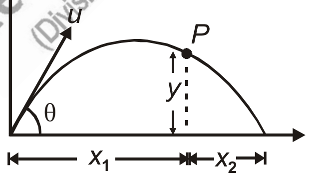
$$v_B^2 = v^2\sin^2\theta - \frac{2g}{2}\left(\frac{u^2\sin^2\theta}{2g}\right)$$

$$v_B^2 = \frac{v^2\sin^2\theta}{2}$$

$$v_B = \frac{v\sin\theta}{\sqrt{2}}$$



45. In the given figure for a projectile



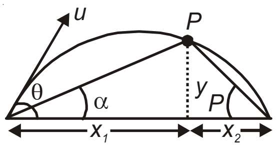
(1) $y = \left[\frac{x_1 x_2}{x_1 - x_2}\right]\tan\theta$ (2) $y = \left[\frac{x_1 x_2}{x_1 + x_2}\right]\tan\theta$ (3) $y = \left[\frac{2x_1 x_2}{x_1 + x_2}\right]\cos\theta$ (4) $y = \left[\frac{2x_1 x_2}{x_1 + x_2}\right]\tan\theta$

Sol. Answer (2)

The equation of trajectory for point '*P*' can be written as :

$$y = x\tan\theta\left(1 - \frac{x}{R}\right) = x_1\tan\theta\left(1 - \frac{x_1}{x_1 + x_2}\right) = x_1\tan\theta\left(\frac{x_1 + x_2 - x_1}{x_1 + x_2}\right)$$

$$y = \frac{x_1 x_2}{x_1 + x_2}\tan\theta$$

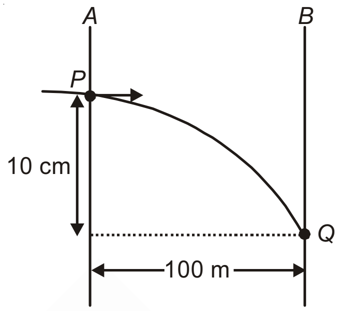


46. Two paper screens A and B are separated by distance 100 m. A bullet penetrates A and B, at points P and Q respectively, where Q is 10 cm below P. If bullet is travelling horizontally at the time of hitting A, the velocity of bullet at A is nearly

(1) 100 m/s (2) 200 m/s (3) 600 m/s (4) 700 m/s

Sol. Answer (4)

10 cm $\Rightarrow$ 10×10^{-2} m $\Rightarrow$ 10^{-1} $\Rightarrow$ 0.1 m



It is a case of horizontal projectile.

So, $a_x = 0$, $u_x = 4$, $u_y = 0$, $a_y = -g$

$R = 100\text{m}$, $T = \sqrt{\dfrac{2H}{g}} \Rightarrow$ Time of flight

$R = u_x T$

$$100 = u\sqrt{\frac{2\times 0.1}{100}} \Rightarrow \frac{u\sqrt{2}}{10} = 100$$

$$u = \frac{1000}{\sqrt{2}} \approx 707\ \text{ms}^{-1}$$

47. A car is going round a circle of radius R_1 with constant speed. Another car is going round a circle of radius R_2 with constant speed. If both of them take same time to complete the circles, the ratio of their angular speeds and linear speeds will be

(1) $\sqrt{\dfrac{R_1}{R_2}}, \dfrac{R_1}{R_2}$ (2) 1, 1 (3) $1, \dfrac{R_1}{R_2}$ (4) $\dfrac{R_1}{R_2}, 1$

Sol. Answer (3)

The angular speed is given by

$$\omega = \frac{2\pi}{T}$$

$$\omega \propto \frac{1}{T} \Rightarrow \frac{\omega_1}{\omega_2} = \frac{T_2}{T_1}$$

if $T_1 = T_2 \Rightarrow \omega_1 = \omega_2$

So, ratio $\Rightarrow$ 1 : 1

and linear speed $v = R\omega$

$V \propto R$

$$\frac{V_1}{V_2} = \frac{R_1}{R_2}$$

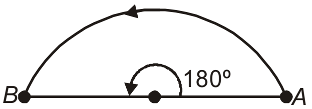
48. A body revolves with constant speed v in a circular path of radius r. The magnitude of its average acceleration during motion between two points in diametrically opposite direction is

(1) Zero (2) $\dfrac{v^2}{r}$ (3) $\dfrac{2v^2}{\pi r}$ (4) $\dfrac{v^2}{2r}$

Sol. Answer (3)

$$a_{avg} = \frac{2v\sin\left(\frac{\theta}{2}\right)}{\left(\frac{r\theta}{v}\right)}$$

$$a_{avg} = \frac{2v^2\sin\left(\frac{\theta}{2}\right)}{r\theta}$$



Here, $\theta = \pi$ rad

$$a_{avg} = \frac{2v^2\sin\left(\frac{\pi}{2}\right)}{r\times\pi}$$

$$a_{avg} = \frac{2v^2}{\pi r}$$

49. An object of mass m moves with constant speed in a circular path of radius R under the action of a force of constant magnitude F. The kinetic energy of object is

(1) $\frac{1}{2}FR$ (2) FR (3) $2FR$ (4) $\frac{1}{4}FR$

Sol. Answer (1)

$$\text{KE} = \frac{1}{2}mv^2 = \frac{1}{2}\frac{F}{a}\times v^2 = \frac{1}{2}\frac{F\times v^2}{\left(\frac{v^2}{R}\right)} = \frac{1}{2}FR$$

50. The angular speed of earth around its own axis is

(1) $\frac{\pi}{43200}$ rad/s (2) $\frac{\pi}{3600}$ rad/s (3) $\frac{\pi}{86400}$ rad/s (4) $\frac{\pi}{1800}$ rad/s

Sol. Answer (1)

Angular speed = $\frac{2\pi}{T}$

$T \rightarrow$ Time period of earth = 24 h

$$\omega = \frac{2\pi}{24\times60\times60} = \frac{\pi}{43200}\ \text{rad s}^{-1}$$

51. A particle moves in a circle of radius 25 cm at two revolutions per second. The acceleration of the particle is (in m/s^2)

(1) π^2 (2) $8\pi^2$ (3) $4\pi^2$ (4) $2\pi^2$

Sol. Answer (3)

$a = r\omega^2$

$$a = \frac{25}{100}(2\times2\pi)^2$$

$a = 4\pi^2$ m/s^2

52. A particle is revolving in a circular path of radius25 m with constant angular speed 12 rev/min. Then the angular acceleration of particle is

(1) $2\pi^2$ rad/s^2 (2) $4\pi^2$ rad/s^2 (3) π^2 rad/s^2 (4) Zero

Sol. Answer (4)

Angular acceleration is the rate of change of angular speed or angular velocity if $\vec{\omega}$ remains constant then $\alpha = 0$

53. Two particles are moving in circular paths of radii r_1 and r_2 with same angular speeds. Then the ratio of their centripetal acceleration is

(1) 1 : 1 (2) $r_1 : r_2$ (3) $r_2 : r_1$ (4) $r_2^2 : r_1^2$

Sol. Answer (2)

Centripetal acceleration is given by

$$a = \frac{v^2}{r} = r\omega^2$$

For same 'ω'

$$a_c \propto r \Rightarrow \frac{a_1}{a_2} = \frac{r_1}{r_2}$$

54. A particle *P* is moving in a circle of radius *r* with uniform speed *v*. *C* is the centre of the circle and *AB* is diameter. The angular velocity of *P* about *A* and *C* is in the ratio

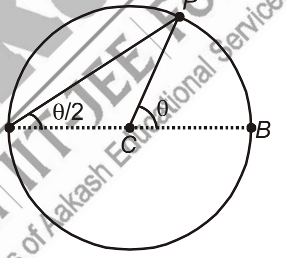
(1) 4 : 1 (2) 2 : 1 (3) 1 : 2 (4) 1 : 1

Sol. Answer (2)

$$W_{P/C} = \frac{d\theta}{dt}$$

$$W_{P/A} = \frac{1}{2}\frac{d\theta}{dt}$$

$$W_{P/A} = \frac{1}{2}W_{P/C}$$



55. A car is moving at a speed of 40 m/s on a circular track of radius 400 m. This speed is increasing at the rate of 3 m/s^2. The acceleration of car is

(1) 4 m/s^2 (2) 7 m/s^2 (3) 5 m/s^2 (4) 3 m/s^2

Sol. Answer (3)

v = 40 ms^{-1}

r = 400 m

a_T = 3 ms^{-2}

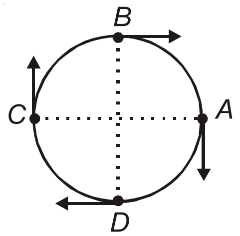
$$a_c = \frac{V^2}{r} = \frac{40\times 40}{400} = 4\ \text{ms}^{-2}$$

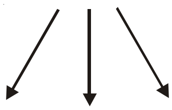
$$a = \sqrt{a_C^2 + a_T^2}$$

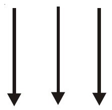
$$a = \sqrt{4^2+3^2} = 5\ \text{ms}^{-2}$$

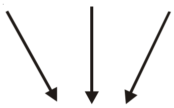
a = 5 ms^{-2}

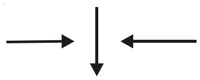
56. Four particles *A*, *B*, *C* and *D* are moving with constant speed *v* each. At the instant shown relative velocity of *A* with respect to *B*, *C* and *D* are in directions



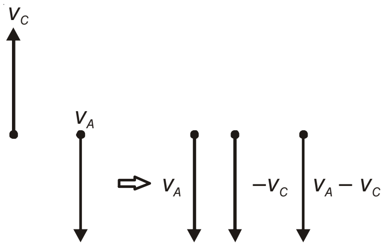
(1) 

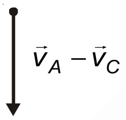
(2) 

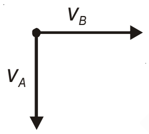
(3) 

(4) 

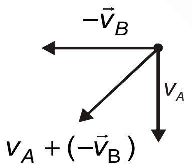
Sol. Answer (1)

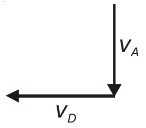
(i) 

$\vec{v}_{AC} = \vec{v}_A - \vec{v}_C \Rightarrow$ 

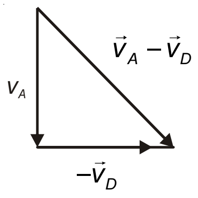
(ii) 

$\Rightarrow \vec{v}_{AB} = \vec{v}_A - \vec{v}_B \Rightarrow \vec{v}_A + (-\vec{v}_A)$



(iii) 

$\Rightarrow \vec{v}_{AD} = \vec{v}_A - \vec{v}_D = \vec{v}_A + (-\vec{v}_D)$

$\Rightarrow$ 

57. The ratio of angular speeds of minute hand and hour hand of a watch is

(1) 6 : 1 (2) 12 : 1 (3) 60 : 1 (4) 1 : 60

Sol. Answer (2)

ω_{mh} = Angular speed of minute hand

ω_{hh} = Angular speed of hour hand

$$\omega_{mh} = \frac{2\pi}{60\,m} = \frac{2\pi}{60\times 60}\text{rad s}^{-1}$$

$$\omega_{hh} = \frac{2\pi}{12\text{ h}} = \frac{2\pi}{12\times 60\times 60}\text{rad s}^{-1}$$

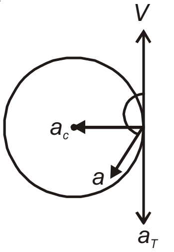
$$\frac{\omega_{mh}}{\omega_{hh}} = \frac{\frac{2\pi}{60\times 60}}{\frac{2\pi}{12\times 60\times 60}} = \frac{1}{1}\times\frac{12}{1}$$

$\omega_{mh} : \omega_{hh} \Rightarrow 12 : 1$

58. If θ is angle between the velocity and acceleration of a particle moving on a circular path with decreasing speed, then

(1) $\theta = 90°$ (2) $0° < \theta < 90°$ (3) $90° < \theta < 180°$ (4) $0° \le \theta \le 180°$

Sol. Answer (3)



θ between *v* & *Q* is

$90° < \theta < 180°$

59. If speed of an object revolving in a circular path is doubled and angular speed is reduced to half of original value, then centripetal acceleration will become/remain

(1) Same (2) Double (3) Half (4) Quadruple

Sol. Answer (3)

$a_c = r\omega^2 = (r\omega)(\omega)$

$a_c = v\omega$

$$a_c = (2v)\left(\frac{\omega}{2}\right) = v\omega = a_c$$

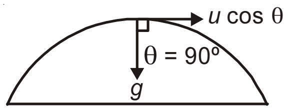
60. An object is projected from ground with speed *u* at angle θ with horizontal. the radius of curvature of its trajectory at maximum height from ground is

(1) $\dfrac{u^2\sin 2\theta}{g}$ (2) $\dfrac{u^2\cos^2\theta}{g}$ (3) $\dfrac{u^2\sin^2\theta}{g}$ (4) $\dfrac{u^2\sin^2\theta}{2g}$

Sol. Answer (2)

$$a_c = \frac{v^2}{r}$$

$$r = \frac{v^2}{a_c}, \frac{u^2\cos^2\theta}{g}$$



$$r = \frac{u^2\cos^2\theta}{g}$$

SECTION - B

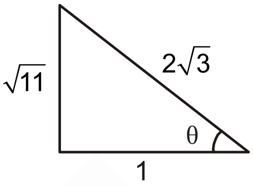
Objective Type Questions

1. If θ is angle between vectors $\vec{a} = \hat{i} - \hat{j}$ and $\vec{b} = 2\hat{i} - \hat{k} + \hat{j}$, then $\tan\theta =$

(1) $\sqrt{3}$ (2) $\sqrt{11}$ (3) $\sqrt{5}$ (4) $2\sqrt{3}$

Sol. Answer (2)

$$\vec{a} = \hat{i} - \hat{j}\ ,\ \vec{b} = 2\hat{i} - \hat{k} + \hat{j}$$



$$\vec{a}\cdot\vec{b} = ab\cos\theta$$

$$2 - 1 = \sqrt{2}\times\sqrt{6}\cos\theta$$

$$1 = \sqrt{2}\times\sqrt{3}\ \sqrt{2}\cos\theta$$

$$\Rightarrow \quad \cos\theta = \frac{1}{2\sqrt{3}} = \frac{B}{H}$$

$$\text{So, } \tan\theta = \frac{P}{B} = \frac{\sqrt{11}}{1}$$

$$\Rightarrow \quad \boxed{\tan\theta = \sqrt{11}}$$

2. The position vector $\vec{r}$ of a particle is given by $\vec{r} = (A\sin\omega t)\hat{i} + (A\cos\omega t)\hat{j}$. If v is velocity of particle then $\vec{v}\cdot\vec{r}$ =

(1) Zero (2) A^2 (3) $A^2\sin^2\omega t$ (4) $A^2\cos^2\omega t$

Sol. Answer (1)

$$\vec{r} = (A\sin\omega t)\hat{i} + (A\cos\omega t)\hat{j}$$

$$v = \frac{d\vec{r}}{dt} = A\omega\cos\omega t\,\hat{i} - A\omega\sin\omega t\,\hat{j}$$

$$\vec{v}\cdot\vec{r} = A^2\omega\sin\omega t\cos\omega t - A^2\omega\sin\omega t\cos\omega t$$

$$\boxed{\vec{v}\cdot\vec{r} = 0}$$

3. Two particles A and B start moving with velocities 20 m/s and $30\sqrt{2}$ m/s along x-axis and at an angle 45º with x-axis respectively in xy-plane from origin. The relative velocity of B w.r.t. A

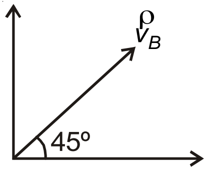
(1) $(10\hat{i} + 30\hat{j})$ m/s (2) $(30\hat{i} + 10\hat{j})$ m/s

(3) $(30\hat{i} - 20\sqrt{2}\hat{j})$m/s (4) $(30\sqrt{2}\hat{i} + 10\sqrt{2}\hat{j})$ m/s

Sol. Answer (1)

v_A = 20 m/s

$v_B = 30\sqrt{2}$ m/s along 45º with x-axis



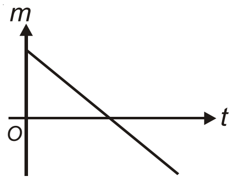
$$\vec{v}_B = v_B\cos 45^\circ\,\hat{i} + v_B\sin 45^\circ\,\hat{j} = 30\hat{i} + 30\hat{j}$$

$$\vec{v}_{BA} = \vec{v}_B - \vec{v}_A = 30\hat{i} + 30\hat{j} - 20\hat{i}$$

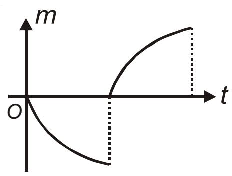
$$\boxed{\vec{v}_{BA} = 10\hat{i} + 30\hat{j}}$$

4. A particle is projected at angle θ with horizontal from ground. The slop (m) of the trajectory of the particle varies with time (t) as

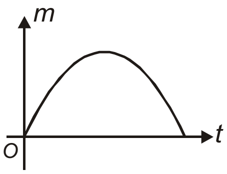
(1)



(2)



(3)



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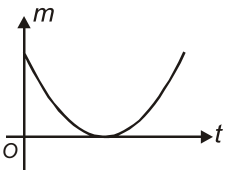


Sol. Answer (1)

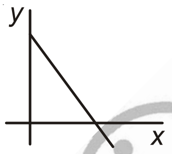
Slope of trajectory

$$\tan\phi = \frac{u\sin\theta - gt}{u\cos\theta}$$

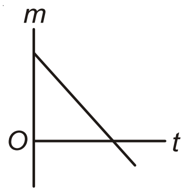
So, $m = \dfrac{u\sin\theta}{u\cos\theta} - \dfrac{gt}{u\cos\theta}$

$$m = \tan\theta - \frac{g}{u\cos\theta}t$$

$\Rightarrow$ $y = a - bx$



Therefore,



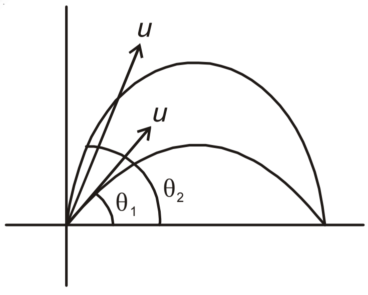
5. If H_1 and H_2 be the greatest heights of a projectile in two paths for a given value of range, then the horizontal range of projectile is given by

(1) $\dfrac{H_1 + H_2}{2}$ (2) $\dfrac{H_1 + H_2}{4}$ (3) $4\sqrt{H_1 H_2}$ (4) $4[H_1 + H_2]$

Sol. Answer (3)

$\theta_1 + \theta_2 = 90°$

$$H_1 = \frac{u^2 \sin^2 \omega_1}{2g}$$



$$H_2 = \frac{u^2 \sin(90° - \theta_1)}{2g}$$

$$H_1 H_2 = \frac{R^2}{16} \qquad \because\ R = \frac{u^2 \sin^2 \theta_1}{g}$$

$$\boxed{R = 4\sqrt{H_1 H_2}}$$

6. If R and H are the horizontal range and maximum height attained by a projectile, than its speed of projection is

(1) $\sqrt{2gR + \dfrac{4R^2}{gH}}$ (2) $\sqrt{2gH + \dfrac{R^2 g}{8H}}$ (3) $\sqrt{2gH + \dfrac{8H}{Rg}}$ (4) $\sqrt{2gH + \dfrac{R^2}{H}}$

Sol. Answer (2)

$$H = \frac{u^2 \sin^2\theta}{2g} \Rightarrow \sin\theta = \sqrt{\frac{2gH}{u^2}}$$

$$R = \frac{2u^2 \sin\theta\cos\theta}{g}$$

$$R = \frac{2u^2}{g}\sqrt{\frac{2gH}{u^2}} \times \sqrt{1 - \frac{2gH}{u^2}}$$

$$R = \frac{2u^2}{g}\sqrt{\frac{2gH}{u^2}} \times \sqrt{\frac{u^2 - 2gH}{u^2}}$$

$$\frac{gR}{2\sqrt{2gH}} = \sqrt{u^2 - 2gH}$$

Squaring both the sides,

$$\frac{gR^2}{4 \times 2gH} = u^2 - 2gH$$

$$\Rightarrow \quad u^2 = 2gH + \frac{9R^2}{8H}$$

$$\boxed{u = \sqrt{2gH + \frac{gR^2}{8H}}}$$

7. A particle projected from ground moves at angle 45º with horizontal one second after projection and speed is minimum two seconds after the projection. The angle of projection of particle is [Neglect the effect of air resistance]

(1) $\tan^{-1}(3)$ (2) $\tan^{-1}(2)$ (3) $\tan^{-1}(\sqrt{2})$ (4) $\tan^{-1}(4)$

Sol. Answer (2)

$\theta = 45^\circ$, $t = 1$ s

$$\tan\phi = \frac{V_y}{U_y} = \frac{u\sin\theta - gt}{u\cos\theta}$$

$$\tan 45^\circ = \frac{u\sin\theta - g \times 1}{u\cos\theta} \Rightarrow u\cos\theta = u\sin\theta - g$$

also, $V_y = 0$, after 1st (as speed is minimum)

$$u\sin\theta - g \times 2 = 0$$

$$\Rightarrow \quad \boxed{u\sin\theta = 2g} \qquad \text{...(i)}$$

so, $u\cos\theta = 2g - g$

$$\boxed{u\cos\theta = g} \qquad \text{...(ii)}$$

so, $\dfrac{\text{(i)}}{\text{(ii)}} = \dfrac{u\sin\theta}{u\cos\theta} = \dfrac{2g}{g}$

$$\Rightarrow \quad \tan\theta = 2$$

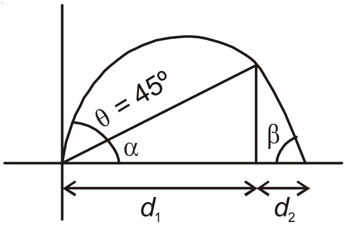
$$\boxed{\theta = \tan^{-1}(2)}$$

8. A ball is projected from ground at an angle 45° with horizontal from distance d_1 from the foot of a pole and just after touching the top of pole it the falls on ground at distance d_2 from pole on other side, the height of pole is

(1) $2\sqrt{d_1d_2}$ (2) $\frac{d_1+d_2}{4}$ (3) $\frac{2d_1d_2}{d_1+d_2}$ (4) $\frac{d_1d_2}{d_1+d_2}$

Sol. Answer (4)

Repeated.



$$\tan\theta+\tan\beta=\tan\theta$$

$$\frac{y}{d_1}+\frac{y}{d_2}=\tan 45^\circ$$

$$y=\left(\frac{d_1d_2}{d_1+d_2}\right)$$

9. A particle is projected with speed u at angle θ with horizontal from ground. If it is at same height from ground at time t_1 and t_2, then its average velocity in time interval t_1 to t_2 is

(1) Zero (2) $u\sin\theta$ (3) $u\cos\theta$ (4) $\frac{1}{2}[u\cos\theta]$

Sol. Answer (3)

When projectile is at same height, average velocity = $u\cos\theta$.

10. A particle is projected from ground at an angle θ with horizontal with speed u. The ratio of radius of curvature of its trajectory at point of projection to radius of curvature at maximum height is

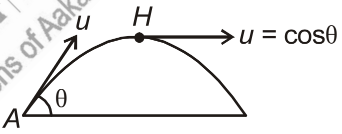
(1) $\frac{1}{\sin^2\theta\cos\theta}$ (2) $\cos^2\theta$ (3) $\frac{1}{\sin^3\theta}$ (4) $\frac{1}{\cos^3\theta}$

Sol. Answer (4)

At the point of projection

$$r_A=\frac{u^2}{g\cos\theta}$$

$$r_H=\frac{u^2\cos^2\theta}{g}$$



Ratio, $\frac{r_A}{r_H}=\frac{\frac{u^2}{g\cos\theta}}{\frac{u^2\cos^2\theta}{g}}=\boxed{\frac{1}{\cos^3\theta}=\frac{r_A}{r_H}}$

11. An object of mass 10 kg is projected from ground with speed 40 m/s at an angle 60° with horizontal. The rate of change of momentum of object one second after projection in SI unit is [Take g = 9.8 m/s^2]

(1) 73 (2) 98 (3) 176 (4) 140

Sol. Answer (2)

Force = $\frac{\Delta p}{\Delta t}$, force remains constant = mg

$\Rightarrow$ 10 × 9.8 $\Rightarrow$ 98 N

At t = 1, particle is at its maximum height.

12. An object is projected from ground with speed 20 m/s at angle 30º with horizontal. Its centripetal acceleration one second after the projection is [Take g = 10 m/s^2]

(1) 10 m/s^2 (2) Zero (3) 5 m/s^2 (4) 12 m/s^2

Sol. Answer (1)

Centripetal acceleration = $\frac{v^2}{r} = g = 10 \text{ ms}^2$

13. A particle is moving on a circular path with constant speed v. It moves between two points A and B, which subtends an angle 60º at the centre of circle. The magnitude of change in its velocity and change in magnitude of its velocity during motion from A to B are respectively

(1) Zero, Zero (2) v, 0 (3) 0, v (4) 2v, v

Sol. Answer (2)

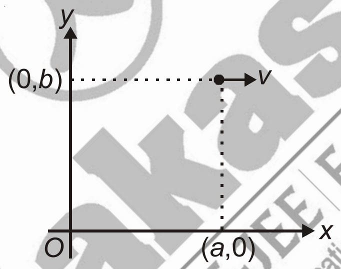
$$\Delta v = 2v\sin\frac{\theta}{2}$$

$$= 2v \times \sin\left(\frac{60}{2}\right)$$

$$\boxed{|\Delta v| = v}$$

Change in magnitude of velocity = 0

14. A particle is moving with constant speed v in xy plane as shown in figure. The magnitude of its angular velocity about point O is



(1) $\frac{v}{\sqrt{a^2+b^2}}$ (2) $\frac{v}{b}$ (3) $\frac{vb}{(a^2+b^2)}$ (4) $\frac{v}{a}$

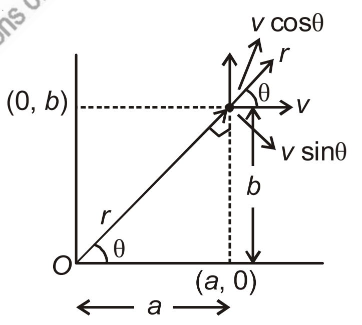
Sol. Answer (3)

$$v\sin\theta = r\omega$$

$$v\sin\theta = \sqrt{a^2+b^2} \times \omega$$

$$\frac{v}{\sqrt{a^2+b^2}}\,\frac{b}{\sqrt{a^2+b^2}} = \omega$$

$$\boxed{\frac{vb}{(a^2+b^2)} = \omega}$$



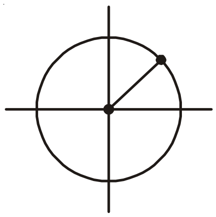
$v_{\perp} = r\omega$

15. A particle is moving in xy-plane in a circular path with centre at origin. If at an instant the position of particle is given by $\frac{1}{\sqrt{2}}(\hat{i}+\hat{j}),$ then velocity of particle is along

(1) $\frac{1}{\sqrt{2}}(\hat{i}-\hat{j})$ (2) $\frac{1}{\sqrt{2}}(\hat{j}-\hat{i})$ (3) $\frac{1}{\sqrt{2}}(\hat{i}+\hat{j})$ (4) Either (1) or (2)

Sol. Answer (4)

$$\vec{r} = \frac{1}{2}\hat{i} + \frac{1}{\sqrt{2}}\hat{j}$$



$\vec{v}\cdot\vec{r} = 0$ as velocity is always tangential to the path.

$$(v_x\hat{i} + v_y\hat{j})\cdot\frac{1}{2}(\hat{i} + \hat{j}) = 0$$

$$v_x + v_y = 0 \quad \Rightarrow \quad \boxed{\begin{matrix} v_x = -v_y \\ \text{or} \quad v_y = -v_x \end{matrix}}$$

$$v = \sqrt{v_x^2 + v_y^2} \quad \Rightarrow \quad \sqrt{2}v_x = v$$

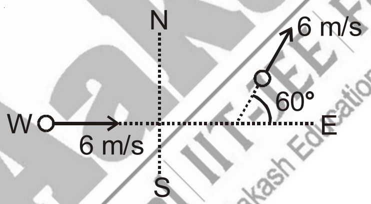
$$\Rightarrow \quad \boxed{v_x = \frac{v}{\sqrt{2}}}$$

$$v_y = -\frac{v}{\sqrt{2}}$$

or $v_x = -\dfrac{v}{\sqrt{2}},\ v_y = \dfrac{v}{\sqrt{2}}$

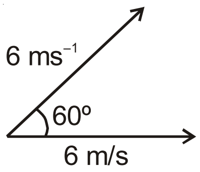
So, possible value of $v \Rightarrow v_x\hat{i} + v_y\hat{j} \Rightarrow \dfrac{v}{\sqrt{2}}\hat{i} - \dfrac{v}{\sqrt{2}}\hat{j}$ or $\dfrac{-v}{\sqrt{2}}\hat{i} + \dfrac{v}{\sqrt{2}}\hat{j}$

16. A particle is moving eastwards with a speed of 6 m/s. After 6 s, the particle is found to be moving with same speed in a direction 60° north of east. The magnitude of average acceleration in this interval of time is



(1) 6 m/s²
(2) 3 m/s²
(3) 1 m/s²
(4) Zero

Sol. Answer (3)



$$a_{av} = \frac{(\Delta\vec{v})}{\Delta t}$$

$$|\Delta\vec{v}| = 2v\sin\frac{\theta}{2} = 2v\sin\left(\frac{60}{2}\right) = 2v\sin 30° = v$$

$$|\Delta\vec{v}| = 6\ \text{ms}^{-1}$$

$$\Delta t = 6\ \text{s}$$

so, $a_{av} = \dfrac{6}{6} = 1\ \text{ms}^{-2}$

17. What is the path followed by a moving body, on which a constant force acts in a direction other than initial velocity (*i.e.* excluding parallel and antiparallel direction)?

(1) Straight line
(2) Parabolic
(3) Circular
(4) Elliptical

Sol. Answer (2)

The path will be parabolic.

18. Two stones are thrown with same speed u at different angles from ground in air. If both stones have same range and height attained by them are h_1 and h_2, then $h_1 + h_2$ is equal to

(1) $\frac{u^2}{g}$ (2) $\frac{u^2}{2g}$ (3) $\frac{u^2}{3g}$ (4) $\frac{u^2}{4g}$

Sol. Answer (2)

If range is same then, one angle is θ and other angle is $(90 - \theta)$

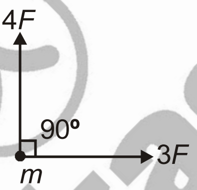
$$\Rightarrow \quad h_1 = \frac{u^2 \sin^2\theta}{2g}, \; h_2 = \frac{u^2 \sin^2(90-\theta)}{2g}$$

$$h_1 = \frac{u^2 \sin^2\theta}{2g}, \; h_2 = \frac{u^2 \cos^2\theta}{2g}$$

$$\text{So, } h_1 + h_2 \Rightarrow \frac{u^2 \sin^2\theta}{2g} + \frac{u^2 \cos^2\theta}{2g} = \frac{u^2}{2g}(\sin^2\theta + \cos^2\theta)$$

$$\boxed{h_1 + h_2 = \frac{u^2}{2g}}$$

19. When a force F acts on a particle of mass m, the acceleration of particle becomes a. Now if two forces of magnitude $3F$ and $4F$ acts on the particle simultaneously as shown in figure, then the acceleration of the particle is



(1) a (2) $2a$ (3) $5a$ (4) $8a$

Sol. Answer (3)

$$F_{\text{net}} = \sqrt{3^2 + 4^2} = 5\,F$$

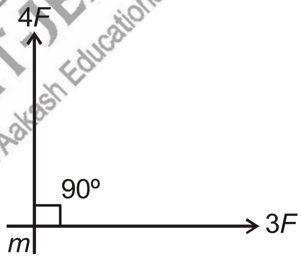
So, $F_{\text{net}} = ma$

$5F = ma'$

$$\Rightarrow \quad a' = \frac{5F}{m}$$

$$\boxed{a' = 5a}$$

$$\frac{F}{m} = a$$



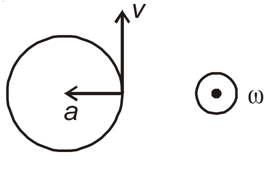
20. Consider the two statements related to circular motion in usual notations

A. In uniform circular motion $\vec{\omega}$, $\vec{v}$ and $\vec{a}$ are always mutually perpendicular

B. In non-uniform circular motion, $\vec{\omega}$, $\vec{v}$ and $\vec{a}$ are always mutually perpendicular

(1) Both A and B are true (2) Both A and B are false (3) A is true but B is false (4) A is false but B is true

Sol. Answer (3)



Only first statement is correct.

ω → mutually perpendicular to v and a.

21. Which of the following quantities remains constant during uniform circular motion?

(1) Centripetal acceleration (2) Velocity

(3) Momentum (4) Speed

Sol. Answer (4)

Speed remains constant.

22. A projectile is projected with speed u at an angle θ with the horizontal. The average velocity of the projectile between the instants it crosses the same level is

(1) $u \cos \theta$ (2) $u \sin \theta$ (3) $u \cot \theta$ (4) $u \tan \theta$

Sol. Answer (1)

Repated.

23. A ball is thrown at an angle θ with the horizontal. Its horizontal range is equal to its maximum height. This is possible only when the value of tan θ is

(1) 4 (2) 2 (3) 1 (4) 0.5

Sol. Answer (1)

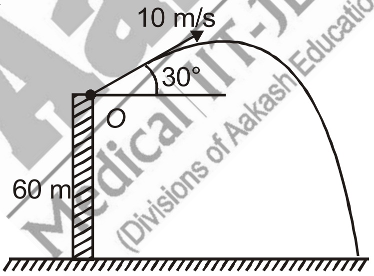
$$\frac{H}{R} = \frac{1}{4}\tan\theta$$

$\Rightarrow$ $H = R$, given,

$$\boxed{\tan\theta = 4}$$

$$\Rightarrow \boxed{\theta = \tan^{-1}(4)}$$

24. A ball is projected from a point O as shown in figure. It will strike the ground after (g = 10 m/s^2)



(1) 4 s (2) 3 s (3) 2 s (4) 5 s

Sol. Answer (1)

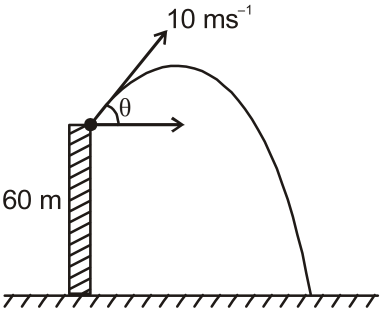
$$s_y = u_x T + \frac{1}{2}a_y T^2$$

$$-60 = 10\sin 30°\cdot T - \frac{1}{2}gT^2$$

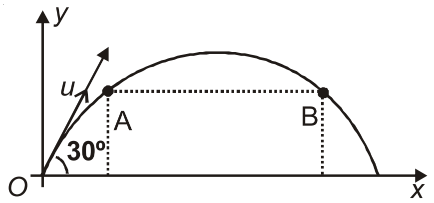
$$-60 = 5T - 5T^2$$

$$T^2 - T - 2 = 0$$

$$\boxed{T = 4\text{ s}}$$



25. A particle is thrown with a velocity of u m/s. It passes A and B as shown in figure at time $t_1 = 1$ s and $t_2 = 3$ s. The value of u is ($g = 10$ m/s^2)



(1) 20 m/s (2) 10 m/s (3) 40 m/s (4) 5 m/s

Sol. Answer (3)

$$t_1 + t_2 = \frac{2u\sin\theta}{g}$$

$$1+3 = \frac{2u \times \sin 30^\circ}{10}$$

$$20 \times 2 = u$$

$$\Rightarrow \boxed{u = 40\text{ ms}^{-1}}$$

26. Which one of the following statements is not true about the motion of a projectile?

(1) The time of flight of a projectile is proportional to the speed with which it is projected at a given angle of projection

(2) The horizontal range of a projectile is proportional to the square root of the speed with which it is projected

(3) For a given speed of projection, the angle of projection for maximum range is 45°

(4) At maximum height, the acceleration due to gravity is perpendicular to the velocity of the projectile

Sol. Answer (2)

$$R = \frac{u^2 \sin 2\theta}{g} \Rightarrow \boxed{R \propto u^2}$$

27. Out of the two cars A and B, car A is moving towards east with a velocity of 10 m/s whereas B is moving towards north with a velocity 20 m/s, then velocity of A w.r.t. B is (nearly)

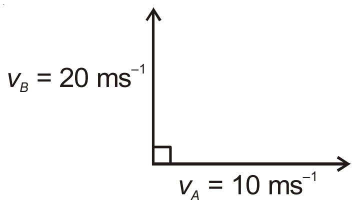
(1) 30 m/s (2) 10 m/s (3) 22 m/s (4) 42 m/s

Sol. Answer (3)

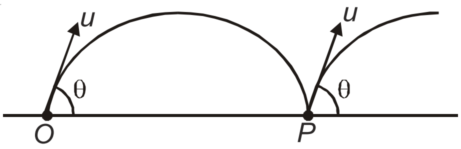
$$\vec{v}_{AB} = \vec{v}_A - \vec{v}_B$$

$$v_{AB} = \sqrt{v_A^2 + v_B^2}$$

$$|\vec{v}_{AB}| = \sqrt{10^2 + 20^2} = \sqrt{100+400} = \sqrt{500} \simeq 22\text{ ms}^{-1}$$



28. Balls are being thrown with speed u at an angle θ with horizontal at the rate n balls per second. Mass of each ball is m. The average force exerted by the balls at point P is (see figure)



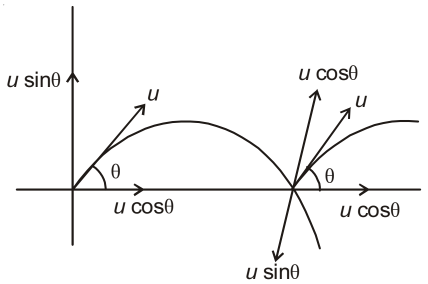
(1) $2nmu$ (2) $2nmu \sin\theta$ (3) $2nmu \cos\theta$ (4) nmu

Sol. Answer (2)

Average force = $\frac{\Delta p}{\Delta t}$

$$F = \frac{2mu\sin\theta}{\frac{1}{n}}$$

$$\boxed{F = 2mnu\sin\theta}$$



29. A projectile is thrown with speed 40 ms^{-1} at angle θ from horizontal. It is found that projectile is at same height at 1s and 3 s. What is the angle of projection?

(1) $\tan^{-1}\left(\frac{1}{\sqrt{2}}\right)$ (2) $\tan^{-1}\left(\frac{1}{\sqrt{3}}\right)$ (3) $\tan^{-1}\left(\sqrt{3}\right)$ (4) $\tan^{-1}\left(\sqrt{2}\right)$

Sol. Answer (2)

$$\tan\theta = \frac{v_y}{v_x}$$

Also, $t_1 + t_2 = \frac{2u\sin\theta}{g}$

$$4 = \frac{2\times 40\times \sin\theta}{10}$$

$$\sin\theta = \frac{1}{2} \Rightarrow \theta = 30^\circ$$

So, $\tan\theta = \tan 30^\circ \Rightarrow \frac{1}{\sqrt{3}}$

$$\boxed{\theta = \tan^{-1}\left(\frac{1}{\sqrt{3}}\right)}$$

30. A particle is moving along circular path with angular velocity $\vec{\omega} = 3\hat{i} - 4\hat{j} + \hat{k}$ and radius vector $\vec{r} = 5\hat{i} - 6\hat{j} + 6\hat{k}$, then the linear velocity $\vec{u}$ is

(1) $8\hat{i} - 3\hat{j} + 8\hat{k}$ (2) $9\hat{i} + 4\hat{j} - 3\hat{k}$ (3) $-18\hat{i} - 13\hat{j} + 2\hat{k}$ (4) $\hat{i} + \hat{j} - \hat{k}$

Sol. Answer (3)

$$\vec{\omega} = 3\hat{i} - 4\hat{j} + \hat{k}$$

$$\vec{r} = 5\hat{i} - 6\hat{j} + 6\hat{k}$$

$$\vec{v} = \vec{\omega}\times\vec{r}$$

$$\Rightarrow \vec{\omega}\times\vec{r} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 3 & -4 & 1 \\ 5 & -6 & 6 \end{vmatrix}$$

$$\Rightarrow \hat{i}(-24+6) - \hat{j}(18-5) + \hat{k}(-18+20)$$

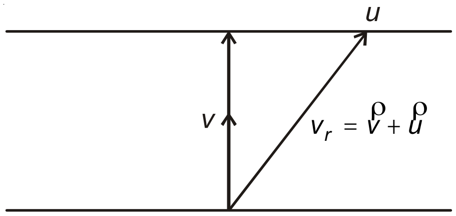
$$\Rightarrow -18\hat{i} - 13\hat{j} + 2\hat{k}$$

SECTION - C

1. A boat is sent across a river with a velocity of 8 km/h. If the resultant velocity of the boat is 10 km/h, then velocity of the river is

(1) 8 km/h (2) 10 km/h (3) 12.8 km/h (4) 6 km/h

Sol. Answer (4)



$v_r = \sqrt{v^2 + u^2}$

v_r = 10 kmh^{-1}, v = 8 kmh^{-1}

u = ?

$100 = 8^2 + u_R^2$

$\Rightarrow \; u_R^2 = 36$

$\Rightarrow \; \boxed{u_R = 6 \text{ km/h}}$

2. The horizontal range and the maximum height of a projectile are equal. The angle of projection of the projectile is

(1) $\theta = \tan^{-1}(2)$ (2) $\theta = 45°$ (3) $\theta = \tan^{-1}\left(\frac{1}{4}\right)$ (4) $\theta = \tan^{-1}(4)$

Sol. Answer (4)

$H = R$

$\tan\theta = 4 \qquad \left(\because \; \frac{H}{R} = \frac{1}{4}\tan\theta\right)$

$\boxed{\theta = \tan^{-1}(4)}$

3. A particle has initial velocity $\left(2\vec{i} + 3\vec{j}\right)$ and acceleration $\left(0.3\vec{i} + 0.2\vec{j}\right)$. The magnitude of velocity after 10 seconds will be

(1) 5 units (2) 9 units (3) $9\sqrt{2}$ units (4) $5\sqrt{2}$ units

Sol. Answer (4)

$\vec{u} = 3\hat{i} + 3\hat{j}$, $\vec{a} = 0.3\hat{i} + 0.2\hat{j}$

Δt = 10 s

$\vec{v} = \vec{u} + \vec{a}t$

$\vec{v} = 2\hat{i} + 3\hat{j} + (0.3\hat{i} + 0.2\hat{j}) \times 10$

$= 2\hat{i} + 3\hat{j} + 3\hat{i} + 2\hat{j}$

$\vec{v} = 5\hat{i} + 5\hat{j}$

$v = \sqrt{5^2 + 5^2} = \sqrt{50}$

$\boxed{v \Rightarrow 5\sqrt{2} \text{ ms}^{-1}}$

4. A particle moves in a circle of radius 5 cm with constant speed and time period 0.2 π s. The acceleration of the particle is

(1) 5 m/s² (2) 15 m/s² (3) 25 m/s² (4) 36 m/s²

Sol. Answer (1)

$r = 5$ cm, $v = ?$, $T = 0.2\,\pi$ s

$$T = \frac{2\pi}{\omega} \Rightarrow \omega = \frac{20\pi}{0.2\pi} = 10 \text{ rad s}^{-1}$$

$$a = r\omega^2 = 5\times10^{-2}\times100$$

$$\boxed{a = 5 \text{ ms}^{-2}}$$

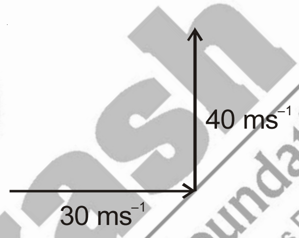
5. A body is moving with velocity 30 m/s towards east. After 10 seconds its velocity becomes 40 m/s towards north. The average acceleration of the body is

(1) 5 m/s² (2) 1 m/s² (3) 7 m/s² (4) $\sqrt{7}$ m/s²

Sol. Answer (1)

$$a_{av} = \frac{|\Delta\vec{v}|}{\Delta t}$$

$$\Delta v = (\vec{v}_2 - \vec{v}_1) = \sqrt{v_2^2 + v_1^2} \qquad (\because\ \theta = 90^\circ)$$



$$= 5\sqrt{30^2 + 40^2} = 50 \text{ ms}^{-1}$$

$$\text{so, } a_{av} = \frac{50}{10}$$

$$\Rightarrow \boxed{5\ ms^{-2} = a_{av}}$$

6. A missile is fired for maximum range with an initial velocity of 20 m/s. If g = 10 m/s², the range of the missile is

(1) 20 m (2) 40 m (3) 50 m (4) 60 m

Sol. Answer (2)

For maximum range θ = 45º

$v = 20$ ms⁻¹

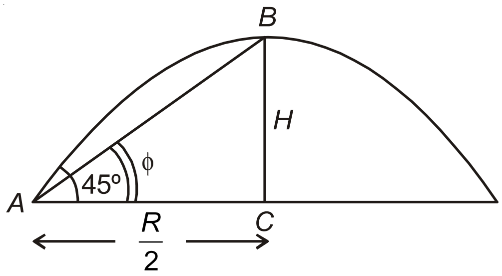
$$R = \frac{u^2}{g} = \frac{20\times20}{10} \qquad [\because\ \theta = 45^\circ]$$

$$\boxed{R = 40 \text{ m}}$$

7. A projectile is fired at an angle of 45° with the horizontal. Elevation angle of the projectile at its highest point as seen from the point of projection is

(1) $\tan^{-}\left(\frac{\sqrt{3}}{2}\right)$ (2) 45° (3) 60° (4) $\tan^{-1}\frac{1}{2}$

Sol. Answer (4)



$$\frac{1}{4}\tan\theta = \frac{H}{R}$$

$$4H = R \qquad \text{...(i)}$$

In ΔABC, $\tan\phi = \dfrac{H}{\dfrac{R}{2}} = \dfrac{2H}{R}$

$$\tan\phi = \frac{2H}{4H} = \frac{1}{2}$$

$$\Rightarrow \quad \phi = \tan^{-1}\left(\frac{1}{2}\right)$$

8. Which of the following is correct relation between an arbitrary vector $\vec{A}$ and null vector $\vec{0}$?

(1) $\vec{A}+\vec{0}+\vec{A}\times\vec{0}=\vec{A}$ (2) $\vec{A}+\vec{0}+\vec{A}\times\vec{0}\neq\vec{A}$ (3) $\vec{A}+\vec{0}+\vec{A}\times\vec{0}=\vec{0}$ (4) None of these

Sol. Answer (1)

Knowledge based.

9. An object is being thrown at a speed of 20 m/s in a direction 45° above the horizontal. The time taken by the object to return to the same level is

(1) $20/g$ (2) $20g$ (3) $20\sqrt{2}/g$ (4) $20\sqrt{2}g$

Sol. Answer (3)

$u = 20 \text{ ms}^{-1}$

$\theta = 45°$

$$T = \frac{2u\sin\theta}{g}$$

$$T = \frac{2u}{g}\times\frac{1}{\sqrt{2}} = \frac{\sqrt{2}}{10}u$$

$$T = \frac{2\times 20}{g}\,\frac{1}{\sqrt{2}} \Rightarrow \boxed{\frac{20\sqrt{2}}{g} = T}$$

10. Two vectors $\vec{A}$ and $\vec{B}$ are such that $|\vec{A}+\vec{B}| = |\vec{A}-\vec{B}|$. The angle between the two vectors will be

(1) 180° (2) 0° (3) 60° (4) 90°

Sol. Answer (4)

$$|\vec{A}+\vec{B}| = |\vec{A}-\vec{B}|$$

$$\sqrt{A^2+B^2+2AB\cos\theta} = \sqrt{A^2+B^2-2AB\cos\theta}$$

Squaring both the sides,

$$\Rightarrow \quad A^2+B^2+2AB\cos\theta = A^2+B^2-2AB\cos\theta$$

$$4AB\cos\theta = 0$$

$$\Rightarrow \quad \cos\theta = 0$$

$$\Rightarrow \quad \boxed{\theta = 90°}$$

11. A body is whirled in a horizontal circle of radius 20 cm. It has an angular velocity of 10 rad/s. What is its linear velocity at any point on circular path?

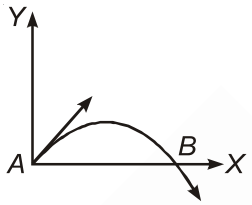
(1) 20 m/s (2) $\sqrt{2}$ m/s (3) 10 m/s (4) 2 m/s

Sol. Answer (4)

$$v = r\omega = 20\times10^{-2}\times10$$

$$\boxed{v = 2\ \text{ms}^{-1}}$$

12. The velocity of a projectile at the initial point *A* is $(2\hat{i}+3\hat{j})$ m/s. Its velocity (in m/s) at point *B* is



(1) $-2\hat{i}+3\hat{j}$ (2) $2\hat{i}-3\hat{j}$ (3) $2\hat{i}+3\hat{j}$ (4) $-2\hat{i}-3\hat{j}$

Sol. Answer (2)

The change is only in the *y*-component

So, $\boxed{v_f = 2\hat{i}-3\hat{j}}$ $\boxed{\because\ a_x = 0}$

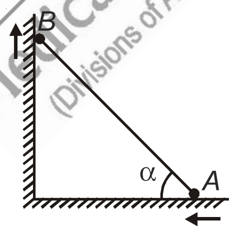
13. Identify the vector quantity among the following.

(1) Distance (2) Angular momentum (3) Heat (4) Energy

Sol. Answer (2)

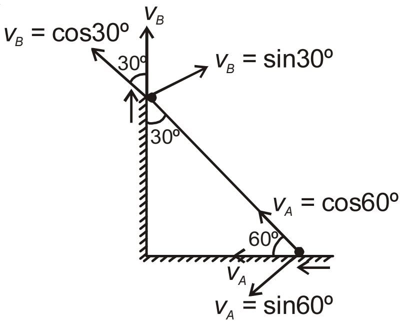
Angular momentum is an axial vector.

14. Two particles *A* and *B* are connected by a rigid rod *AB*. The rod slides along perpendicular rails as shown here. The velocity of *A* to the left is 10 m/s. What is the velocity of *B* when angle α = 60°?



(1) 10 m/s (2) 9.8 m/s (3) 5.8 m/s (4) 17.3 m/s

Sol. Answer (3)



$$v_A\cos60° = v_B\cos30°$$

$$10\times\frac{1}{2} = v_B\times\frac{\sqrt{3}}{2}$$

$$\boxed{v_B = \frac{10}{\sqrt{3}}}$$

15. The speed of a boat is 5 km/h in still water. It crosses a river of width 1.0 km along the shortest possible path in 15 minute. The velocity of the river water (in km/h) is

(1) 3
(2) 1
(3) 4
(4) 5

Sol. Answer (1)

Repeated.

$v = 5\ \text{kmh}^{-1}$

$d = 1.0$ km

$t = 15$ min

16. Two racing cars of masses m_1 and m_2 are moving in circles of radii r_1 and r_2 respectively. Their speeds are such that each makes a complete circle in the same time t. The ratio of the angular speeds of the first to the second car is

(1) $r_1 : r_2$
(2) $m_1 : m_2$
(3) $1 : 1$
(4) $m_1\, m_2 : r_1\, r_2$

Sol. Answer (3)

If time is same then,

$$\omega_1 : \omega_2 \Rightarrow 1 : 1 \qquad \left[\because\ \omega = \frac{2\pi}{T}\right]$$

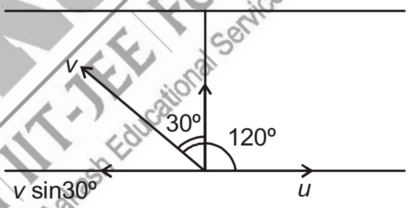
17. A person aiming to reach exactly opposite point on the bank of a stream is swimming with a speed of 0.5 m/s at an angle of 120° with the direction of flow of water. The speed of water in the stream is

(1) 0.25 m/s
(2) 0.5 m/s
(3) 1.0 m/s
(4) 0.433 m/s

Sol. Answer (1)

$v \sin 30^\circ = u$

$$0.5 \times \frac{1}{2} = u \ \Rightarrow\ \boxed{u = 0.25\ \text{ms}^{-1}}$$



18. Two projectiles of same mass and with same velocity are thrown at an angle 60° and 30° with the horizontal, then which will remain same

(1) Time of flight
(2) Range of projectile
(3) Maximum height acquired
(4) All of these

Sol. Answer (2)

Range is same for complimentary angles.

19. Two particles having mass M and m are moving in a circular path having radius R and r. If their time periods are same, then the ratio of their angular velocities will be

(1) $\dfrac{r}{R}$
(2) $\dfrac{R}{r}$
(3) 1
(4) $\sqrt{\dfrac{R}{r}}$

Sol. Answer (3)

Repeated.

20. If $|\overrightarrow{A}+\overrightarrow{B}|=|\overrightarrow{A}|=|\overrightarrow{B}|$ then angle between A and B will be

(1) 90° (2) 120° (3) 0° (4) 60°

Sol. Answer (2)

$$|\vec{A}+\vec{B}|=|\vec{A}|=|\vec{B}|$$

$$|\vec{A}+\vec{B}|=\sqrt{A^2+B^2+2AB\cos\theta}$$

$$A^2=A^2+A^2+2A^2\cos\theta$$

$$-\frac{1}{2}=\cos\theta \Rightarrow \boxed{\theta=120^\circ}$$

21. A particle moves along a circle of radius $\left(\frac{20}{\pi}\right)$ m with constant tangential acceleration. If the velocity of the particle is 80 m/s at the end of the second revolution after motion has begun, the tangential acceleration is

(1) 40 m/s^2 (2) 640π m/s^2 (3) 160π m/s^2 (4) 40π m/s^2

Sol. Answer (1)

$$r=\frac{20}{\pi}\text{ m}$$

$a_T \rightarrow$ constant

v = 80 ms^{-1}, θ = 4π rad

$v = r\omega$

$$80=\frac{20}{\pi}\cdot\omega \Rightarrow \boxed{\omega=4\pi\text{ rad s}^{-1}}$$

ω = 0,

$$\omega^2=\omega_0^2+2\alpha\theta$$

$$4\pi\times4\pi=2\times\alpha\times4\pi$$

$$\Rightarrow \boxed{\alpha=2\pi\text{ rad s}^{-2}}$$

$$a=r\alpha=\frac{20}{\pi}\times2\pi$$

$$\boxed{a=40\text{ ms}^{-2}}$$

22. The vector sum of two forces is perpendicular to their vector differences. In that case, the forces

(1) Are equal to each other (2) Are equal to each other in magnitude

(3) Are not equal to each other in magnitude (4) Cannot be predicted

Sol. Answer (2)

$$(\vec{A}+\vec{B})\cdot(\vec{A}-\vec{B})=0$$

$$A^2-B^2-AB+BA=0$$

$$A^2=B^2$$

$$\Rightarrow \boxed{A=B}$$

so, $\boxed{|\vec{A}|=|\vec{B}|}$

23. A stone tied to the end of a string of 1 m long is whirled in a horizontal circle with a constant speed. If the stone makes 22 revolutions in 44 seconds, what is the magnitude and direction of acceleration of the stone?

(1) π^2 ms^{-2} and direction along the radius towards the centre

(2) π^2 ms^{-2} and direction along the radius away from the centre

(3) π^2 ms^{-2} and direction along the tangent to the circle

(4) $\pi^2/4$ ms^{-2} and direction along the radius towards the centre

Sol. Answer (1)

$\omega = 22\ r\omega/\text{s} \Rightarrow 22 \times 2\pi$

$\frac{22\times 2\pi}{44\text{ s}} \Rightarrow \pi \text{ rad s}^{-1}$

$a = r\omega^2$

$\boxed{a = 1\times\pi^2}$ ms^{-2} centripetal acceleration.

24. Two boys are standing at the ends *A* and *B* of a ground where *AB* = *a*. The boy at *B* starts running in a direction perpendicular to *AB* with velocity v_1. The boy at *A* starts running simultaneously with velocity *v* and catches the other in a time *t*, the value of *t* is

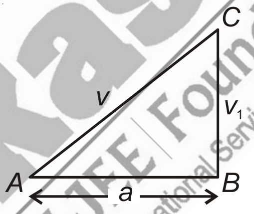
(1) $\frac{a}{\sqrt{v^2+v_1^2}}$ (2) $\frac{a}{v+v_1}$ (3) $\frac{a}{v-v_1}$ (4) $\sqrt{\frac{a^2}{v^2-v_1^2}}$

Sol. Answer (4)

The distance travelled by body at *B*,

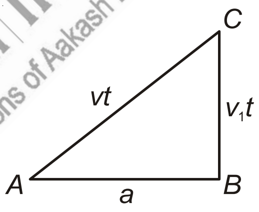
= Speed × *t*

= $v_1 t$



So, $BC = v_1 t$, similarly, $AC = vt$

Applying pythagoras in ΔABC,



$v^2t^2 = v_1^2t^2 + a^2$

$(v^2 - v_1^2)t^2 = a^2$

$t^2 = \frac{a^2}{v^2-v_1^2}$

$\boxed{t = \frac{a}{\sqrt{v^2-v_1^2}}}$

25. For angles of projection of a projectile equal to (45° – θ) and (45° + θ) with horizontal, the horizontal ranges described by the projectile are in the ratio of

(1) 2 : 1 (2) 1 : 1 (3) 2 : 3 (4) 1 : 2

Sol. Answer (2)

Repeated.

26. A car runs at a constant speed on a circular track of radius 100 m, taking 62.8 seconds for every circular lap. The average velocity and average speed for each circular lap respectively is

(1) 10 m/s, 0 (2) 0, 0 (3) 0, 10 m/s (4) 10 m/s, 10 m/s

Sol. Answer (3)

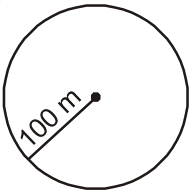
$T = 62.8$ s

$r = 100$ m

$$T = \frac{2\pi}{\omega}$$

$$\omega = \frac{2\pi}{T} = \frac{2\times 3.14\times 10}{62.8\times 100}$$

$$\boxed{\omega = 0.1 \text{ rad s}^{-1}}$$



$v = r\omega$

$v = 100 \times 0.1$

$$\boxed{v = 10 \text{ ms}^{-1}}$$

$$\boxed{\begin{array}{l}\text{Average velocity} = 0\\ \text{Average speed} = 10 \text{ ms}^{-1}\end{array}}$$

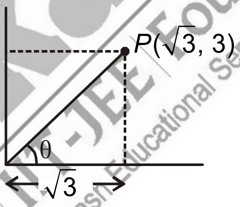
27. A particle starting from the origin (0, 0) moves in a straight line in the (x, y) plane. Its coordinates at a later time are ($\sqrt{3}, 3$). The path of the particle makes with the x-axis an angle of

(1) 45° (2) 60° (3) 0° (4) 30°

Sol. Answer (2)

$$\tan\theta = \frac{P}{B} = \frac{3}{\sqrt{3}}$$

$$\boxed{\theta = 60^\circ}$$



28. A wheel has angular acceleration of 3.0 rad/s^2 and an initial angular speed of 2.00 rad/s. In a time of 2 s it has rotated through an angle (in radian) of

(1) 10 (2) 12 (3) 4 (4) 6

Sol. Answer (1)

$\alpha = 3$ rad s^{-2}

$\omega_0 = 2$ rad s^{-1}

$t = 2$ s

$\omega = \omega_0 + \alpha t$

$\omega = 2 + 3 \times 2$

$$\boxed{\omega = 8 \text{ rad s}^{-1}}$$

$$\omega^2 - \omega_0^2 = 2\times\theta$$

$$64 - 4 = 2\times 3\times\theta$$

$$\frac{60}{6} = \theta \Rightarrow \boxed{\theta = 10 \text{ rad s}^{-1}}$$

29. A particle of mass m is projected with velocity V making an angle of 45° with the horizontal. When the particle lands on the level ground the magnitude of the change in its momentum will be

(1) Zero (2) $2\ mV$ (3) $mV/\sqrt{2}$ (4) $mV\sqrt{2}$

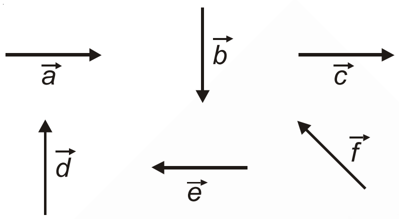
Sol. Answer (4)

$$\Delta p = -2mV\sin\theta\hat{j}$$

$$|\Delta\vec{p}| = 2mV\sin\theta = 2mV\times\frac{1}{\sqrt{2}}$$

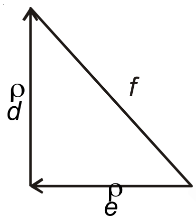
$$\boxed{|\Delta\vec{p}| = \sqrt{2}\ mV}$$

30. Six vectors, $\vec{a}$ through $\vec{f}$ have the magnitudes and directions indicated in the figure. Which of the following statements is true?



(1) $\vec{b}+\vec{e}=\vec{f}$ (2) $\vec{b}+\vec{c}=\vec{f}$ (3) $\vec{d}+\vec{c}=\vec{f}$ (4) $\vec{d}+\vec{e}=\vec{f}$

Sol. Answer (4)



$$\vec{d}+\vec{e}=\vec{f}$$

31. A particle has initial velocity $(3\hat{i}+4\hat{j})$ and has acceleration $(0.4\hat{i}+0.3\hat{j})$. Its speed after 10 s is

(1) 10 units (2) 7 units (3) $7\sqrt{2}$ units (4) 8.5 units

Sol. Answer (3)

$$\vec{v}=\vec{u}+\vec{a}t \quad = 3\hat{i}+4\hat{j}+(0.4\hat{i}+0.3\hat{j})\times 10 \quad = 3\hat{i}+4\hat{j}+4\hat{i}+3\hat{j} \quad = 7\hat{i}+7\hat{j}$$

$$|\vec{v}| = \sqrt{7^2+7^2} = 7\sqrt{2}\ \text{ms}^{-1}$$

32. The speed of a projectile at its maximum height is half of its initial speed. The angle of projection is

(1) 60° (2) 15° (3) 30° (4) 45°

Sol. Answer (1)

$$u_H = u\cos\theta$$

$$\frac{u}{2} = u\cdot\cos\theta$$

$$\cos\theta = \frac{1}{2}$$

$$\boxed{\theta = 60^\circ}$$

33. A particle moves in x-y plane according to rule $x = a \sin \omega t$ and $y = a \cos\omega t$. The particle follows
    (1) An elliptical path
    (2) A circular path
    (3) A parabolic path
    (4) A straight line path inclined equally to x and y-axes

Sol. Answer (2)

$$x = a\sin\omega t \Rightarrow x^2 = a^2 \sin^2 \omega t$$

$$y = a\cos\omega t \Rightarrow y^2 = a^2 \cos^2 \omega t$$

$$x^2 + y^2 = a^2(\sin^2 \omega t + \cos^2 \omega t)$$

$\boxed{x^2 + y^2 = a^2}$ → equation of circle.

SECTION - D

Assertion - Reason Type Questions

1. A : $\vec{A}\times\vec{B}$ is perpendicular to both $\vec{A}$ and $\vec{B}$.

   R : The direction of $\vec{A}\times\vec{B}$ can be found out by using right hand thumb rule.

Sol. Answer (2)

2. A : If $\vec{A}\perp\vec{B}$, then $|\vec{A}+\vec{B}| = |A-\vec{B}|$.

   R : If $\vec{A}\perp\vec{B}$, then $(\vec{A}+\vec{B})$ is perpendicular to $\vec{A}-\vec{B}$.

Sol. Answer (3)

3. A : The addition of two vectors $\vec{P}$ and $\vec{Q}$ is commutative.

   R : By triangle law of vector addition we can prove $\vec{P}+\vec{Q} = \vec{Q}+\vec{P}$.

Sol. Answer (1)

4. A : If $\vec{P}\cdot\vec{Q} = \vec{Q}\cdot\vec{R}$, then $|\vec{P}| = |\vec{R}|$.

   R : The dot product of two vectors depends only on magnitude of vectors because it is a scalar quantity.

Sol. Answer (4)

5. A : A vector cannot be divided by other vector.

   R : A vector can be divided by a scalar.

Sol. Answer (2)

6. A : At the highest point the velocity of projectile is zero.

   R : At maximum height projectile comes to rest.

Sol. Answer (4)

7. A : Horizontal range of a projectile is always same for angle of projection θ with horizontal or θ with vertical.

R : Horizontal range depends only on angle of projection.

Sol. Answer (4)

8. A : Horizontal motion of projectile without effect of air is uniform motion.

R : Without air effect the horizontal acceleration of projectile is zero.

Sol. Answer (1)

9. A : Path of a projectile with respect to another projectile is straight line.

R : Acceleration of a projectile with respect to another projectile is zero.

Sol. Answer (1)

10. A : In the case of ground to ground projection of a projectile from ground the angle of projection with horizontal is $\theta = 30^\circ$. There is no point on its path such that instantaneous velocity is normal to the initial velocity.

R : Maximum deviation of the projectile is $2\theta = 60^\circ$.

Sol. Answer (1)

11. A : Three vectors having magnitudes 10, 10 and 25 cannot produce zero resultant.

R : If three vectors are producing zero resultant, then sum of magnitude of any two is more than or equal to magnitude of third and difference is less than or equal to the magnitude of third.

Sol. Answer (1)

12. A : Uniform circular motion is accelerated motion still speed remains unchanged.

R : Instantaneous velocity is always normal to instantaneous acceleration in uniform circular motion.

Sol. Answer (1)

13. A : When a body moves on a curved path with increasing speed, then angle between instantaneous velocity and acceleration is acute angle.

R : When the speed is increasing, its tangential acceleration is in the direction of instantaneous velocity.

Sol. Answer (1)

14. A : A uniform circular motion have non uniform acceleration.

R : The direction of acceleration of a particle in uniform circular motion changes continuously.

Sol. Answer (1)

15. A : Angular displacement is vector quantity only for small values.

R : The direction of angular displacement is perpendicular to plane of rotation of object.

Sol. Answer (2)

❑ ❑ ❑

Chapter 5

Laws of Motion

Solutions

SECTION - A

Objective Type Questions

1. An athlete does not come to rest immediately after crossing the winning line due to the

(1) Inertia of rest (2) Inertia of motion (3) Inertia of direction (4) None of these

Sol. Answer (2)

While running athlete is in the state of motion. So due to inertia of motion athlete does not come to rest.

2. When an object is at rest

(1) Force is required to keep it in rest state

(2) No force is acting on it

(3) A large number of forces may be acting on it which balance each other

(4) It is in vacuum

Sol. Answer (3)

Object can be at rest only if net force acting on it is zero.

$$\vec{F}_{\text{net}} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \vec{F}_4 + \ldots\ldots\ldots\ldots \vec{F}_n = 0$$

3. Newton's first law is applicable

(1) In all reference frames (2) Only in inertial reference frames

(3) Only in non-inertial reference frames (4) None of these

Sol. Answer (2)

Newton's law is applicable only in inertial reference frames.

4. From Newton's second law of motion, it can be inferred that

(1) No force is required to move a body uniformly along straight line

(2) Accelerated motion is always due to an external force

(3) Inertial mass of a body is equal to force required per unit acceleration in the body

(4) All of these

Sol. Answer (4)

By Newton's second law

$\vec{F} = m\vec{a}$ ...(i)

for (i) Uniform motion means body is moving with constant velocity. By (i) it can be said that only for accelerated motion force is required (2) is true using (i)

(3) Using (i) $\vec{a} = \dfrac{\vec{F}}{m}$ so this is true

5. If a force of constant magnitude acts in direction perpendicular to the motion of a particle, then its

(1) Speed is uniform (2) Momentum is uniform (3) Velocity is uniform (4) All of these

Sol. Answer (1)

No component of force is in the direction of motion (as $\vec{F} \perp \vec{V}$) so it cannot change the speed of particle. But velocity cannot be constant because force will change the direction of motion.

6. When an object is in equilibrium state, then

(1) It must be at rest (2) No force is acting on it

(3) Its net acceleration must be zero (4) All of these

Sol. Answer (3)

Equilibrium ⇒ $\vec{F}_{net} = 0$

Using Newton's second law, $\vec{a} = 0$

7. When a force of constant magnitude and a fixed direction acts on a moving object, then its path is

(1) Circular (2) Parabolic (3) Straight line (4) Either (2) or (3)

Sol. Answer (4)

1. To move a particle in circular motion centripetal force is required which has variable direction.
2. Parabolic is possible (example projectile motion)
3. If force is in the direction of motion or just opposite to it, path will be straight line

8. A body of mass 2 kg is sliding with a constant velocity of 4 m/s on a frictionless horizontal table. The force required to keep the body moving with the same velocity is

(1) 8 N (2) 0 N (3) 2×10^4 N (4) $\dfrac{1}{2}$ N

Sol. Answer (2)

For constant velocity, no force is required so $\vec{F} = 0$

9. A 10 g bullet moving at 200 m/s stops after penetrating 5 cm of wooden plank. The average force exerted on the bullet will be

(1) 2000 N (2) –2000 N (3) 4000 N (4) –4000 N

Sol. Answer (4)

m = 10 g, u = 200 m/s, s = 5 cm

final velocity $v = 0$

Using $v^2 = u^2 + 2as$

$$a = \frac{u^2}{2s}$$

and for force $F = -ma$ (retarding force)

10. A ball of mass 50 g is dropped from a height of 20 m. A boy on the ground hits the ball vertically upwards with a bat with an average force of 200 N, so that it attains a vertical height of 45 m. The time for which the ball remains in contact with the bat is [Take g = 10 m/s^2]

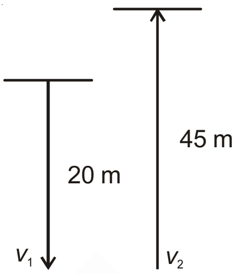
(1) 1/20th of a second (2) 1/40th of a second (3) 1/80th of a second (4) 1/120th of a second

Sol. Answer (3)

Using $v^2 = u^2 + 2as$

$$v_1 = \sqrt{2g\,(20)} = 20 \text{ m/s}$$

$$v_2 = \sqrt{2g(45)} = 30 \text{ m/s}$$



Impulse $= F\Delta t = m(\vec{v}_2 - \vec{v}_1)$

$$\Rightarrow 200\,t = \frac{50}{1000}\,(20 - (-30))$$

$$t = \frac{5}{400} = \frac{1}{80}\text{ s}$$

11. A string tied on a roof can bear a maximum tension of 50 kg wt. The minimum acceleration that can be acquired by a man of 98 kg to descend will be [Take g = 9.8 m/s^2]

(1) 9.8 m/s^2 (2) 4.9 m/s^2 (3) 4.8 m/s^2 (4) 5 m/s^2

Sol. Answer (3)

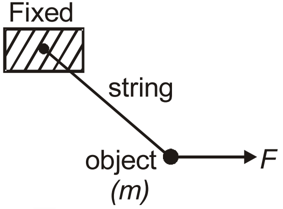
$T_{\max}$ = 50 g = 50 × 9.8 = 490 N

Using $F_{\text{net}} = ma$

$98g - 50g = 98a$

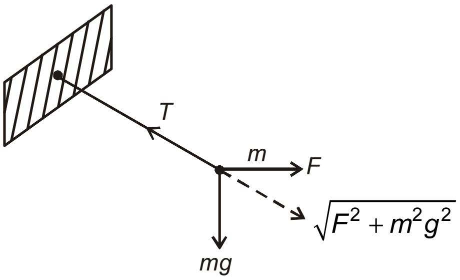
$a = 4.8$ m/s^2

12. In the following figure, the object of mass m is held at rest by a horizontal force as shown. The force exerted by the string on the block is



(1) F (2) mg (3) $F + mg$ (4) $\sqrt{F^2 + m^2g^2}$

Sol. Answer (4)



For mass m to be at rest, net force on m should be zero

So $T = \sqrt{F^2 + m^2g^2}$

13. In accordance with Newton's third law of motion
    (1) Action and reaction never balance each other
    (2) For appearance of action and reaction, physical contact is not necessary
    (3) This law is applicable whether the bodies are at rest or they are in motion
    (4) All of these

Sol. Answer (4)
    (1) Action and reaction act on the different bodies.
    (2) Example : Gravitational force, coulomb force
    (3) 3rd law is irrespective of the state of motion

14. When a 4 kg rifle is fired, the 10 g bullet receives an acceleration of 3 × 10^6 cm/s^2. The magnitude of the force acting on the rifle (in newton) is

(1) Zero (2) 120 (3) 300 (4) 3000

Sol. Answer (3)

Using Newton's third law, bullet will apply the same force in the opposite direction.

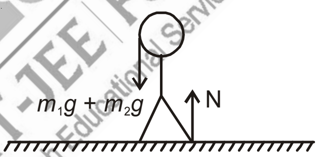
So, using $F = ma = \frac{10}{1000}\times 3\times 10^6 \times 10^{-2} = 300$ N

15. A man of mass 50 kg carries a bag of weight 40 N on his shoulder. The force with which the floor pushes up his feet will be

(1) 882 N (2) 530 N (3) 90 N (4) 600 N

Sol. Answer (2)

$N = m_1g + m_2g$
$= 50\ (9.8) + 40$
$= 490 + 40 = 530$ N



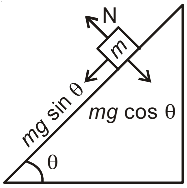
16. A block of mass m is released on a smooth inclined plane of inclination θ with the horizontal. The force exerted by the plane on the block has a magnitude

(1) mg (2) $\frac{mg}{\cos\theta}$ (3) $mg\tan\theta$ (4) $mg\cos\theta$

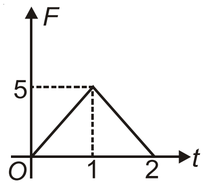
Sol. Answer (4)

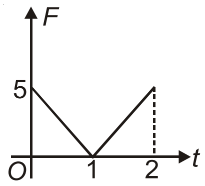
Force enerted by the plane on the block will be N

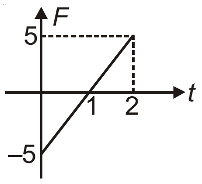
$N = mg\cos\theta$

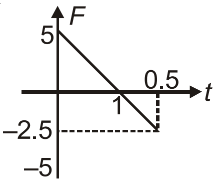


17. In which of the following graphs, the total change in momentum is zero?

(1)


(2)


(3)


(4)


Sol. Answer (3)

Total change in momentum = $\int F.dt$ = Area under *Ft* curve.

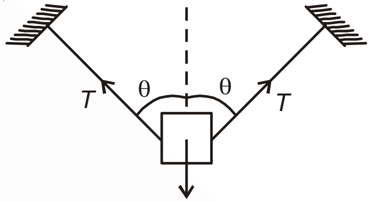
Area above *t*-axis will be positive and below *t*-axis will be negative in option (3)

$$\text{Area} = -\left[\frac{1}{2}\times 5\times 1\right]+\frac{1}{2}\times 5\times 1 = 0$$

18. A weight *Mg* is suspended from the middle of a rope whose ends are at the same level. The rope is no longer horizontal. The minimum tension required to completely straighten the rope is

(1) $\frac{Mg}{2}$ (2) $Mg\cos\theta$ (3) $2Mg\cos\theta$ (4) Infinitely large

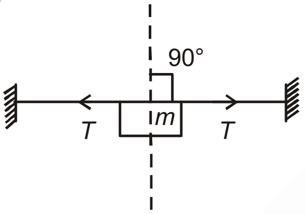
Sol. Answer (4)



$2T\cos\theta = mg$

$$T = \frac{mg}{2\cos\theta} \quad \text{...(i)}$$

To make this string completely straight

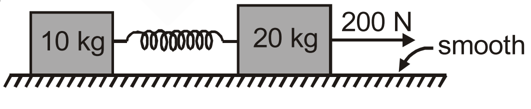


$\theta = 90°$

in (i) put $\theta = 90°$

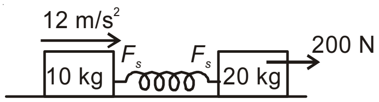
$$T = \frac{mg}{2\cos 90°} \approx \infty$$

19. Two masses of 10 kg and 20 kg respectively are connected by a massless spring as shown in fig. A force of 200 N acts on the 20 kg mass. At the instant shown the 10 kg mass has acceleration 12 m/s^2 towards right. The acceleration of 20 kg mass at this instant is



(1) 12 m/s^2 (2) 4 m/s^2 (3) 10 m/s^2 (4) Zero

Sol. Answer (2)



F_s is spring force

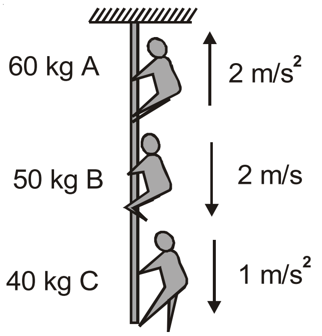
$F_s = 10 \times 12 = 120$ N

for 20 kg block

$200 - 120 = 20a$

$$a = \frac{80}{20} = 4\text{m/s}^2$$

20. Tension in the rope at the rigid support is (g = 10 m/s^2)



(1) 760 N (2) 1360 N (3) 1580 N (4) 1620 N

Sol. Answer (3)

For 40 kg

$400 - T_1 = 40\ (1)$

$T_1 = 360$ N

for 50 kg

$500 + T_1 - T_2 = 50\ (2)$

$\Rightarrow T_2 = 760$ N

for 60 kg $\Rightarrow T_3 - 600 - T_2 = 60\ (2)$

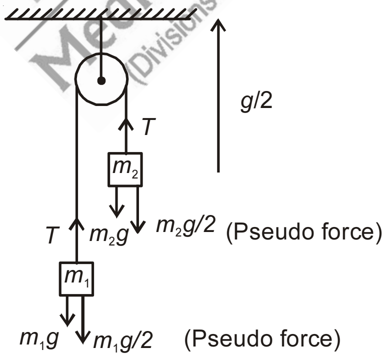
$T_3 = 1580$ N

T_3 will be the tension at the topmost point on the rigid support.

21. Two bodies of masses m_1 and m_2 are connected by a light string which passes over a frictionless, massless pulley. If the pulley is moving upward with uniform acceleration $\frac{g}{2}$, then tension in the string will be

(1) $\frac{3m_1m_2}{m_1+m_2}g$ (2) $\frac{m_1+m_2}{4m_1m_2}g$ (3) $\frac{2m_1m_2}{m_1+m_2}g$ (4) $\frac{m_1m_2}{m_1+m_2}g$

Sol. Answer (1)



Writing equation from the reference frame of pulley

$$\frac{3m_1g}{2} - T = m_1a \qquad \ldots\text{(i)}$$

$$T - \frac{3m_2g}{2} = m_2a \qquad \ldots\text{(ii)}$$

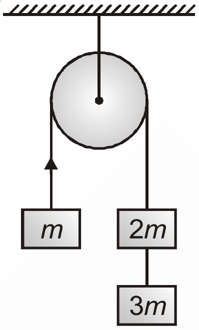
Add (i) and (ii)

$$\frac{3g}{2}\left(\frac{m_1-m_2}{m_1+m_2}\right) = a$$

Use a in eq. (i) or (ii)

Solving $T = \dfrac{3m_1m_2}{m_1+m_2}g$

22. In the figure given below, with what acceleration does the block of mass m will move? (Pulley and strings are massless and frictionless)



(1) $\dfrac{g}{3}$ (2) $\dfrac{2g}{5}$ (3) $\dfrac{2g}{3}$ (4) $\dfrac{g}{2}$

Sol. Answer (3)

For the single pulley system $a = \left(\dfrac{m_1-m_2}{m_1+m_2}\right)g$

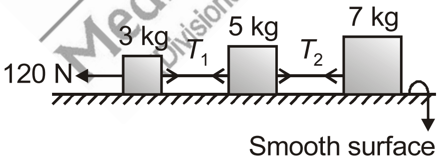
take $2m$ and $3m$ as a system (*i.e.,* single block of $5m$ mass)

$m_1 = 5m$

$m_2 = m$

$a = \left(\dfrac{5m-m}{5m+m}\right) g = \dfrac{2g}{3}$

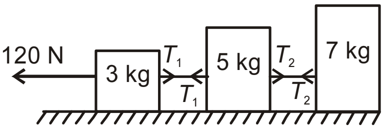
23. T_1 and T_2 in the given figure are



(1) 28 N, 48 N (2) 48 N, 28 N (3) 96 N, 56 N (4) 56 N, 96 N

Sol. Answer (3)

Acceleration of the system $a = \dfrac{F_{\text{ext}}}{M_{\text{Total}}} = \dfrac{120}{3+5+7} = 8\text{ m/s}^2$



Writing equation for 7 kg mass

$T_2 = 7(8)$

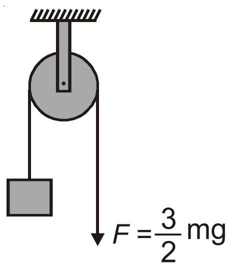
$= 56$ N

Writing equation for 5 kg mass

$T_1 = T_2 + 5\,(a)$

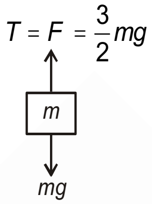
$= 56 + 5\,(8) = 96$ N

24. In the arrangement shown, the mass *m* will ascend with an acceleration (Pulley and rope are massless)



(1) Zero (2) $\frac{g}{2}$ (3) g (4) $2g$

Sol. Answer (2)



$F_{\text{net}} = ma$

$\frac{3}{2}mg - mg = ma$

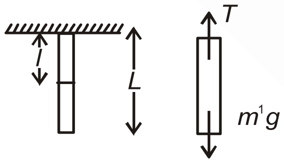
$a = g/2$

25. A uniform rope of mass *M* and length *L* is fixed at its upper end vertically from a rigid support. Then the tension in the rope at the distance *l* from the rigid support isx

(1) $Mg\frac{L}{L+l}$ (2) $\frac{Mg}{L}(L-l)$ (3) Mg (4) $\frac{l}{L}Mg$

Sol. Answer (2)

For the lower part



Mass of the lower part is m'

m' = Mass per unit length × length of lower part

$= \frac{M}{L}(L-l)$

So, Using $\vec{F}_{net} = m\vec{a}$

here $\vec{a} = 0$

$T - \frac{M}{L}(L-l)\,g = 0$

$T = \frac{M}{L}(L-l)\,g$

26. A man slides down a light rope whose breaking strength is η times the weight of man ($\eta < 1$). The maximum acceleration of the man so that the rope just breaks is

(1) $g(1 - \eta)$ (2) $g(1 + \eta)$ (3) $g\eta$ (4) $\frac{g}{\eta}$

Sol. Answer (1)

Given that $T_{max} = \eta\, w$

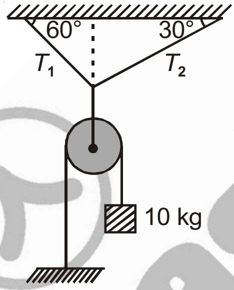
Using $F_{net} = ma$

$w - T_{max} = \frac{w}{g}a$

$T_{max} = \eta\, w$

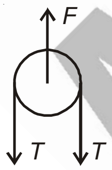
So $a = g(1 - \eta)$

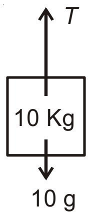
27. In the arrangement as shown, tension T_2 is ($g = 10$ m/s^2)

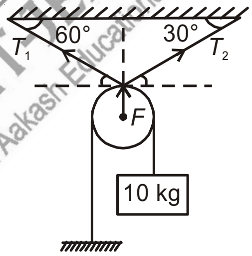


(1) 50 N (2) 100 N (3) $50\sqrt{3}$ N (4) $100\sqrt{3}$ N

Sol. Answer (2)







For pulley

$F = 2T$

for block

$T = 10\,g = 100$ N

$F = 200$ N

For horizontal equilibrium

$T_1 \cos 60° = T_2 \cos 30°$

$T_1 = 2T_2 \frac{\sqrt{3}}{2} = \sqrt{3}\, T_2$ …(i)

For vertical equilibrium

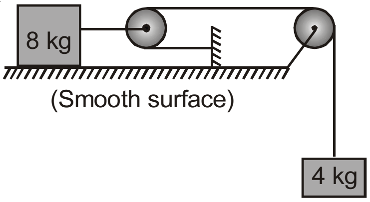
$T_1 = \sin 60° + T_2 \sin 30° = 200$ …(ii)

Using (i) and (ii) solve for T_2

$2T_2 = 200$

$T_2 = 100$ N

28. If pulleys shown in the diagram are smooth and massless and a_1 and a_2 are acceleration of blocks of mass 4 kg and 8 kg respectively, then



(1) $a_1 = a_2$ (2) $a_1 = 2a_2$ (3) $2a_1 = a_2$ (4) $a_1 = 4a_2$

Sol. Answer (2)

For 8 kg $T' = 8a_1$ …(i)

for 4 kg

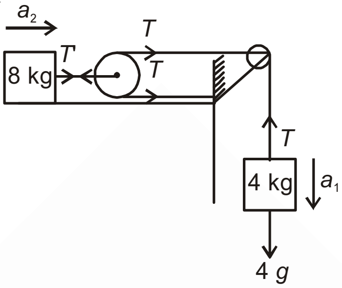
$4g - T = 4a_2$ …(ii)

for pulley

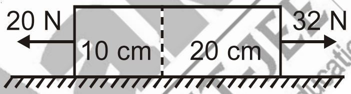
$T^1 = 2T$ …(iii)

Using (i), (ii) and (iii)

$$a_2 = \frac{a_1}{2}$$



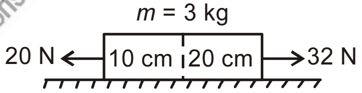
29. Figure shows a uniform rod of length 30 cm having a mass 3.0 kg. The rod is pulled by constant forces of 20 N and 32 N as shown. Find the force exerted by 20 cm part of the rod on the 10 cm part (all surfaces are smooth) is



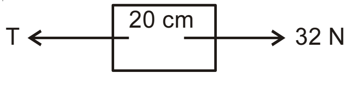
(1) 36 N (2) 12 N (3) 64 N (4) 24 N

Sol. Answer (4)

$$\text{Acceleration of the system} = \frac{\vec{F}_{\text{net}}}{m}$$



$$= \frac{32-20}{3} = 4 \text{ m/s}^2$$



Free body diagram of 20 cm part

$$\text{Mass of 20 cm part } m' = \frac{\text{Total mass}}{\text{Total length}} \times (20 \text{ cm})$$

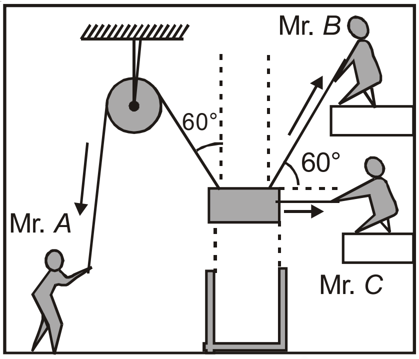
$$= \frac{3}{30}(20) = 2 \text{ kg}$$

Using equation $\vec{F}_{\text{net}} = m'a$

$32 - T = 2(4)$

$T = 24$ N

30. Mr. *A*, *B* and *C* are trying to put a heavy piston into a cylinder at a mechanical workshop in railway yard. If they apply forces F_1, F_2 and F_3 respectively on ropes then for which set of forces at that instant, they will be able to perform the said job?



(1) $\sqrt{3}F_1 = F_2 + 2F_3$ (2) $2F_1 = F_2 + F_3$ (3) $2F_2 = \sqrt{3}F_1 - \frac{F_3}{2}$ (4) $F_3 = 2F_1 - \sqrt{3}F_2$

Sol. Answer (1)

Piston is vertically above the cylinder so to drop it inside the cylinder, Net horizontal force must be zero on the piston

So,

$F_1 \sin 60 = F_2 \cos 60 + F_3$

$F_1\frac{\sqrt{3}}{2} = \frac{F_2}{2} + F_3$

$\sqrt{3}F_1 = F_2 + 2F_3$

31. In a rocket, fuel burns at the rate of 2 kg/s. This fuel gets ejected from the rocket with a velocity of 80 km/s. Force exerted on the rocket is

(1) 16,000 N (2) 1,60,000 N (3) 1600 N (4) 16 N

Sol. Answer (2)

For variable mass system $F = \frac{u\,dm}{dt}$

$= 80 \times 10^3 \times 2 = 1{,}60{,}000$ N

32. A machine gun fires a bullet of mass 65 g with a velocity of 1300 m/s. The man holding it can exert a maximum force of 169 N on the gun. The number of bullets he can fire per second will be

(1) 1 (2) 2 (3) 3 (4) 4

Sol. Answer (2)

$nmv = F$

n is number of bullets fired per second

$n\left[\frac{65}{1000}.1300\right] = 169$

$n = 2$

33. A bullet of mass 40 g is fired from a gun of mass 10 kg. If velocity of bullet is 400 m/s, then the recoil velocity of the gun will be

(1) 1.6 m/s in the direction of bullet
(2) 1.6 m/s opposite to the direction of bullet
(3) 1.8 m/s in the direction of bullet
(4) 1.8 m/s opposite to the direction of bullet

Sol. Answer (2)

Using conservation of momentum

$P_i = P_f$ …(i)

$P_i = 0$

$P_f = \frac{40}{1000}(400) + 10\,v$

So in (i)

$o = \frac{40}{1000}(400) + 10\,v$

$v = -\,1.6$ m/s

34. A cracker rocket is ejecting gases at a rate of 0.05 kg/s with a velocity 400 m/s. The accelerating force on the rocket is

(1) 20 dyne
(2) 20 N
(3) 200 N
(4) Zero

Sol. Answer (2)

For a variable mass system

$F = \frac{vdm}{dt}$

$= 400 \times 0.05 = 20$ N

35. A rocket of mass 5700 kg ejects mass at a constant rate of 15 kg/s with constant speed of 12 km/s. The acceleration of the rocket 1 minute after the blast is (g = 10 m/s^2)

(1) 34.9 m/s^2
(2) 27.5 m/s^2
(3) 3.50 m/s^2
(4) 13.5 m/s^2

Sol. Answer (2)

$F = \frac{vdm}{dt} - mg$ …(i)

where m is mass of the rocket after 1 minute

So $m = [5700 - 15\,(60)]$

$= 4800$ kg

in (i)

$F = (12 \times 10^3)\,(15) - (4800)\,g$

$= (12000)\,(15) - 48000$

$a = \frac{F}{m} = \frac{12000(15) - 48000}{4800}$

$= 27.5$ m/s^2

36. A balloon has 2 g of air. A small hole is pierced into it. The air comes out with a velocity of 4 m/s. If the balloon shrinks completely in 2.5 s. The average force acting on the balloon is

(1) 0.008 N (2) 0.0032 N (3) 8 N (4) 3.2 N

Sol. Answer (2)

$$F = \frac{vdm}{dt}$$

$$= 4\left(\frac{2}{1000 \times 2.5}\right)$$

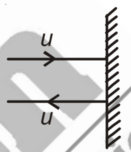
$$= 0.0032 \text{ N}$$

37. If *n* balls hit elastically and normally on a surface per unit time and all balls of mass *m* are moving with same velocity *u*, then force on surface is

(1) mun (2) $2\,mun$ (3) $\frac{1}{2}mu^2n$ (4) mu^2n

Sol. Answer (2)

As collision is elastic, velocity after the collision will be $-u$

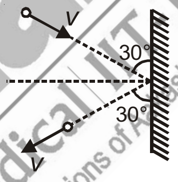


So using $F = \frac{dp}{dt}$

$$= n\,(mu - (-\,mu))$$

$$= 2nmu$$

38. A particle of mass *m* strikes a wall with speed *v* at an angle 30° with the wall elastically as shown in the figure. The magnitude of impulse imparted to the ball by the wall is



(1) mv (2) $\frac{mv}{2}$ (3) $2mv$ (4) $\sqrt{3}\,mv$

Sol. Answer (1)

Impulse = change in momentum

applying equation of change in momentum in horizontal direction

$$I = mv\sin 30^\circ - (-\,mv\sin 30^\circ)$$

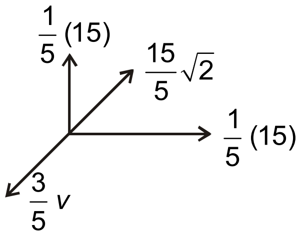
$$= 2mv\left(\frac{1}{2}\right) = mv$$

39. A bomb of mass 1 kg initially at rest, explodes and breaks into three fragments of masses in the ratio 1 : 1 : 3. The two pieces of equal mass fly off perpendicular to each other with a speed 15 m/s each. The speed of heavier fragment is

(1) 5 m/s (2) 15 m/s (3) 45 m/s (4) $5\sqrt{2}$ m/s

Sol. Answer (4)

Momentum of the system will be conserved before explosion and after explosion



Using conservation of momentum equation

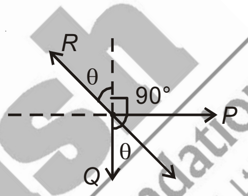
$$\frac{3}{5}V = \frac{15}{5}\sqrt{2}$$

$$V = 5\sqrt{2} \text{ m/s}$$

40. A 6 kg bomb at rest explodes into three equal pieces *P*, *Q* and *R*. If *P* flies with speed 30 m/s and *Q* with speed 40 m/s making an angle 90° with the direction of *P*. The angle between the direction of motion of *P* and *R* is about

(1) 143° (2) 127° (3) 120° (4) 150°

Sol. Answer (2)



$P_p = 30(2) = 60 \text{ kg ms}^{-1}$

$P_Q = 40\ (2) = 80 \text{ kg ms}^{-1}$

$$\tan\theta = \frac{60}{80} = 3/4$$

$$\theta = 37°$$

So angle between *P* and *R* will be 90° + 37° = 127°

41. A particle of mass 2*m* moving with velocity *v* strikes a stationary particle of mass 3*m* and sticks to it. The speed of the system will be

(1) 0.8*v* (2) 0.2*v* (3) 0.6*v* (4) 0.4*v*

Sol. Answer (4)

Collision is completely inelastic using momentum conservation

$2mv + 0 = (2m + 3m)v'$

$$v' = \frac{2v}{5} = 0.4v$$

42. Which of the following is self-adjusting force?

(1) Static friction (2) Limiting friction (3) Kinetic friction (4) Rolling friction

Sol. Answer (1)

Static friction is self adjusting force. Its value varies from $0 \le f_s \le \mu_s N$

43. Maximum force of friction is called

(1) Limiting friction (2) Static friction (3) Sliding friction (4) Rolling friction

Sol. Answer (1)

Limiting friction is maximum force of friction.

44. The limiting friction between two bodies in contact is independent of

(1) Nature of the surface in contact (2) The area of surfaces in contact

(3) Normal reaction between the surfaces (4) The materials of the bodies

Sol. Answer (2)

45. It is difficult to move a cycle with brakes on because

(1) Rolling friction opposes motion on road (2) Sliding friction opposes motion on road

(3) Rolling friction is more than sliding friction (4) Sliding friction is more than the rolling friction

Sol. Answer (4)

Sliding friction > Rolling friction

46. Which is a suitable method to decrease friction?

(1) Polishing (2) Lubrication (3) Ball bearing (4) All of these

Sol. Answer (4)

47. A cubical block rests on a plane of $\mu = \sqrt{3}$. The angle through which the plane be inclined to the horizontal so that the block just slides down will be

(1) 30° (2) 45° (3) 60° (4) 75°

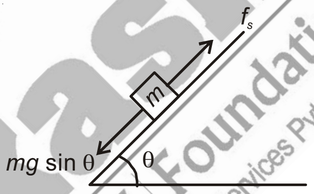
Sol. Answer (3)

$f_s = mg \sin \theta$

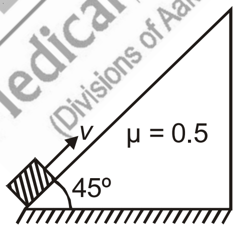
$\mu\, mg \cos \theta = mg \sin \theta$

$\tan \theta = \mu = \sqrt{3}$

$\theta = 60°$



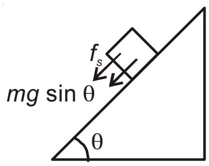
48. A block of mass 1 kg is projected from the lowest point up along the inclined plane. If $g = 10$ ms^{-2}, the retardation experienced by the block is



(1) $\frac{15}{\sqrt{2}}$ ms^{-2} (2) $\frac{5}{\sqrt{2}}$ ms^{-2} (3) $\frac{10}{\sqrt{2}}$ ms^{-2} (4) Zero

Sol. Answer (1)

Retarding forces will be friction and gravitational force



$a = -(g \sin 45° + \mu\, g \cos 45°)$

$$= -\left(\frac{10}{\sqrt{2}} + (0.5)\frac{(10)}{\sqrt{2}}\right)$$

$= 15/\sqrt{2}$

49. A child weighing 25 kg slides down a rope hanging from a branch of a tall tree. If the force of friction acting against him is 200 N, the acceleration of child is (g = 10 m/s^2)

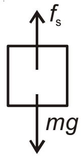
(1) 22.5 m/s^2 (2) 8 m/s^2 (3) 5 m/s^2 (4) 2 m/s^2

Sol. Answer (4)

$mg - f_s = ma$

$250 - 200 = 25a$

$a = 2\text{m/s}^2$



50. An object of mass 1 kg moving on a horizontal surface with initial velocity 8 m/s comes to rest after 10s. If one wants to keep the object moving on the same surface with velocity 8 m/s the force required is

(1) 0.4 N (2) 0.8 N (3) 1.2 N (4) Zero

Sol. Answer (2)

To find the frictional force offered by the ground

$v = u + at$

$v = 0$

$0 = 8 - \mu g\ (10)$

$\mu = \frac{8}{100} = 0.08$

To move the body with constant velocity on this surface, internal force applied should be equal to friction force $F = \mu mg$

$= (0.08)\ (1)\ (10) = 0.8$ N

51. A heavy box is solid across a rough floor with an initial speed of 4 m/s. It stops moving after 8 seconds. If the average resisting force of friction is 10 N, the mass of the box (in kg) is

(1) 40 (2) 20 (3) 5 (4) 2.5

Sol. Answer (2)

Same like previous question

$\mu = \frac{4}{80} = 0.05$

$F = \mu\ mg$

$10 = 0.5m$

$m = 20$ kg

52. If a block moving up an inclined plane at 30° with a velocity of 5 m/s, stops after 0.5 s, then coefficient of friction will be nearly

(1) 0.5 (2) 0.6 (3) 0.9 (4) 1.1

Sol. Answer (2)

Using $v = u + at$

retardation will be provided by friction as well as gravitational force

$a = \frac{u}{t}$

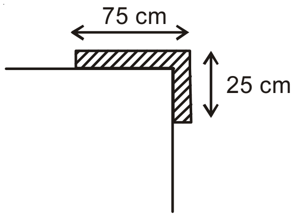
$g \sin 30° + \mu\ g \cos 30° = \frac{5}{0.5} = 10$

$\mu = \frac{1}{\sqrt{3}} \cong 0.6$

53. A metallic chain 1m long lies on a horizontal surface of a table. The chain starts sliding on the table if 25 cm (or more of it) hangs over the edge of a table. The correct value of the coefficient of friction between the table and the chain is

(1) $\frac{1}{3}$ (2) $\frac{2}{3}$ (3) $\frac{1}{4}$ (4) $\frac{1}{5}$

Sol. Answer (1)



$$\frac{M}{4}g = \frac{\mu 3M}{4}g$$

$$\mu = 1/3$$

54. A block of mass m placed on an inclined plane of angle of inclination θ slides down the plane with constant speed. The coefficient of kinetic friction between block and inclined plane is

(1) $\sin\theta$ (2) $\cos\theta$ (3) $\tan\theta$ (4) $\tan^{-1}\theta$

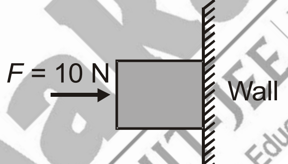
Sol. Answer (3)

Sliding with constant velocity implies that net force acting on the block is zero. So,

$$\mu\, mg \cos\theta = mg \sin\theta$$

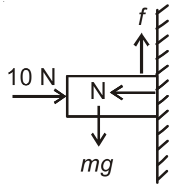
$$\mu = \tan\theta$$

55. A horizontal force 10 N is necessary to just hold a block stationary against a wall. The coefficient of friction between the block and the wall is 0.2, the weight of the block is



(1) 20 N (2) 50 N (3) 100 N (4) 2 N

Sol. Answer (4)



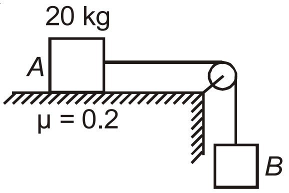
Normal reaction N = 10 newton

in vertical direction frictional force will balance its weight

$$f = mg = W$$

$$\mu N = (0.2)(10) = 2 \text{ newton}$$

56. In the figure shown, the coefficient of static friction between the block A of mass 20 kg and horizontal table is 0.2. What should be the minimum mass of hanging block just beyond which blocks start moving?



(1) 2 kg (2) 3 kg (3) 4 kg (4) 5 kg

Sol. Answer (3)

Tension produced in the string should be just greater than the frictional force acting on the 20 kg block

$T = m_Bg$

$T > \mu\, m_Ag$

$m_Bg > (0.2)\ (20\ (g)$

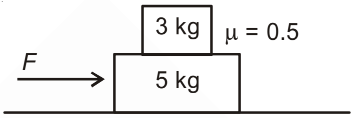
$m_B > 4$ kg

57. Two blocks *A* and *B* of masses 5 kg and 3 kg respectively rest on a smooth horizontal surface with *B* over *A*. The coefficient of friction between *A* and *B* is 0.5. The maximum horizontal force (in kg wt.) that can be applied to *A*, so that there will be motion of *A* and *B* without relative slipping, is

(1) 1.5 (2) 2.5 (3) 4 (4) 5

Sol. Answer (3)

It both are moving together



$a = \dfrac{F}{8}$

for 3 kg block

$f = 3\left(\dfrac{F}{8}\right)$

$(0.5\ (3)\ g = \dfrac{3F}{8}$

$F = 40$ N

So, $m = 4$ kg

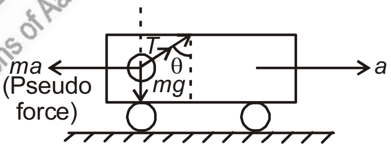
58. A small metallic sphere of mass *m* is suspended from the ceiling of a car accelerating on a horizontal road with constant acceleration *a*. The tension in the string attached with metallic sphere is

(1) mg (2) $m(g + a)$ (3) $m(g - a)$ (4) $m\sqrt{g^2 + a^2}$

Sol. Answer (4)

$T \cos\theta = mg$ …(i)

$T \sin\theta = ma$ …(ii)



Square and add (i) and (ii)

$T = m\sqrt{a^2 + g^2}$

59. A cyclist riding the bicycle at a speed of $14\sqrt{3}$ m/s takes a turn around a circular road of radius $20\sqrt{3}$ m without skidding. What is his inclination to the vertical?

(1) 30° (2) 45° (3) 60° (4) 75°

Sol. Answer (3)

$$\tan\theta = \frac{v^2}{rg}$$

$$= \frac{14\times14\times3}{20\sqrt{3}\times10} \simeq \sqrt{3}$$

$\theta = 60°$

60. A bus turns a slippery road having coefficient of friction of 0.5 with a speed of 10 m/s. The minimum radius of the arc in which bus turns is [Take g = 10 m/s^2]

(1) 4 m (2) 10 m (3) 15 m (4) 20 m

Sol. Answer (4)

$$\frac{v^2}{r} = \mu g$$

$$\frac{10\times10}{r} = 0.5 \times 10$$

$$r = 20 \text{ m}$$

61. A car is moving on a horizontal circular track of radius 0.2 km with a constant speed. If coefficient of friction between tyres of car and road is 0.45, then speed of car may be [Take g = 10 m/s^2]

(1) 15 m/s (2) 30 m/s (3) 20 m/s (4) 40 m/s

Sol. Answer (2)

$$\frac{v^2}{r} = \mu g$$

$$\frac{v^2}{0.2\times10^3} = 4.5$$

$$v = \sqrt{900} = 30 \text{ m/s}$$

62. A boy is sitting on the horizontal platform of a joy wheel at a distance of 5 m from the center. The wheel begins to rotate and when the angular speed exceeds 1 rad/s, the boy just slips. The coefficient of friction between the boy and the wheel is (g = 10 m/s^2)

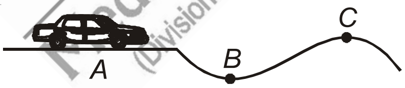
(1) 0.5 (2) 0.32 (3) 0.71 (4) 0.2

Sol. Answer (1)

$$\frac{v^2}{r} = \omega^2 r = \mu\, g$$

$$m = 0.5$$

63. A vehicle is moving on a track with constant speed as shown in figure. The apparent weight of the vehicle is



(1) Maximum at A (2) Maximum at B

(3) Maximum at C (4) Same at A, B and C

Sol. Answer (2)

at A $N = mg$

at B $N - mg = \frac{mv^2}{r}$

$$N = mg + \frac{mv^2}{r}$$

at C $mg - N = \frac{mv^2}{r}$

$$N = mg - \frac{mv^2}{r}$$

So, at B, N is maximum. Hence apparent weight of the vechicle is maximum at B

64. A train is running at 20 m/s on a railway line with radius of curvature 40,000 metres. The distance between the two rails is 1.5 metres. For safe running of train the elevation of outer rail over the inner rail is ($g = 10\ \text{m/s}^2$)

(1) 2.0 mm (2) 1.75 mm (3) 1.50 mm (4) 1.25 mm

Sol. Answer (3)

$$\tan\theta = \frac{h}{d} = \frac{v^2}{rg}$$

$$h = \frac{(1.5)(20)(20)}{40{,}000 \times 10}$$

$$= 1.5\ \text{mm}$$

65. A car is moving on a horizontal circular road of radius 0.1 km with constant speed. If coefficient of friction between tyres of car and road is 0.4, then speed of car may be ($g = 10\ \text{m/s}^2$)

(1) 5 m/s (2) 10 m/s (3) 20 m/s (4) All of these

Sol. Answer (4)

Maximum speed for the circular road

$$\frac{v^2_{\text{maximum}}}{r} = \mu g$$

$$V_{\text{maximum}} = \sqrt{\mu r g}$$

$$= \sqrt{0.4 \times 100 \times 10} = \sqrt{400} = 20\ \text{m/s}$$

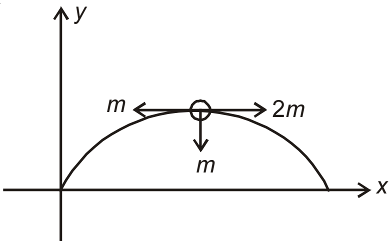
SECTION - B

Objective Type Questions

1. A projectile is fired with velocity u at an angle θ with horizontal. At the highest point of its trajectory it splits up into three segments of masses m, m and 2 m. First part falls vertically downward with zero initial velocity and second part returns via same path to the point of projection. The velocity of third part of mass 2 m just after explosion will be

(1) $u\cos\theta$ (2) $\frac{3}{2}u\cos\theta$ (3) $2u\cos\theta$ (4) $\frac{5}{2}u\cos\theta$

Sol. Answer (4)



along x-axis no internal force exists, hence momentum will be conserved along x-axis

$$P_i)_x = P_f)_x$$

$$(m + m + 2m)\cos\theta = -mu\cos\theta + 0 + 2mV$$

$\Rightarrow$ $2mv = 5\ mu\cos\theta$

$$v = \frac{5}{2}u\cos\theta$$

and along y direction $\left.P_i\right)_y = 0$ So $\left.P_f\right)_y = 0$

2. A bomb of mass 9 kg explodes into two pieces of masses 3 kg and 6 kg. The velocity of mass 3 kg is 16 m/s. The kinetic energy of mass 6 kg in joule is

   (1) 196 (2) 320 (3) 192 (4) 620

Sol. Answer (3)

Using momentum conservation

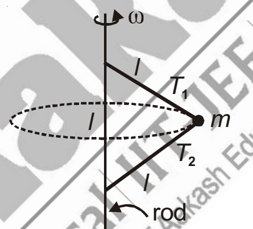
$$o = m_1v_1 + m_2v_2$$

$$V_2 = -\frac{3\times 16}{6}$$

$$= -8 \text{ m/s}$$

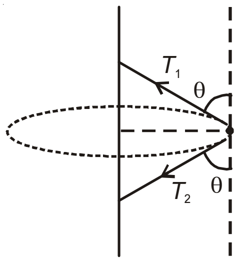
K.E. $= \frac{1}{2}mv^2 = \frac{1}{2}(6)(8)^2 = 192$ J

3. In the figure, a ball of mass m is tied with two strings of equal length as shown. If the rod is rotated with angular velocity ω, then



   (1) $T_1 > T_2$ (2) $T_2 > T_1$ (3) $T_1 = T_2$ (4) $T_1 = \frac{T_2}{6}$

Sol. Answer (1)



For vertical equilibrium

$$T_1\cos\theta = mg + T_2\cos\theta$$

$$T_1 = \frac{mg}{\cos\theta} + T_2$$

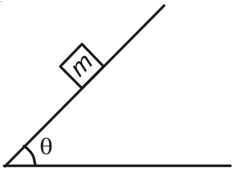
$\theta < 90°$ so $\cos\theta > 0$

$\Rightarrow$ $T_1 > T_2$

4. A block of weight 1 N rests on an inclined plane of inclination θ with the horizontal. The coefficient of friction between the block and the inclined plane is μ. Τηε minimum force that has to be applied parallel to the inclined plane to make the body just move up the plane is

   (1) $\mu\sin\theta$ (2) $\mu\cos\theta$ (3) $\mu\cos\theta - \sin\theta$ (4) $\mu\cos\theta + \sin\theta$

Sol. Answer (4)



Given $mg = 1$ N

To just move the body up

F = friction force + gravitation force

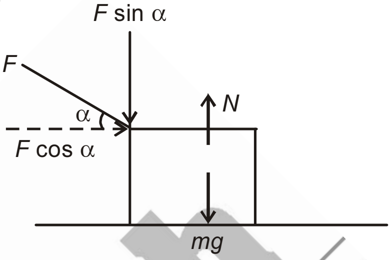
$= \mu\, mg \cos\theta + mg \sin\theta$

$= \mu \cos\theta + \sin\theta$

5. If a pushing force making an angle α with horizontal is applied on a block of mass m placed on horizontal table and angle of friction is β, then minimum magnitude of force required to move the block is

(1) $\dfrac{mg\sin\beta}{\cos[\alpha-\beta]}$ (2) $\dfrac{mg\sin\beta}{\cos[\alpha+\beta]}$ (3) $\dfrac{mg\sin\beta}{\sin[\alpha+\beta]}$ (4) $\dfrac{mg\cos\beta}{\cos[\alpha-\beta]}$

Sol. Answer (2)



Angle of friction is β

$\Rightarrow \mu = \tan\beta$

$N = mg + F\sin\alpha$

To just move the block

$F\cos\alpha = \mu N$

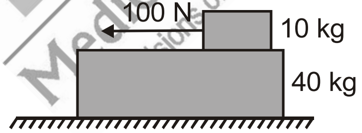
$F\cos\alpha = \tan\beta\,(mg + F\sin\alpha)$

$F(\cos\alpha - \tan\beta\sin\alpha) = mg\tan\beta$

$F(\cos\alpha\cos\beta - \sin\alpha\sin\beta) = mg\sin\beta$

$F = \dfrac{mg\sin\beta}{\cos(\alpha+\beta)}$

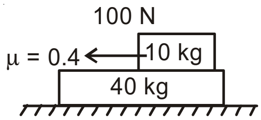
6. A 40 kg slab rests on a frictionless floor. A 10 kg block rests on top of the slab. The coefficient of friction between the block and the slab is 0.40. The 10 kg block is acted upon by a horizontal force of 100 N. If $g = 10$ m/s^2, the resulting acceleration of the slab will be



(1) 1.0 m/s^2 (2) 1.47 m/s^2 (3) 1.52 m/s^2 (4) 6.1 m/s^2

Sol. Answer (1)

Maximum external force when blocks move together $= \dfrac{f_{max}}{40}(40+10) = 50\text{ N}$



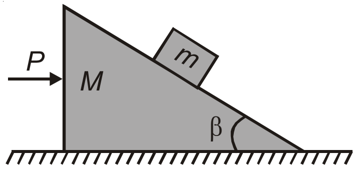
Now since external force is 100 N (which is > 50 N)

$\Rightarrow$ blocks will not move together. Hence net force acting on 40 kg will be only friction force

So using $F_{net} = ma$

$40 = (40\,a) \Rightarrow a = 1$ m/s^2

7. A block of mass *m*, is kept on a wedge of mass *M*, as shown in figure such that mass *m* remains stationary w.r.t. wedge. The magnitude of force *P* is



(1) $g \tan \beta$ (2) $mg \tan \beta$ (3) $(m + M)g \tan \beta$ (4) $mg \cot \beta$

Sol. Answer (3)

If acceleration of the system is a then $P = (M + m)\, a$

from the reference frame of wedge

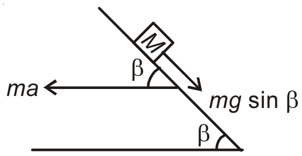
Component of ma along the inclined will be $ma \cos \beta$

for the block to be in equilibrium w.r.t. wedge

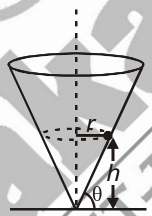
$$ma \cos \beta = mg \sin \beta$$

$$a = g \tan \beta$$

hence $P = (M + m)\, g \tan \beta$

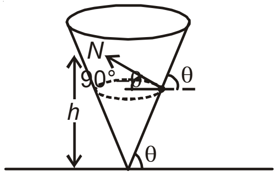


8. A particle describes a horizontal circle of radius *r* on the smooth surface of an inverted cone as shown. The height of plane of circle above vertex is *h*. The speed of particle should be



(1) $\sqrt{rg}$ (2) $\sqrt{2rg}$ (3) $\sqrt{gh}$ (4) $\sqrt{2gh}$

Sol. Answer (3)



$$N \cos (90° - \theta) = \frac{mv^2}{r}$$

$$N \sin (90° - \theta) = mg$$

$$N = \frac{mg}{\cos\theta} \quad \text{...(i)}$$

and $$N \sin \theta = \frac{mv^2}{r} \quad \text{...(ii)}$$

dividing (ii) and (i)

$$mg \tan \theta = \frac{mv^2}{r}$$

$$g\left(\frac{h}{r}\right) = \frac{v^2}{r} \Rightarrow v = \sqrt{gh}$$

9. If the string of a conical pendulum makes an angle θ with horizontal, then square of its time period is proportional to

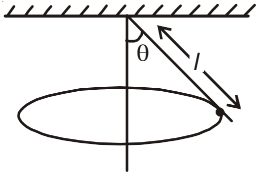
(1) $\sin\theta$ (2) $\cos\theta$ (3) $\tan\theta$ (4) $\cot\theta$

Sol. Answer (1)

For conical pendulum we know that

$$T = 2\pi\sqrt{\frac{l\cos\theta}{g}}$$

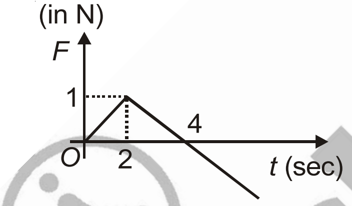
where θ is the angle from vertical but in question θ is given from horizontal



hence $T = 2\pi\sqrt{\frac{l\sin\theta}{g}}$

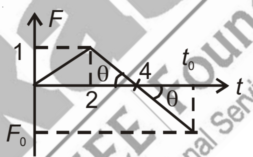
$$T^2 \propto \sin\theta$$

10. Force acting on a body varies with time as shown below. If initial momentum of the body is $\vec{p}$, then the time taken by the body to retain its momentum $\vec{p}$ again is



(1) 8 s (2) $(4+2\sqrt{2})$ s (3) 6 s (4) Can never obtain

Sol. Answer (2)



$$\tan\theta = \frac{1}{2} = \frac{F_0}{t_0 - 4}$$

$$\Rightarrow \quad F_0 = \frac{t_0 - 4}{2}$$

Total change in momentum should be zero, then only it will retain its initial momentum.

So, positive area of $F - t$ curve should be equal to negative area of $F - t$ curve till time t_0.

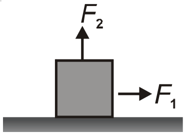
$$\frac{1}{2}(4)(1) = \frac{1}{2}(t_0 - 4)F_0$$

$$8 = \frac{(t_0-4)}{2}\cdot\frac{(t_0-4)}{2}$$

$$(t_0 - 4)^2 = 32$$

$$t_0 = 4 + 2\sqrt{2}$$

11. In the figure shown, horizontal force F_1 is applied on a block but the block does not slide. Then as the magnitude of vertical force F_2 is increased from zero the block begins to slide; the correct statement is



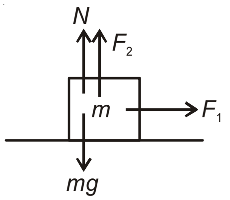
(1) The magnitude of normal reaction on block increases

(2) Static frictional force acting on the block increases

(3) Maximum value of static frictional force decreases

(4) All of these

Sol. Answer (3)



$N + F_2 = mg$

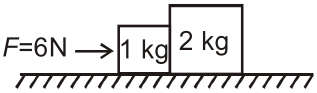
$N = mg - F_2$

As F_2 increases N will decrease

Static friction $f_s = \mu_s N = \mu_s (mg - F_2)$

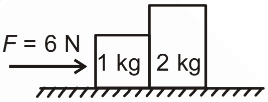
$\Rightarrow$ By increasing F_2, f_s will decrease hence the block will slide

12. Arrangement of two block system is as shown. The net force acting on 1 kg and 2 kg blocks are (assuming the surfaces to be frictionless) respectively



(1) 4 N, 8 N (2) 1 N, 2 N (3) 2 N, 4 N (4) 3 N, 6 N

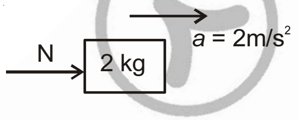
Sol. Answer (3)



acceleration of the system $= \dfrac{F_{\text{ext}}}{M_{\text{Total}}}$

$= \dfrac{6}{3} = 2 \text{ m/s}^2$

for 2 kg block



$N = 2(2) = 4\text{N}$

for 1 kg block

$F_{\text{net}} = 6 - 4 = 2 \text{ N}$

13. A 6000 kg rocket is set for firing. If the exhaust speed is 1000 m/s, how much gas must be ejected each second to supply the thrust needed to overcome the weight of the rocket?

(1) 30 kg (2) 40 kg (3) 50 kg (4) 60 kg

Sol. Answer (4)

$F = v\dfrac{dm}{dt} = \text{mg}$

$1000\left(\dfrac{dm}{dt}\right) = 60000$

$\dfrac{dm}{dt} = 60 \text{ kg}$

14. Which of the following is self adjusting force?

(1) Sliding friction (2) Dynamic friction (3) Static friction (4) Limiting friction

Sol. Answer (3)

Static friction

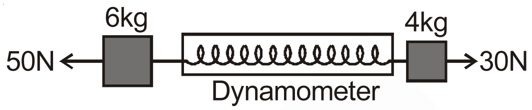
15. An open carriage in a goods train is moving with a uniform velocity of 10 m/s. If the rain adds water with zero velocity at the rate of 5 kg/s, then the additional force required by the engine to maintain the same velocity of the train is

(1) 0.5 N (2) 20 N (3) 50 N (4) Zero

Sol. Answer (3)

$$F_{(\text{additional})} = \frac{vdm}{dt} = (10) \times 5 = 50 \text{ N}$$

16. A dynamometer *D* is attached to two blocks of masses 6 kg and 4 kg as shown in the figure. The reading of the dynamometer is



(1) 18 N (2) 28 N (3) 38 N (4) 48 N

Sol. Answer (3)

The tension in the spring will be the reading of dynamometer

$$\left.F\right)_{\text{ext}} = Ma$$

$$50–30 = 10(a)$$

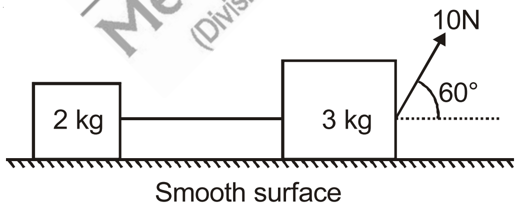
$$a = 2 \text{ m/s}^2$$

for 6 kg block

$$50 - T = 6\ (2)$$

$$T = 38 \text{ N}$$

17. Figure shows two blocks connected by a light inextensible string as shown in figure. A force of 10 N is applied on the bigger block at 60° with horizontal, then the tension in the string connecting the two masses is



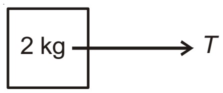
(1) 5 N (2) 2 N (3) 1 N (4) 3 N

Sol. Answer (2)

$$F_{\text{net}} = Ma$$

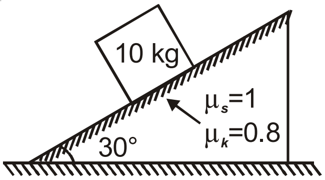
$$(10 \cos 60°) = (3 + 2)\ a$$

$$a = 1 \text{ m/s}^2$$



$$T = 2(1) = 2 \text{ N}$$

18. A block of 10 kg mass is placed on a rough inclined surface as shown in figure. The acceleration of the block will be



(1) Zero (2) g (3) $\frac{g}{2}$ (4) $\frac{\sqrt{3}g}{2}$

Sol. Answer (1)

$$F_L = \mu_s\, mg \cos\theta$$

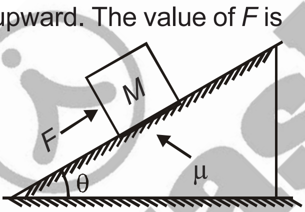
$$= (1)\,(100)\,\frac{\sqrt{3}}{2} = 50\sqrt{3}$$

Gravitational force = $mg \sin\theta = 50$ N

$f_L > mg \sin\theta$

⇒ block will not move

19. A block (mass = M kg) is placed on a rough inclined plane. A force F is applied parallel to the inclined (as shown in figure) such that it just starts moving upward. The value of F is



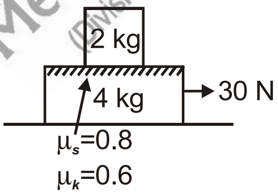
(1) $Mg\sin\theta - \mu Mg\cos\theta$ (2) $Mg\sin\theta + \mu Mg\cos\theta$ (3) $Mg\sin\theta$ (4) $\mu Mg\cos\theta$

Sol. Answer (2)

F will oppose friction force and gravitation force

$F = mg\sin\theta + \mu\, mg\cos\theta$

20. Figure shows two block system, 4 kg block rests on a smooth horizontal surface, upper surface of 4 kg is rough. A block of mass 2 kg is placed on its upper surface. The acceleration of upper block with respect to earth when 4 kg mass is pulled by a force of 30 N, is



(1) 6 m/s^2 (2) 5 m/s^2 (3) 8 m/s^2 (4) 2 m/s^2

Sol. Answer (2)

It both move together

$$a = \frac{30}{(4+2)} = 5 \text{ m/s}^2$$

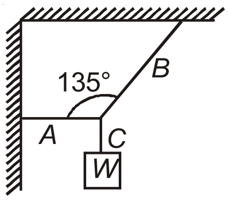
2 kg will move due to frictional force

$F = ma \Rightarrow f = 2(5) = 10$ N

and limiting friction $f_L = (0.8)\,(2g) = 16$ N

⇒ Friction is sufficient to move both block together hence $a = 5$ m/s^2

21. A block of weight W is supported by three strings as shown in figure. Which of the following relations is true for tension in the strings? (Here T_1, T_2 and T_3 are the tension in the strings A, B and C respectively)



(1) $T_1 = T_2$ (2) $T_1 = T_3$ (3) $T_2 = T_3$ (4) $T_1 = T_2 = T_3$

Sol. Answer (2)

Tension will be same in A & C hence $T_1 = T_3$

22. A car accelerates on a horizontal road due to force exerted by

(1) The engine of the car (2) The driver of the car

(3) The earth as weight of the car (4) The road

Sol. Answer (4)

Due to frictional force by the road.

23. Which of the following quantity/quantities are dependent on the choice of orientation of the co-ordinate axes?

(a) $\vec{a}+\vec{b}$

(b) $3a_x + 2b_y$

(c) $(\vec{a}+\vec{b}-\vec{c})$

(1) Only (b) (2) Both (a) & (b) (3) Both (a) & (c) (4) Both (b) & (c)

Sol. Answer (1)

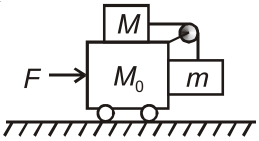
24. The acceleration vector of a particle in uniform circular motion averaged over the cycle is a null vector. This statement is

(1) True (2) False (3) May be true (4) May be false

Sol. Answer (1)

Acceleration will be towards centre at every instant.

25. Two blocks of mass M and m are kept on the trolley whose all surfaces are smooth select the correct statement



(1) If $F = 0$ blocks cannot remain stationary

(2) For one unique value of F, blocks will be stationary

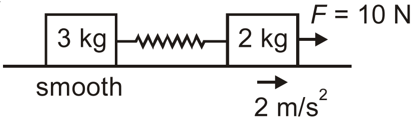
(3) Blocks cannot be stationary for any value of F because all surfaces are smooth

(4) Both (1) & (2)

Sol. Answer (4)

As all the surfaces are smooth, block can be at rest only due to Pseduo force

26. What is the acceleration of 3 kg mass when acceleration of 2 kg mass is 2 m/s^2 as shown?



(1) 3 m/s^2 (2) 2 m/s^2 (3) 0.5 m/s^2 (4) Zero

Sol. Answer (2)

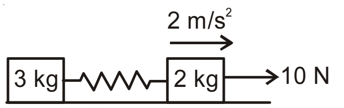
for 2 kg $10 - T = 2(2)$

$T = 10 - 4 = 6$ N

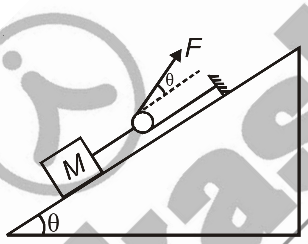
for 3 kg $T = 3(a)$

$6 = 3a$

$a = 2$ m/s^2



27. What is the minimum value of F needed so that block begins to move upward on frictionless incline plane as shown



(1) $Mg\tan\left(\frac{\theta}{2}\right)$ (2) $Mg\cot\left(\frac{\theta}{2}\right)$ (3) $\frac{Mg\sin\theta}{(1+\sin\theta)}$ (4) $Mg\sin\left(\frac{\theta}{2}\right)$

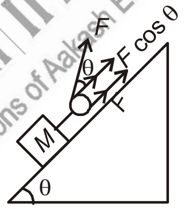
Sol. Answer (1)

$F + F\cos\theta = mg\sin\theta$

$$F = \frac{mg\sin\theta}{1+\cos\theta}$$

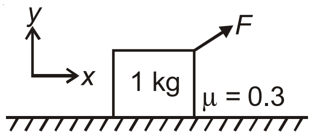
$$F = \frac{mg\ 2\sin\frac{\theta}{2}\cos\frac{\theta}{2}}{2\cos^2\frac{\theta}{2}}$$

$$= mg\tan\frac{\theta}{2}$$



$\left(\because \sin\theta = 2\sin\frac{\theta}{2}.\cos\frac{\theta}{2} \text{ and } 1+\cos\theta = 2\cos^2\frac{\theta}{2}\right)$

28. A force $\vec{F} = \hat{i} + 4\hat{j}$ acts on the block shown. The force of friction acting on the block is



(1) $-\hat{i}$ (2) $-18\hat{i}$ (3) $-2.4\hat{i}$ (4) $-3\hat{i}$

Sol. Answer (1)

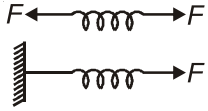
Limiting friction $F_L = (0.3)(1)(g)$

$= 3$ N

x-component or horizontal component of force is = 1 N

hence this much of magnitude will act in backward direction due to friction.

29. Figure shows two cases. In first case a spring (spring constant K) is pulled by two equal and opposite forces F at both ends and in second case is pulled by a force F at one end. Extensions (x) in the springs will be



(1) In both cases $x = \frac{2F}{K}$

(2) In both cases $x = \frac{F}{K}$

(3) In first case $x = \frac{2F}{K}$, in second case $x = \frac{F}{K}$

(4) In first case $x = \frac{F}{K}$, in second case $x = \frac{2F}{K}$

Sol. Answer (2)

Figure (2) is F.B.D. of figure (1)

at equilibrium $F = Kx$

$x = F/K$

30. A monkey of mass 40 kg climbs up a rope, of breaking load 600 N hanging from a ceiling. If it climbs up the rope with the maximum possible acceleration, then the time taken by monkey to climb up is [Length of rope is 10 m]

(1) 2 s (2) 1 s (3) 4 s (4) 3 s

Sol. Answer (1)

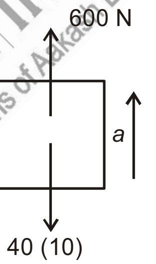
$600 - 400 = 40a$

$a = \frac{200}{40} = 5$ m/s^2

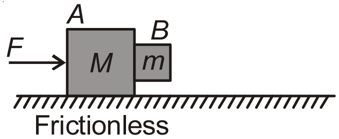
$S = ut + \frac{1}{2}at^2$

$10 = \frac{1}{2}(5)t^2$

$\Rightarrow$ $t = 2$ second



31. Coefficient of friction between A and B is μ. The minimum force F with which A will be pushed such that B will not slip down is



(1) $\frac{Mg}{\mu}$ (2) $\frac{mg}{\mu}$ (3) $\frac{(M+m)g}{\mu}$ (4) $\frac{(M-m)g}{\mu}$

Sol. Answer (3)

From the reference frame of *A*

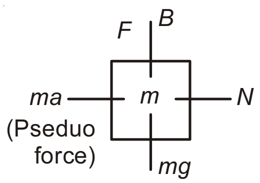
$$\mu N = mg$$

$$N = ma$$

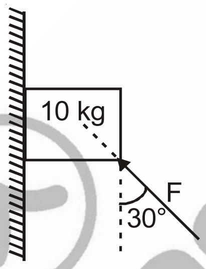
$$N = m\left(\frac{F}{M+m}\right)$$

$$\mu m\left(\frac{F}{M+m}\right) = mg$$

$$F = \left(\frac{M+m}{\mu}\right) g$$



32. A block of mass 10 kg is held at rest against a rough vertical wall [$\mu = 0.5$] under the action a force *F* as shown in figure. The minimum value of *F* required for it is ($g = 10$ m/s^2)



(1) 162.6 N (2) 89.7 N (3) 42.7 N (4) 95.2 N

Sol. Answer (2)

$$N = F\sin 30^\circ = F/2$$

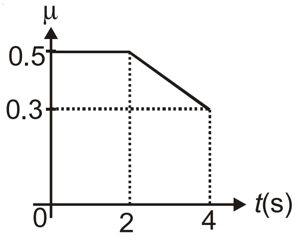
$$F\cos 30^\circ + \mu N = (10)g$$

$$\frac{F\sqrt{3}}{2} + 0.5\left(\frac{F}{2}\right) = 100$$

$$F\left(\frac{2\sqrt{3}+1}{4}\right) = 100$$

$$F \simeq 89.7 \text{ N}$$

33. A block is projected with speed 20 m/s on a rough horizontal surface. The coefficient of friction (μ) between the surfaces varies with time (t) as shown in figure. The speed of body at the end of 4 second will be (g = 10 m/s^2)



(1) 2 m/s (2) 5 m/s (3) 7.2 m/s (4) 9.5 m/s

Sol. Answer (1)

Retardation

$$\frac{dv}{dt} = -\mu g$$

$$\int dv = -\int \mu g\, dt$$

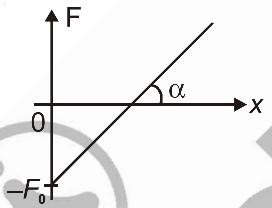
$$\Delta v = -g \int \mu\, dt$$

$\int \mu\, dt$ is area under $\mu - t$ curve

$$v - 20 = -10\left(2\frac{1}{2} + \frac{1}{2}(2)(0.2) + (2)(0.3)\right)$$

$$v = 20 - 18 = 2 \text{ m/s}$$

34. An object starts from rest and is acted upon by a variable force F as shown in figure. If F_0 is the initial value of the force, then the position of the object, where it again comes to rest will be



(1) $\frac{2F_0}{\tan\alpha}$ (2) $\frac{F_0}{\sin\alpha}$ (3) $\frac{2F_0}{\cot\alpha}$ (4) $\frac{F_0}{2\cos\alpha}$

Sol. Answer (1)

F-x curve is straight line. Equation of F in terms of x can be written as

$$F = x\tan\alpha - F_0$$

$$a = \frac{vdv}{dx} = \frac{F}{m} = \frac{x\tan\alpha}{m} - \frac{F_0}{m}$$

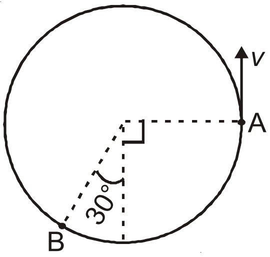
Integrating both sides

$$\frac{v^2 - x^2}{2} = \frac{x^2\tan\alpha}{2m} - \frac{F_0 x}{m} = 0$$

$$\frac{x\tan\alpha}{2} = F_0$$

$$x = \frac{2F_0}{\tan\alpha}$$

35. A particle of mass m moves with constant speed v on a circular path of radius r as shown in figure. The average force on it during its motion from A to B is



(1) $\frac{\sqrt{3}mv^2}{2\pi r}$ (2) $\frac{mv^2}{r}$ (3) $\frac{2\sqrt{3}mv^2}{\pi r}$ (4) $\frac{3\sqrt{3}mv^2}{4\pi r}$

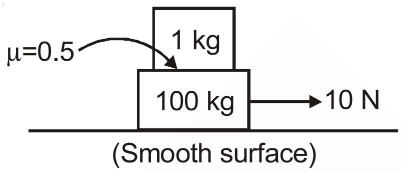
Sol. Answer (4)

$$F = ma = \frac{m\Delta v}{\Delta t} = \left[\frac{2v^2 \sin\theta/2}{r\theta}\right]$$

$$= m\left[\frac{2v^2 \sin(2\pi - 2\pi/3)}{r.\left(\frac{4\pi}{3}\right)}\right]$$

$$= \frac{3\sqrt{3}\, mv^2}{4\pi r}$$

36. The frictional force acting on 1 kg block is



(1) 0.1 N (2) 2 N (3) 0.5 N (4) 5 N

Sol. Answer (1)

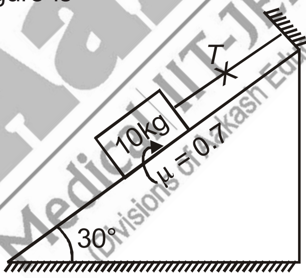
If both move together $a = \frac{10}{101} \simeq 0.1\ \text{m/s}^2$

Now, $F_{\text{net}} = 1\ (0.1) = 0.1\text{N}$

$f_L = (0.5)\ (1)\ (g) = 5\ \text{N}$

So, $f = 0.1\text{N}$

37. The tension T in the string shown in figure is



(1) Zero (2) 50 N (3) $35\sqrt{3}$ N (4) $(\sqrt{3}-1)\ 50$ N

Sol. Answer (1)

$mg \sin\theta = 10\ (10) \sin 30° = 50$ N

Frictional force = $\mu\, mg \cos\theta = (0.7)\ (10)\ (10)\ \frac{\sqrt{3}}{2} = 35\sqrt{3}\,\text{N}$

Frictional force is sufficient to oppose gravitational force. Tension will be zero.

38. An object of mass 2 kg at rest at origin starts moving under the action of a force

$$\vec{F} = (3t^2\hat{i} + 4t\hat{j})\ \text{N}$$

The velocity of the object at $t = 2$ s will be

(1) $(3\hat{i} + 2\hat{j})\text{m/s}$ (2) $(2\hat{i} + 4\hat{j})\text{m/s}$ (3) $(4\hat{i} + 4\hat{j})\text{m/s}$ (4) $(3\hat{i} - 4\hat{j})\text{m/s}$

Sol. Answer (3)

$$\vec{F} = 3t^2\hat{i} + 4t\hat{j}$$

$$P_2 - P_1 = \frac{3t^3}{3}\hat{i} + \frac{4t^2}{2}\hat{j}$$

$$P_1 = 0$$

$$(2)v = (2)^3\hat{i} + 2(2)^2\hat{j}$$

$$v = 4\hat{i} + 4\hat{j}$$

39. A block of mass m is at rest on a rough inclined plane of angle of inclination θ. If coefficient of friction between the block and the inclined plane is μ, then the minimum value of force along the plane required to move the block on the plane is

(1) $mg[\mu\cos\theta - \sin\theta]$ (2) $mg[\sin\theta + \mu\cos\theta]$ (3) $mg[\mu\cos\theta + \sin\theta]$ (4) $mg[\sin\theta - \mu\cos\theta]$

Sol. Answer (4)

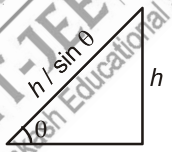
$$F_{\min} = mg[\sin\theta - \mu\cos\theta]$$

40. A block of mass m takes time t to slide down on a smooth inclined plane of angle of inclination θ and height h. If same block slide down on a rough inclined plane of same angle of inclination and some height and takes time n times of initial value, then coefficient friction between block and inclined plane is

(1) $[1 + n^2]\tan\theta$ (2) $\left[1 - \frac{1}{n^2}\right]\tan\theta$ (3) $[1 - n^2]\tan\theta$ (4) $\left[1 + \frac{1}{n^2}\right]\tan\theta$

Sol. Answer (2)

$$t_1 = \sqrt{\frac{2}{g}\left(\frac{h}{\sin^2\theta}\right)} = \frac{1}{\sin\theta}\sqrt{\frac{2h}{g}}$$



$$t_2 = \sqrt{\frac{2h}{g\sin\theta(\sin\theta - \mu\cos\theta}}$$

According to problem

$$\frac{n}{\sin\theta}\sqrt{\frac{2h}{g}} = \sqrt{\frac{2h}{g\sin\theta(\sin\theta - \mu\cos\theta)}}$$

$$\frac{n^2}{\sin^2\theta} = \frac{1}{\sin^2\theta - \mu\sin\theta\cos\theta}$$

$$n^2\sin^2\theta - n^2\mu\sin\theta\cos\theta = \sin^2\theta$$

$$n^2\left[1 - \frac{\mu}{\tan\theta}\right] = 1$$

$$\mu = \left[1 - \frac{1}{n^2}\right]\tan\theta$$

41. A person stands in contact against the inner wall of a rotor of radius r. The coefficient of friction between the wall and the clothing is μ and the rotor is rotating about vertical axis. The minimum speed of the rotor so that the person does not slip downward is

(1) $\sqrt{\frac{\mu g}{r}}$ (2) $\sqrt{\frac{\mu r}{g}}$ (3) $\sqrt{\frac{g}{\mu r}}$ (4) $\sqrt{\mu r g}$

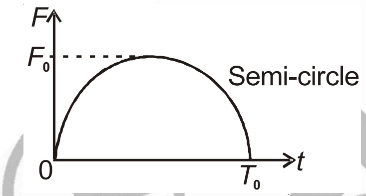
Sol. Answer (3)

$$N = \frac{mv^2}{r}$$

$$f_L = \mu N = \mu\left[\frac{mv^2}{r}\right] = mg$$

$$v = \sqrt{\frac{gr}{\mu}}$$

42. The magnitude of force acting on a particle moving along x-axis varies with time (t) as shown in figure. If at t = 0 the velocity of particle is v_0, then its velocity at t = T_0 will be



(1) $v_0 + \frac{\pi F_0 T_0}{4m}$ (2) $v_0 + \frac{\pi F_0}{2m}$ (3) $v_0 + \frac{\pi T_0^2}{4m}$ (4) $v_0 + \frac{\pi F_0 T_0}{m}$

Sol. Answer (1)

$$\int F dt = m\Delta v$$

$\int F dt$ is area under F–t curve

$$m\Delta v = \pi\left(\frac{F_0}{2}\right).\left(\frac{T_0}{2}\right) \quad [\text{area} = \frac{\pi ab}{2}]$$

$$v - v_0 = \frac{\pi F_0 T_0}{4m}$$

$$v = v_0 + \frac{\pi F_0 T_0}{4m}$$

43. Three forces $\vec{F}_1 = (2\hat{i} + 4\hat{j})$ N ; $\vec{F}_2 = (2\hat{j} - \hat{k})$ N and $\vec{F}_3 = (\hat{k} - 4\hat{i} - 2\hat{j})$ N are applied on an object of mass 1 kg at rest at origin. The position of the object at t = 2s will be

(1) (–2 m, –6 m) (2) (–4 m, 8 m) (3) (3 m, 6 m) (4) (2 m, –3 m)

Sol. Answer (2)

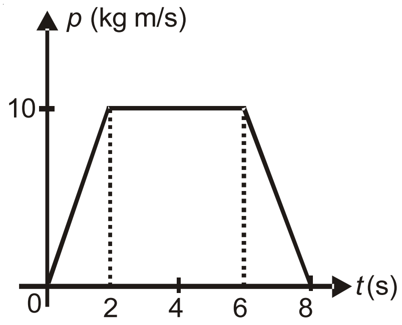
$$\vec{a} = \frac{\vec{F}_1 + \vec{F}_2 + \vec{F}_3}{1} = -2\hat{i} + 4\hat{j}$$

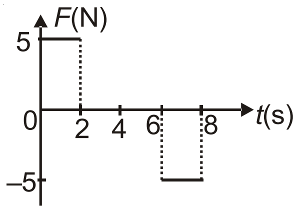
$$S = \frac{1}{2} at^2$$

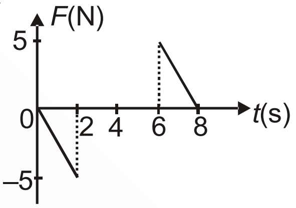
$$= \frac{1}{2}(-2\hat{i} + 4\hat{j})(2)^2$$

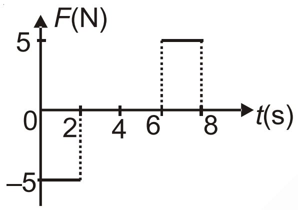
$$= -4\hat{i} + 8\hat{j}$$

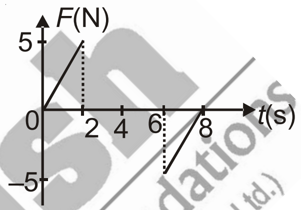
44. The momentum p of an object varies with time (t) as shown in figure. The corresponding force (F)-time (t) graph is



(1)


(2)


(3)


(4)


Sol. Answer (1)

$F = \dfrac{dp}{dt}$ = slope of P–t curve

From $t = 0$ to $t = 2$ second slope is constant and positive

From $t = 2$ to $t = 6$ second slope is zero

From $t = 6$ to $t = 8$ second slope is constant and negative

SECTION - C

Previous Years Questions

1. A car of mass 1000 kg negotiates a banked curve of radius 90 m on a fictionless road. If the banking angle is 45º, the speed of the car is

(1) 5 ms^{-1} (2) 10 ms^{-1} (3) 20 ms^{-1} (4) 30 ms^{-1}

Sol. Answer (4)

$\tan\theta = \dfrac{v^2}{rg}$

$\tan 45° = \dfrac{v^2}{90(10)}$

$v = 30$ m/s

2. A stone is dropped from a height h. It hits the ground with a certain momentum P. If the same stone is dropped from a height 100% more than the previous height, the momentum when it hits the ground will change by

(1) 68% (2) 41% (3) 200% (4) 100%

Sol. Answer (2)

$$\frac{h'-h}{h}\times 100 = 100 \Rightarrow h' = 2h$$

$$mv_1 = m\sqrt{2gh}$$

$$mv_2 = m\sqrt{2g(2h)} = \sqrt{2}\,mv_1$$

$$\text{change\%} = \frac{\sqrt{2}\,mv_1 - mv_1}{mv_1}\times 100$$

$$= 41\%$$

3. A car of mass m is moving on a level circular track of radius R. If μ_s represents the static friction between the road and tyres of the car, the maximum speed of the car in circular motion is given by

(1) $\sqrt{\mu_s mRg}$ (2) $\sqrt{\frac{Rg}{\mu_s}}$ (3) $\sqrt{mRg/\mu_s}$ (4) $\sqrt{\mu_s Rg}$

Sol. Answer (4)

$$\tan\theta = \mu_s = \frac{v^2}{rg}$$

$$\Rightarrow\ v_{\text{max.}} = \sqrt{\mu_s rg}$$

4. A person of mass 60 kg is inside a lift of mass 940 kg and presses the button one control panel. The lift starts moving upwards with an acceleration 1.0 m/s^2. If g = 10 ms^{-2}, the tension in the supporting cable is

(1) 1200 N (2) 8600 N (3) 9680 N (4) 11000 N

Sol. Answer (4)

$$T = mg + ma$$

$$= m(g + a)$$

$$= 1000\,(10 + 1) = 11000\text{ N}$$

5. A body of mass M hits normally a rigid wall with velocity V and bounces back with the same velocity. The impulse experienced by the body is

(1) Zero (2) MV (3) 1.5 MV (4) 2 MV

Sol. Answer (4)

Impulse = change in momentum

$$= MV - (-MV) = 2MV$$

6. A conveyor belt is moving at a constant speed of 2 m/s. A box is gently dropped on it. The coefficient of friction between them is μ = 0.5. The distance that the box will move relative to belt before coming to rest on it, taking g = 10 ms^{-2}, is

(1) Zero (2) 0.4 m (3) 1.2 m (4) 0.6 m

Sol. Answer (2)

$v^2 - u^2 = 2as$

$(2)^2 - 0 = 2\,(0.5 \times 10)s$

$$s = \frac{4}{10} = 0.4 \text{ m}$$

7. A mass m moving horizontally (along the x-axis) with velocity v collides and sticks to a mass of $3m$ moving vertically upward (along the y-axis) with velocity $2v$. The final velocity of the combination is

(1) $\frac{2}{3}v\hat{i} + \frac{1}{3}v\hat{j}$ (2) $\frac{3}{2}v\hat{i} + \frac{1}{4}v\hat{j}$ (3) $\frac{1}{4}v\hat{i} + \frac{3}{2}v\hat{j}$ (4) $\frac{1}{3}v\hat{i} + \frac{2}{3}v\hat{j}$

Sol. Answer (3)

Using momentum conservation

$$mv\hat{i} + 3m(2v)\hat{j} = 4m\vec{v}$$

$$\vec{v} = \frac{1}{4}v\hat{i} + \frac{3}{2}v\hat{j}$$

8. An object is moving on a plane surface uniform velocity 10 ms^{-1} in presence of a force 10 N. The frictional force between the object and the surface is

(1) 1 N (2) –10 N (3) 10 N (4) 100 N

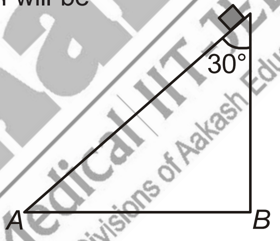
Sol. Answer (2)

$F_{\text{net}} = 0$ to move with constant velocity

$F + F = 0$

$F = -10$ N

9. A body of mass M starts sliding down on the inclined plane where the critical angle is $\angle ACB = 30°$ as shown in figure. The coefficient of kinetic friction will be



(1) $\frac{Mg}{\sqrt{3}}$ (2) $\sqrt{3}Mg$ (3) $\sqrt{3}$ (4) None of these

Sol. Answer (3)

$mg \sin\theta = \mu mg \cos\theta$

where $\theta = 90 - 30° = 60°$

$\tan\theta = \mu$

$\mu = \sqrt{3}$

10. In non-inertial frame, the second law of motion is written as

(1) $F = ma$ (2) $F = ma + F_p$ (3) $F = ma - F_p$ (4) $F = 2ma$

where F_p is a pseudo-force while a is the acceleration of the body relative to non-inertial frame.

Sol. Answer (3)

$F = ma - F_p$

where F_p is pseudo force

11. A person holding a rifle (mass of person and rifle together is 100 kg) stands on a smooth surface and fires 10 shots horizontally, in 5 s. Each bullet has a mass of 10 g with a muzzle velocity of 800 ms^{-1}. The final velocity acquired by the person and the average force exerted on the person are

(1) –1.6 ms^{-1}; 8 N (2) –0.08 ms^{-1}; 16 N (3) –0.8 ms^{-1}; 8 N (4) –1.6 ms^{-1}; 16 N

Sol. Answer (2)

Bullet shots per second = $\frac{10}{5} = 2$

Using momentum conservation

$$0 = 10 \times \frac{10}{1000}(800) + 100\,V$$

$$V = -\,0.8 \text{ m/s}$$

$$F = n\,mV$$

$$= 2 \times \frac{(10)}{1000} \times 800 = 16 \text{ N}$$

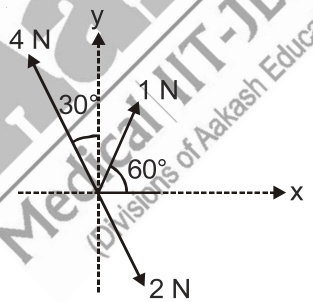
12. Sand is being dropped on a conveyor belt at the rate of *M* kg/s. The force necessary to keep the belt moving with a constant velocity of *V* m/s will be

(1) Zero (2) *MV* newton (3) 2 *MV* newton (4) $\frac{MV}{2}$ newton

Sol. Answer (2)

$$F = \frac{VdM}{dt} = VM$$

13. Three forces acting on a body are shown in the figure. To have the resultant force only along the y-direction, the magnitude of the minimum additional force needed is



(1) $\sqrt{3}$ N (2) 0.5 N (3) 1.5 N (4) $\frac{\sqrt{3}}{4}$N

Sol. Answer (2)

To have the resultant force only along the *y*-direction

⇒ Component of forces along *x*-axis should be zero

$4 \sin 30° - 1 \cos 60° - 2 \cos 60° = x$

$x = 0.5$ N

14 In a rocket, fuel burns at the rate of 1 kg/s. This fuel is ejected from the rocket with a velocity of 60 km/s. This exerts a force on the rocket equal to

(1) 6000 N (2) 60000 N (3) 60 N (4) 600 N

Sol. Answer (2)

$$F = \frac{vdm}{dt}$$

$$= 60 \times 10^3 \times (1)$$

$$= 60000 \text{ N}$$

15. A satellite in force-free space sweeps stationary interplanetary dust at a rate of $dM/dt = \alpha v$, where M is mass and v is the speed of satellite and α is a constant. The tangential acceleration of satellite is

(1) $\frac{-\alpha v^2}{2M}$ (2) $-\alpha v^2$ (3) $\frac{-2\alpha v^2}{M}$ (4) $\frac{-\alpha v^2}{M}$

Sol. Answer (4)

$$a = \frac{F}{M} = \frac{-\alpha\, v.v}{M} = \frac{-\alpha\, v^2}{M}$$

16. A man fires a bullet of mass 200 gm at a speed of 5 m/s. The gun is of one kg mass. By what velocity the gun rebounds backward?

(1) 1 m/s (2) 0.01 m/s (3) 0.1 m/s (4) 10 m/s

Sol. Answer (1)

Using momentum conservation

$$v = \frac{(0.2)5}{1} = 1 \text{ m/s}$$

17. A force vector applied on a body is represented as $\vec{F} = 6\hat{i} - 8\hat{j} + 10\hat{k}$ and it accelerates the body with 1 m/s^2. What will be the mass of the body?

(1) 10 kg (2) 20 kg (3) $10\sqrt{2}$ kg (4) $2\sqrt{10}$ kg

Sol. Answer (3)

$$\vec{F} = 6\hat{i} - 8\hat{j} + 10\hat{k}$$

$$a = \left|\frac{F}{m}\right| = 1 \text{ m/s}^2$$

$$m = \sqrt{6^2 + 8^2 + 10^2} = 10\sqrt{2} \text{ kg}$$

18. A 10 N force is applied on a body produces in it an acceleration of 1 m/s^2. The mass of the body is

(1) 15 kg (2) 20 kg (3) 10 kg (4) 5 kg

Sol. Answer (3)

$$m = \frac{F}{a} = \frac{10}{1} = 10 \text{ kg}$$

19. A force of 6 N acts on a body at rest and of mass 1 kg. During this time, the body attains a velocity of 30 m/s. The time for which the force acts on the body is

(1) 7 second (2) 5 second (3) 10 second (4) 8 second

Sol. Answer (2)

$$a = \frac{6}{1} = 6 \text{ m/s}^2$$

$$v = at$$

$$\Rightarrow \; t = \frac{v}{a} = \frac{30}{6} = 5 \text{ s}$$

20. A shell, in flight, explodes into four unequal parts. Which of the following is conserved?

(1) Potential energy (2) Momentum (3) Kinetic energy (4) Both (1) & (3)

Sol. Answer (2)

21. A 5000 kg rocket is set for vertical firing. The exhaust speed is 800 ms^{-1}. To give an initial upward acceleration of 20 ms^{-2}, the amount of gas ejected per second to supply the needed thrust will be (g= 10 ms^{-2})

(1) 185.5 kg s^{-1} (2) 187.5 kg s^{-1} (3) 127.5 kg s^{-1} (4) 137.5 kg s^{-1}

Sol. Answer (2)

m = 5000 kg v = 800 m/s a = 20 m/s^2

$$a = \frac{v\dfrac{dm}{dt} - mg}{m} = \frac{800\left(\dfrac{dm}{dt}\right) - 50000}{5000} = 2$$

$$\Rightarrow \frac{dm}{dt} = 187.5 \text{ kg/s}$$

22. A bullet is fired from a gun. The force on the bullet is given by $F = 600 - 2 \times 10^5\, t$, where F is in newton and t in second. The force on the bullet becomes zero as soon as it leaves the barrel. What is the impulse imparted to the bullet?

(1) 9 Ns (2) Zero (3) 1.8 Ns (4) 0.9 Ns

Sol. Answer (4)

When bullet leaves the barrel, force becomes zero

$$F = 600 - 2 \times 10^5 t = 0$$

$$t = \frac{600}{2\times10^5} = 3 \times 10^{-3} \text{ s}$$

$$I = \int F dt = \int_0^{3\times10^{-3}} (600 - 2\times10^5 t)\; dt$$

$$\left[600t - 2\times\frac{10^5 t^2}{2}\right]_0^{3\times10^{-3}} = 1.8 - 0.9 = 0.9 \text{ N.S}$$

23. A ball of mass 0.25 kg attached to the end of a string of length 1.96 m is moving in a horizontal circle. The string will break if the tension is more than 25 N. What is the maximum speed with which the ball can be moved?

(1) 5 m/s (2) 3 m/s (3) 14 m/s (4) 3.92 m/s

Sol. Answer (3)

$$T_{max.} = 25 = \frac{mv^2max.}{R}$$

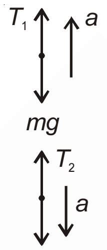
$$v^2_{max.} = 196$$

$$v_{max.} = 14 \text{ m/s}$$

24. A mass of 1 kg is suspended by a thread. It is (i) lifted up with an acceleration 4.9 m/s^2, (ii) lowered with an acceleration 4.9 m/s^2. The ratio of the tensions is

(1) 1 : 3 (2) 1 : 2 (3) 3 : 1 (4) 2 : 1

Sol. Answer (3)



$$T_1 = mg + ma$$

$$T_2 = mg - ma$$

$$\frac{T_1}{T_2} = \frac{9.8+4.9}{9.8-4.9} = \frac{3}{1}$$

25. If the force on a rocket, that releases the exhaust gases with a velocity of 300 m/s is 210 N, then the rate of combustion of the fuel is

(1) 0.07 kg/s (2) 1.4 kg/s (3) 0.7 kg/s (4) 10.7 kg/s

Sol. Answer (3)

$$F = \frac{vdm}{dt}$$

$$\frac{dm}{dt} = \frac{F}{v} = \frac{210}{300} = 0.7 \text{ kg/s}$$

26. A 500 kg car takes a round turn of radius 50 m with a velocity of 36 km/h. The centripetal force is

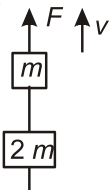
(1) 1000 N (2) 750 N (3) 250 N (4) 1200 N

Sol. Answer (1)

$$F_c = \frac{mv^2}{r} = \frac{500(10)^2}{50} = 1000 \text{ N}$$

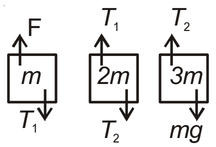
27. Three blocks with masses *m*, 2*m* and 3*m* are connected by strings, as shown in the figure. After an upward force F is applied on block *m*, the masses move upward at constant speed *v*. What is the net force on the block of mass 2 *m*?

(*g* is the acceleration due to gravity)



(1) 2 *mg* (2) 3 *mg* (3) 6 *mg* (4) Zero

Sol. Answer (4)



$a = 0$

Using $F_{\text{net}} = M_{\text{total}}a$

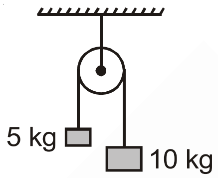
$F - (m + 2m + 3m) = 0$

$F = 6\ m$

$T_1 = F$, $T_2 = T_1$ since $a = 0$

Hence net force on $2m$ will be $T_1 - T_2 = 0$

28. Two masses as shown are suspended from a massless pulley. Calculate the acceleration of the 10 kg mass when masses are left free



(1) $\frac{2g}{3}$ (2) $\frac{g}{3}$ (3) $\frac{g}{9}$ (4) $\frac{g}{7}$

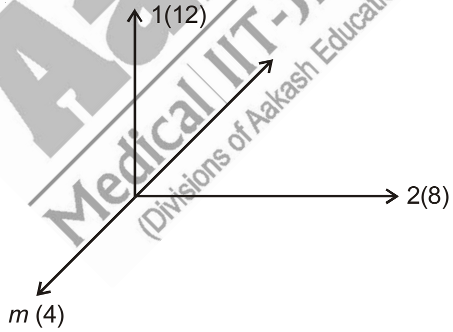
Sol. Answer (2)

$$a = \left(\frac{m_1 - m_2}{m_1 + m_2}\right) g = \frac{g}{3}$$

29. An explosion breaks a rock into three parts in a horizontal plane. Two of them go off at right angles to each other. The first part of mass 1 kg moves with a speed of 12 ms^{-1} and the second part of mass 2 kg moves with 8 ms^{-1} speed. If the third part flies off with 4 ms^{-1} speed, then its mass is

(1) 5 kg (2) 7 kg (3) 17 kg (4) 3 kg

Sol. Answer (1)



Using momentum conservation

$$m(4) = \sqrt{(12)^2 + (16)^2}$$

$4m = 20$

$m = 5$ kg

30. A mass of 1 kg is thrown up with a velocity of 100 m/s. After 5 second, it explodes into two parts. One part of mass 400 g moves down with a velocity 25 m/s. Calculate the velocity of other part just after the explosion. (g = 10 ms^{-2})

(1) 40 m/s ↑ (2) 40 m/s ↓ (3) 100 m/s ↑ (4) 60 m/s ↑

Sol. Answer (3)

$v = u - g(t)$

$= 50$ m/s

So, $1\ (50) = \frac{400}{1000}\ (25) + \frac{600}{1000} v$

$v = 100$ m/s ↑

31. A man is slipping on a frictionless inclined plane and a bag falls down from the same height. Then the velocity of both is related as (V_B = velocity of bag and V_m = velocity of man)

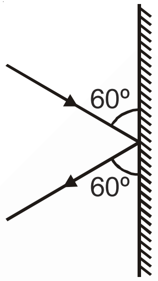
(1) $V_B > V_m$
(2) $V_B < V_m$
(3) $V_B = V_m$
(4) V_B and V_m can't be related

Sol. Answer (3)

Height is same and friction is absent so using mechanical energy conservation both will reach with the same speed.

$$mgh = \frac{1}{2}mv^2$$

32. A body of mass 3 kg moving with velocity 10 m/s hits a wall at an angle of 60° and returns at the same angle. The impact time was 0.2 s. Calculate the force exerted on the wall.



(1) $150\sqrt{3}$ N
(2) $50\sqrt{3}$ N
(3) 100 N
(4) 75 N

Sol. Answer (1)

$$F = \frac{\Delta p}{\Delta t} = \frac{2(3)(10)\sin 60^\circ}{0.2} = 300\frac{\sqrt{3}}{2} = 150\sqrt{3}\text{ N}$$

33. A cricketer catches a ball of mass 150 g in 0.1 s moving with speed 20 m/s, then he experiences force of

(1) 300 N
(2) 30 N
(3) 3 N
(4) 0.3 N

Sol. Answer (2)

$$F = \frac{\Delta p}{\Delta t} = \frac{0 - \frac{150}{1000}(20)}{0.1} = 30\text{ N}$$

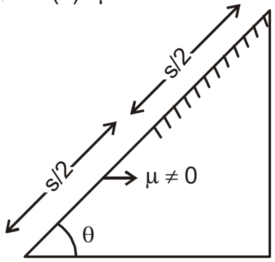
34. The upper half of an inclined plane of inclination θ is perfectly smooth while lower half is rough. A block starting from rest at the top of the plane will again come to rest at the bottom, if the coefficient of friction between the block and lower half of the plane is given by

(1) $\mu = \frac{2}{\tan\theta}$
(2) $\mu = 2\tan\theta$
(3) $\mu = \tan\theta$
(4) $\mu = \frac{1}{\tan\theta}$

Sol. Answer (2)

For first half

$$v = \sqrt{2g\sin\theta\left(\frac{s}{2}\right)} = \sqrt{sg\sin\theta}$$



for second half

$$\frac{s}{2} = \frac{sg\sin\theta}{2\,(g\sin\theta - \mu g\cos\theta)}$$

Solving this

$$\mu = 2\tan\theta$$

35. On the horizontal surface of a truck, a block of mass 1 kg is placed ($\mu = 0.6$) and truck is moving with acceleration 5 m/s^2 then the frictional force on the block will be

(1) 5 N (2) 6 N (3) 5.88 N (4) 8 N

Sol. Answer (1)

$f_L = 0.6 \times 1\ g = 6$ N

Now, $F_{net} = 1\ (5) = 5$ N

$\Rightarrow$ only static friction is acting on it.

36. An object of mass 3 kg is at rest. Now a force $\vec{F} = 6t^2\hat{i} + 4t\hat{j}$ is applied on the object then velocity of object at t = 3s is

(1) $18\hat{i} + 3\hat{j}$ (2) $18\hat{i} + 6\hat{j}$ (3) $3\hat{i} + 18\hat{j}$ (4) $18\hat{i} + 4\hat{j}$

Sol. Answer (2)

$\vec{F} = 6t^2\,\hat{i} + 4t\,\hat{j}$

$\frac{mdv}{dt} = 6t^2\,\hat{i} + 4\,\hat{t}\ \hat{j}$

$mdv = 6t^2\ dt\,\hat{i} + 4tdt.\ \hat{j}$

Integrating both sides

$m(v-u) = \left[2t^3\hat{i} + 2t^2\hat{j}\right]_{t=0}^{t=3}$

given $u = 0$, $m = 3$ kg

$v = 18\hat{i} + 6\hat{j}$

37. A block of mass 10 kg placed on rough horizontal surface having coefficient of friction $\mu = 0.5$, if a horizontal force of 100 N is acting on it then acceleration of the block will be (g = 10 ms^{-2})

(1) 10 m/s^2 (2) 5 m/s^2 (3) 15 m/s^2 (4) 0.5 m/s^2

Sol. Answer (2)

$$a = \frac{F - f_k}{m} = \frac{100 - (0.5)(10)\,(10)}{10} = \frac{50}{10} = 5 \text{ m/s}^2$$

38. A lift of mass 1000 kg is moving with acceleration of 1 m/s^2 in upward direction, then the tension developed in string which is connected to lift is

(1) 9800 N (2) 10,800 N (3) 11,000 N (4) 10,000 N

Sol. Answer (2)

$T = m(g + a) = 1000\ (9.8 + 1) = 10800$ N

39. A monkey of mass 20 kg is holding a vertical rope. The rope will not break when a mass of 25 kg is suspended from it but will break if the mass exceeds 25 kg. What is the maximum acceleration with which the monkey can climb up along the rope? (g = 10 m/s^2)

(1) 5 m/s^2 (2) 10 m/s^2 (3) 25 m/s^2 (4) 2.5 m/s^2

Sol. Answer (4)

$T_{max.} - mg = ma$

$250 - 20g = 20a$

$a = 2.5$ m/s^2

40. A man weighs 80 kg. He stands on a weighing scale in a lift which is moving upwards with a uniform acceleration of 5 m/s^2. What would be the reading on the scale? (g = 10 m/s^2)

(1) Zero (2) 400 N (3) 800 N (4) 1200 N

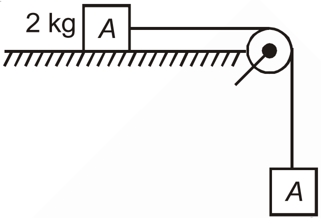
Sol. Answer (4)

$W_{app} = m(g + a)$

$= 80\ (10 + 5)$

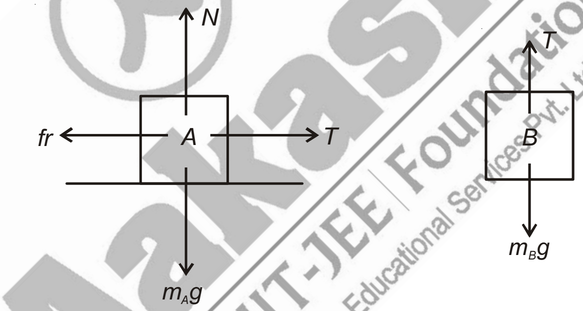
$= 1200$ N

41. The coefficient of static function, (μ_s) between block A of mass 2 kg and the table as shown in the figure is 0.2. What would be the maximum mass value of block B so that the two blocks do not move? (The string and the pulley are assumed to be smooth and massless)



(1) 2.0 kg (2) 4.0 kg (3) 0.2 kg (4) 0.4 kg

Sol. Answer (4)



$T < fr$

$M_B g < \mu_S\ (2)\ (g)$

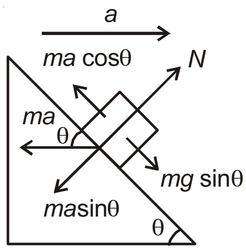
$M_B < (0.2)\ (g)$

$M_B < 0.4$ kg

42. A block of mass m is placed on a smooth wedge of inclination θ. The whole system is accelerated horizontally so that the block does not slip on the wedge. The force exerted by the wedge on the block (g is acceleration due to gravity) will be

(1) $mg\cos\theta$ (2) $mg\sin\theta$ (3) mg (4) $mg/\cos\theta$

Sol. Answer (4)



$mg\sin\theta = ma\cos\theta$

$\Rightarrow a = g\tan\theta$

$N = ma\sin\theta + mg\cos\theta$

$$N = \frac{mg\sin^2\theta}{\cos\theta} + mg\cos\theta = \frac{mg}{\cos\theta}$$

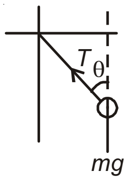
43. A car is moving in a circular horizontal track of radius 10 m with a constant speed of 10 m/s. A bob is suspended from the roof of the car by a light wire of length 1.0 m. The angle made by the wire with the vertical is

(1) 0° (2) $\frac{\pi}{3}$ (3) $\frac{\pi}{6}$ (4) $\frac{\pi}{4}$

Sol. Answer (4)

$T \cos\theta = mg$

$T \sin\theta = \dfrac{mv^2}{r}$



Divide both equations

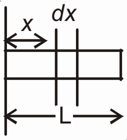
$$\tan\theta = \frac{v^2}{rg} = \frac{10\times10}{10\times10}$$

$$\theta = 45°$$

44. A tube of length L is filled completely with an incompressible liquid of mass M and closed at both the ends. The tube is then rotated in a horizontal plane about one of its ends with a uniform angular velocity ω. The force exerted by the liquid at the other end is

(1) $\dfrac{ML^2\omega^2}{2}$ (2) $\dfrac{ML\omega^2}{2}$ (3) $\dfrac{ML^2\omega}{2}$ (4) $ML\omega^2$

Sol. Answer (2)

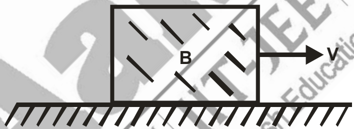


$$dm = \frac{M}{L}dx$$

$$\int dF = \int_0^L dM\,\omega^2 x \qquad [\because F = M\omega^2 r]$$

$$F = \frac{M\omega^2}{L}\int_0^L x\,dx = \frac{M\omega^2}{L}\left(\frac{L^2}{2}\right) = \frac{M\omega^2 L}{2}$$

45. A block B is pushed momentarily along a horizontal surface with an initial velocity v. If μ is the coefficient of sliding friction between B and the surface then, block B will come to rest after a time



(1) $\dfrac{g\mu}{v}$ (2) $\dfrac{g}{v}$ (3) $\dfrac{v}{\mu g}$ (4) $\dfrac{v^2}{g\mu}$

Sol. Answer (3)

$v = u - at$

$v = 0$

$t = \dfrac{v}{\mu g}$

46. A roller coaster is designed such that riders experience "weightlessness" as they go round the top of a hill whose radius of curvature is 20 m. The speed of the car at the top of the hill is between

(1) 13 m/s and 14 m/s (2) 14 m/s and 15 m/s (3) 15 m/s and 16 m/s (4) 16 m/s and 17 m/s

Sol. Answer (2)

$$\frac{mv^2}{r} = mg$$

$$\Rightarrow \quad v = \sqrt{20\times10} = 10\sqrt{2}$$

$$\cong 14.1 \text{ m/s}$$

47. The mass of a lift is 2000 kg. When the tension in the supporting cable is 28000 N, then its acceleration is

(1) 14 ms^{-2} upwards (2) 30 ms^{-2} downwards (3) 4 ms^{-2} upwards (4) 4 ms^{-2} downwards

Sol. Answer (3)

$$F_{net} = ma$$

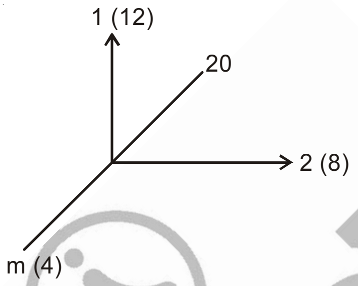
$$28000 - 2000\,g = 2000\,a$$

$$a = \frac{8000}{2000} = 4 \text{ m/s}^2 \text{ upwards}$$

48. An explosion blows a rock into three parts. Two parts go off at right angles to each other. These two are, 1 kg first part moving with a velocity of 12 ms^{-1} and 2 kg second part moving with a velocity of 8 ms^{-1}. If the third part flies off with a velocity of 4 ms^{-1}, its mass would be

(1) 3 kg (2) 5 kg (3) 7 kg (4) 17 kg

Sol. Answer (2)

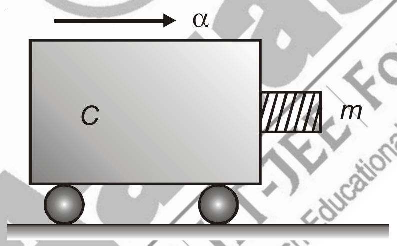


Using momentum conservation

$$20 = 4\,m$$

$$m = 5 \text{ kg}$$

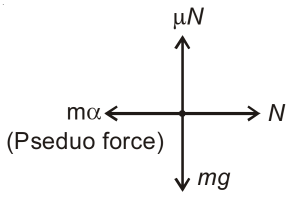
49. A block of mass m is in contact with the cart C as shown in the figure.



The coefficient of static friction between the block and the cart is μ. The acceleration α of the cart that will prevent the block from falling satisfies

(1) $\alpha < \frac{g}{\mu}$ (2) $\alpha > \frac{mg}{\mu}$ (3) $\alpha > \frac{g}{\mu m}$ (4) $\alpha \geq \frac{g}{\mu}$

Sol. Answer (4)



$$\Rightarrow \quad mg \leq \mu(m\alpha)$$

$$\alpha \geq \frac{g}{\mu}$$

50. A man of 50 kg mass is standing in a gravity free space at a height of 10 m above the floor. He throws a stone of 0.5 kg mass downwards with a speed 2 m/s. When the stone reaches the floor, the distance of the man above the floor will be

(1) 20 m (2) 9.9 m (3) 10.1 m (4) 10 m

Sol. Answer (3)

Using momentum conservation

$$0 = 0.5\,(2) + 50\,V$$

$$\Rightarrow \quad V = \frac{1}{50} \text{ m/s}$$

Time taken by stone to reach the ground

$$S = ut$$

$$10 = 2(t) \Rightarrow t = 5 \text{ second}$$

Distance covered by man upwards will be

$$S = \left(\frac{1}{50}\right)5 = 0.1 \text{ m}$$

Total height above the ground

$$= 10 + 0.1 = 10.1 \text{ m}$$

51. A gramophone record is revolving with an angular velocity ω. A coin is placed at a distance r from the centre of the record. The static coefficient of friction is μ. The coin will revolve with the record if

(1) $r \geq \frac{\mu g}{\omega^2}$ (2) $r = \mu g \omega^2$ (3) $r < \frac{\omega^2}{\mu g}$ (4) $r \leq \frac{\mu g}{\omega^2}$

Sol. Answer (4)

$$m\omega^2 r \leq \mu\, mg$$

$$r \leq \frac{\mu g}{\omega^2}$$

SECTION - D

Assertion-Reason Type Questions

1. A : Due to inertia an object is unable to change by itself its state of rest and uniform motion.

   R : An object cannot change its state unless acted upon by an unbalanced external force.

Sol. Answer (1)

2. A : Acceleration of an object in uniform motion is zero.

   R : No force is required to move an object uniformly

Sol. Answer (1)

3. A : Newton's second law of motion gives the measurement of force.

   R : According to second law of motion, force is directly proportional to the rate of change of momentum.

Sol. Answer (1)

4. A : According to Newton's third law of motion for every action, there is an equal and opposite reaction.

   R : There is no time lag between action and reaction.

Sol. Answer (2)

5. A : Inertia depends on the mass of an object.

R : Greater the mass, larger is the force required to change its state of rest or of uniform motion.

Sol. Answer (1)

6. A : In case of free fall of a lift, the apparent weight of a man in it will be zero.

R : In free fall, acceleration of lift is equal to acceleration due to gravity.

Sol. Answer (1)

7. A : Static friction force is a self adjusting force.

R : The interatomic forces at the point of contact give rise to friction between the surfaces.

Sol. Answer (2)

8. A : The value of kinetic friction is less than the limiting friction.

R : When motion of an object started, the inertia of rest has been overcome.

Sol. Answer (1)

9. A : During horizontal circular turn of a car, the centripetal force required should be less than the limiting friction between its tyres and road.

R : The centripetal force to car is provided by the frictional force between its tyres and the road.

Sol. Answer (1)

10. A : A person on a frictionless surface can get away from it by blowing air out of his mouth.

R : For every action there is an equal and opposite reaction.

Sol. Answer (1)

11. A : It is difficult to move a cycle along a road with its brakes on.

R : Sliding friction is greater than rolling friction.

Sol. Answer (1)

12. A : It makes easier to walk on slippery muddy road if we throw some sand on it.

R : On throwing sand, frictional force of the surface increases.

Sol. Answer (1)

13. A : Banking of roads reduces the wear and tear of the tyres of automobiles.

R : By banking of the roads, one component of the normal reaction on the automobile contributes to necessary centripetal force.

Sol. Answer (1)

14. A : The centripetal and centrifugal forces never cancel each other.

R : They are action and reaction forces.

Sol. Answer (3)

15. A : Work done by friction can increase the kinetic energy of the body.

R : Friction is a type of contact force and it always opposes the relative motion or tendency of relative motion.

Sol. Answer (2)

❑ ❑ ❑

Chapter 6

Work, Energy and Power

Solutions

SECTION - A

Objective Type Questions

1. A string is used to pull a block of mass m vertically up by a distance h at a constant acceleration $\frac{g}{3}$. The work done by the tension in the string is

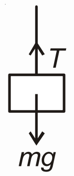
(1) $\frac{2}{3}mgh$ (2) $\frac{-mgh}{3}$ (3) mgh (4) $\frac{4}{3}mgh$

Sol. Answer (4)

$T - mg = ma$

$T = m(g + a)$

$= \frac{4}{3}mg$



Work (w) = $T.h$

$= \frac{4}{3}mgh$

2. A particle moves along X-axis from $x = 0$ to $x = 1$ m under the influence of a force given by $F = 3x^2 + 2x - 10$. Work done in the process is

(1) +4 J (2) –4 J (3) +8 J (4) –8 J

Sol. Answer (4)

$$W = \int_0^1 \left(3x^2 + 2x - 10\right) dx$$

$$= \left[x^3 + x^2 - 10x\right]_0^1 = -8J$$

3. A body constrained to move in z direction is subjected to a force given by $\vec{F} = (3\hat{i} - 10\hat{j} + 5\hat{k})$N. What is the work done by this force in moving the body through a distance of 5 m along z-axis?

(1) 15 J (2) – 15 J (3) –50 J (4) 25 J

Sol. Answer (4)

$$W = \left(3\hat{i} - 10\hat{j} + 5\hat{k}\right).5\hat{k}$$

$$= 25\ J$$

4. If 250 J of work is done in sliding a 5 kg block up an inclined plane of height 4 m. Work done against friction is (g = 10 ms^{-2})

(1) 50 J (2) 100 J (3) 200 J (4) Zero

Sol. Answer (1)

$W_{Total} = W_{friction} + W_{gravity}$

$-250 = W_f - 50(4)$

$W_f = -50J$

5. A man carries a load on his head through a distance of 5 m. The maximum amount of work is done when he

(1) Moves it over an inclined plane (2) Moves it over a horizontal surface

(3) Lifts it vertically upwards (4) None of these

Sol. Answer (3)

Displacement is maximum while moving it vertically upwards.

6. A body moves a distance of 10 m along a straight line under the action of a force 5 N. If the work done is 25 joule, the angle which the force makes with the direction of motion of body is

(1) 0° (2) 30° (3) 60° (4) 90°

Sol. Answer (3)

$\vec{F}\,.\,\vec{S} = 25$

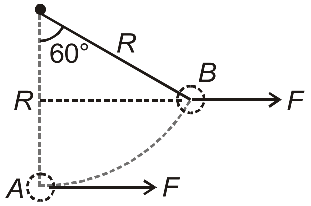
$FS\cos\theta = 25$

$(5)\,(10)\cos\theta = 25$

$$\cos\theta = \frac{1}{2}$$

$\theta = 60°$

7. A block of mass m is pulled along a circular arc by means of a constant horizontal force F as shown. Work done by this force in pulling the block from A to B is

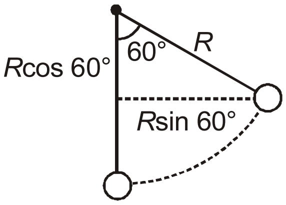


(1) $\dfrac{FR}{2}$ (2) FR (3) $\dfrac{\sqrt{3}}{2}FR$ (4) mgR

Sol. Answer (3)

Work = Force × (Displacement in the direction of force,

$$= F(R\sin 60°) = \frac{\sqrt{3}}{2}FR$$



8. A particle is displaced from a position $(2\hat{i} - \hat{j} + \hat{k})$ metre to another position $(3\hat{i} + 2\hat{j} - 2\hat{k})$ metre under the action of force $(2\hat{i} + \hat{j} - \hat{k})$ N. Work done by the force is

(1) 8 J (2) 10 J (3) 12 J (4) 36 J

Sol. Answer (1)

$W = \vec{F}\,.\,\vec{S}$

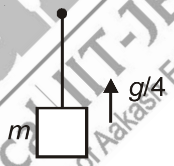
Displacement vector $\left(\vec{S}\right)$ = $(3i + 2j - 2k) - (2i - j + k)$

$= i + 3\hat{j} - 3\hat{k}$

W = $(2i + j - k)\,.\,(i + 3j - 3k)$

$= 2 + 3 + 3 = 8J$

9. A string is used to pull a block of mass m vertically up by a distance h at a constant acceleration $\frac{g}{4}$. The work done by the tension in the string is



(1) $+\frac{3mgh}{4}$ (2) $-\frac{mgh}{4}$ (3) $+\frac{5}{4}mgh$ (4) $+ mgh$

Sol. Answer (3)

$T - mg = ma$

$T = m(g+a) \Rightarrow T = m\left(g + \frac{g}{4}\right) = \frac{5}{4}mg$

$W = T.h = \frac{5}{4}mgh$

10. Work done by frictional force

(1) Is always negative (2) Is always positive

(3) Is zero (4) May be positive, negative or zero

Sol. Answer (4)

Frictional force can act in the direction of displacement, opposite to it and sometimes not let the body move. So the work can be positive, negative or zero.

11. Under the action of a force, a 2 kg body moves such that its position x as a function of time t is given by $x = \frac{t^2}{3}$, where x is in metres and t in seconds. The workdone by the force in first two seconds is

(1) 1600 J (2) 160 J (3) 16 J (4) $\frac{16}{9}$ J

Sol. Answer (4)

$$x = \frac{t^2}{3} \quad \Rightarrow \quad v = \frac{2t}{3}$$

$$W = \Delta K.E. = \frac{1}{2}(2)\left[\left(\frac{4}{3}\right)^2 - 0\right]$$

$$= \frac{16}{9} J$$

12. A rifle bullets loses $\left(\frac{1}{20}\right)$th of its velocity in passing through a plank. Assuming that the plank exerts a constant retarding force, the least number of such planks required just to stop the bullet is

(1) 11 (2) 20 (3) 21 (4) Infinite

Sol. Answer (1)

Let the retarding force by one block is F and displacement inside one block is x.

So using work energy theorem for one block

$$-F.x = \frac{1}{2}m\left[\left(\frac{19}{20}v\right)^2 - v^2\right] \quad \ldots(1)$$

Applying work energy theorem for n blocks

$$-F.nx = \frac{1}{2}m\left[o - v^2\right]$$

Using value of Fx from …(1)

$$\frac{1}{2}m\left[v^2 - \left(\frac{19}{20}v\right)^2\right]n = \frac{1}{2}m\left[o - v^2\right]$$

Solving for n

$n = 10.25$ So, 11 Planks

13. A particle moves along x-axis from $x = 0$ to $x = 5$ metre under the influence of a force $F = 7 - 2x + 3x^2$. The work done in the process is

(1) 70 (2) 135 (3) 270 (4) 35

Sol. Answer (2)

$$W = \int_0^5 \vec{F}.dx = \int_0^5 \left(7 - 2x + 3x^2\right)dx$$

$$= [7x - x^2 + x^3]_0^5 = 135$$

14. A particle of mass 2 kg travels along a straight line with velocity $v = a\sqrt{x}$, where a is a constant. The work done by net force during the displacement of particle from $x = 0$ to $x = 4$ m is

(1) a^2 (2) $2a^2$ (3) $4a^2$ (4) $\sqrt{2}\,a^2$

Sol. Answer (3)

$$v = a\sqrt{x}$$

$$W = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$$

$$= \frac{1}{2}(2)\left[\left(a\sqrt{4}\right)^2 - 0\right]$$

$$= 4a^2$$

15. The position x of a particle moving along x-axis at time (t) is given by the equation $t = \sqrt{x} + 2$, where x is in metres and t in seconds. Find the work done by the force in first four seconds.

(1) Zero (2) 2 J (3) 4 J (4) 8 J

Sol. Answer (1)

$$x = (t - 2)^2$$

$$\frac{dx}{dt} = v = 2(t-2)$$

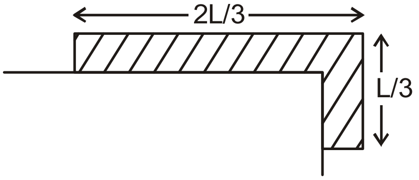
$$W = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$$

$$= \frac{m}{2}\left[4^2 - 4^2\right] = 0$$

16. A uniform chain of length L and mass M is lying on a smooth table and one third of its length is hanging vertically down over the edge of the table. If g is acceleration due to gravity, the minimum work required to pull the hanging part of the chain on the table is

(1) MgL (2) $\frac{MgL}{3}$ (3) $\frac{MgL}{9}$ (4) $\frac{MgL}{18}$

Sol. Answer (4)



Mass of $\frac{L}{3}$ part will be $\frac{M}{3}$

Centre of mass of $\frac{L}{3}$ part is $\frac{L}{6}$ below the table

So total displacement of C.M. to bring it on the table

$$W = \frac{M}{3}g\left(\frac{L}{6}\right) = \frac{MgL}{18}$$

17. Two bodies of masses m_1 and m_2 have same kinetic energy. The ratio of their momentum is

(1) $\sqrt{\dfrac{m_2}{m_1}}$ (2) $\sqrt{\dfrac{m_1}{m_2}}$ (3) $\dfrac{m_1^2}{m_2^2}$ (4) $\dfrac{m_2^2}{m_1^2}$

Sol. Answer (2)

$$\frac{P_1^2}{2m_1} = \frac{P_2^2}{2m_2}$$

$$\frac{P_1}{P_2} = \sqrt{\frac{m_1}{m_2}}$$

18. Two bodies of masses m_1 and m_2 have same momentum. The ratio of their KE is

(1) $\sqrt{\dfrac{m_2}{m_1}}$ (2) $\sqrt{\dfrac{m_1}{m_2}}$ (3) $\dfrac{m_1}{m_2}$ (4) $\dfrac{m_2}{m_1}$

Sol. Answer (4)

$$\sqrt{2m_1k_1} = \sqrt{2m_2k_2}$$

$$\frac{k_1}{k_2} = \frac{m_2}{m_1}$$

19. KE of a body is increased by 44%. What is the percent increase in the momentum?

(1) 10% (2) 20% (3) 30% (4) 44%

Sol. Answer (2)

$$1.44K = \frac{\left(P^1\right)^2}{2m}$$

$$P^1 = 1.2\ P$$

$$\frac{P^1 - P}{P} \times 100 = \frac{1.2P - P}{P} = 20\%$$

20. When momentum of a body increases by 200%, its KE increases by

(1) 200% (2) 300% (3) 400% (4) 800%

Sol. Answer (4)

$$P^1 = 3P$$

$$K^1 = \frac{(3P)^2}{2m} = \frac{9P^2}{2m}$$

$$\frac{K^1 - K}{K} \times 100 = \frac{\dfrac{9P^2}{2m} - \dfrac{P^2}{2m}}{\dfrac{P^2}{2m}} \times 100 = 800\%$$

21. Two bodies of masses m_1 and m_2 are moving with same kinetic energy. If P_1 and P_2 are their respective momentum, the ratio $\frac{P_1}{P_2}$ is equal to

(1) $\frac{m_1}{m_2}$ (2) $\sqrt{\frac{m_2}{m_1}}$ (3) $\sqrt{\frac{m_1}{m_2}}$ (4) $\frac{m_1{}^2}{m_2{}^2}$

Sol. Answer (3)

$$\frac{P_1^2}{2m_1} = \frac{P_2^2}{2m_2}$$

$$\frac{P_1}{P_2} = \sqrt{\frac{m_1}{m_2}}$$

22. KE acquired by a mass *m* in travelling a certain distance *d*, starting from rest, under the action of a constant force *F* is

(1) Directly proportional to $\sqrt{m}$ (2) Directly proportional to *m*

(3) Directly proportional to $\frac{1}{m}$ (4) None of these

Sol. Answer (4)

F.d = ΔK

F.d = K_f

K is independent of mass here.

23. A simple pendulum with bob of mass *m* and length *x* is held in position at an angle θ_1 and then angle θ_2 with the vertical. When released from these positions, speeds with which it passes the lowest positions are v_1 & v_2 respectively. Then, $\frac{v_1}{v_2}$ is

(1) $\frac{1-\cos\theta_1}{1-\cos\theta_2}$ (2) $\sqrt{\frac{1-\cos\theta_1}{1-\cos\theta_2}}$ (3) $\sqrt{\frac{2gx(1-\cos\theta_1)}{1-\cos\theta_2}}$ (4) $\sqrt{\frac{1-\cos\theta_1}{2gx(1-\cos\theta_2)}}$

Sol. Answer (2)

$U_i + k_i = U_f + k_f$ (Mechanical energy conservation)

$$mgl(1-\cos\theta) = \frac{1}{2}mv^2$$

$$\frac{v_1^2}{v_2^2} = \frac{1-\cos\theta_1}{1-\cos\theta_2}$$

$$\frac{v_1}{v_2} = \sqrt{\frac{1-\cos\theta_1}{1-\cos\theta_2}}$$

24. A U–238 nucleus originally at rest, decays by emitting an α-particle, say with a velocity of *v* m/s. The recoil velocity (in ms^{-1}) of the residual nucleus is

(1) $\frac{4v}{238}$ (2) $-\frac{4v}{238}$ (3) $\frac{v}{4}$ (4) $-\frac{4v}{234}$

Sol. Answer (4)

Using momentum conservation

$0 = 4v + 234\ v^1$

$$v^1 = \frac{-4v}{234}$$

25. The total work done on a particle is equal to the change in its kinetic energy. This is applicable

(1) Always (2) Only if the conservative forces are acting on it

(3) Only in inertial frames (4) Only when pseudo forces are absent

Sol. Answer (1)

$W = \Delta k$ is always applicable

26. Potential energy is defined

(1) Only in conservative fields

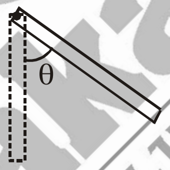
(2) As the negative of work done by conservative forces

(3) As the negative of workdone by external forces when $\Delta K = 0$

(4) All of these

Sol. Answer (1)

27. A stick of mass m and length l is pivoted at one end and is displaced through an angle θ. The increase in potential energy is



(1) $mg\,\frac{l}{2}(1-\cos\theta)$ (2) $mg\,\frac{l}{2}(1+\cos\theta)$ (3) $mg\,\frac{l}{2}(1-\sin\theta)$ (4) $mg\,\frac{l}{2}(1+\sin\theta)$

Sol. Answer (1)

Using mechanical energy conservation

$$U = \frac{mgl}{2}(1-\cos\theta)$$

28. A spring with spring constants k when compressed by 1 cm, the potential energy stored is U. If it is further compressed by 3 cm, then change in its potential energy is

(1) $3U$ (2) $9U$ (3) $8U$ (4) $15U$

Sol. Answer (4)

$$U = \frac{1}{2}k(1)^2 = \frac{k}{2}$$

$$U^1 = \frac{1}{2}k(4)^2 = \frac{1}{2}k(16) = 16U$$

$$\Delta U = U^1 - U = 16U - U = 15U$$

29. Two springs have force constant K_1 and K_2 ($K_1 > K_2$). Each spring is extended by same force F. It their elastic potential energy are E_1 and E_2 then $\frac{E_1}{E_2}$ is

(1) $\frac{K_1}{K_2}$ (2) $\frac{K_2}{K_1}$ (3) $\sqrt{\frac{K_1}{K_2}}$ (4) $\sqrt{\frac{K_2}{K_1}}$

Sol. Answer (2)

$$x = \frac{F}{K}$$

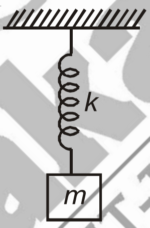
$$U = \frac{1}{2}Kx^2 = \frac{1}{2}K\left(\frac{F}{K}\right)^2$$

$$U = \frac{F^2}{2K}$$

$$U \alpha \frac{1}{K}$$

$$\frac{U_1}{U_2} = \frac{K_2}{K_1}$$

30. Initially mass m is held such that spring is in relaxed condition. If mass m is suddenly released, maximum elongation in spring will be



(1) $\frac{mg}{k}$ (2) $\frac{2mg}{k}$ (3) $\frac{mg}{2k}$ (4) $\frac{mg}{4k}$

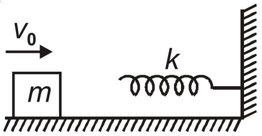
Sol. Answer (2)

$E_i = E_f$

$$\Rightarrow 0 = -mgx + \frac{1}{2}kx^2$$

$$x = \frac{2mg}{k}$$

31. A block of mass m moving with velocity v_0 on a smooth horizontal surface hits the spring of constant k as shown. The maximum compression in spring is



(1) $\sqrt{\frac{2m}{k}} \cdot v_0$ (2) $\sqrt{\frac{m}{k}} \cdot v_0$ (3) $\sqrt{\frac{m}{2k}} \cdot v_0$ (4) $\frac{m}{2k} \cdot v_0$

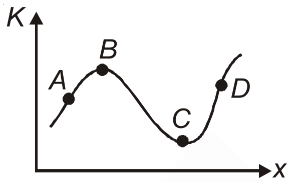
Sol. Answer (2)

$E_i = E_f$

$$\frac{1}{2} m v_0^2 = \frac{1}{2} k x^2$$

$$x = \sqrt{\frac{m}{k}} v_0$$

32. For a particle moving under the action of a variable force, kinetic energy-position graph is given, then



(1) At *A* particle is decelerating
(2) At *B* particle is accelerating
(3) At *C* particle has maximum velocity
(4) At *D* particle has maximum acceleration

Sol. Answer (4)

$F.dx = dK$

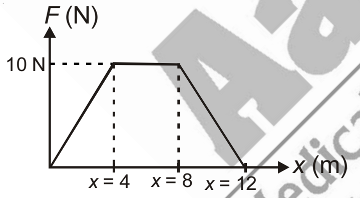
$$\frac{dK}{dx} = F$$

$\Rightarrow$ Slope of $K - x$ curve gives force

So slope is max at *D*, hence acceleration is maximum at *D*

33. A particle of mass 0.1 kg is subjected to a force which varies with distance as shown. If it starts its journey from rest at $x = 0$, then its velocity at $x = 12$ m is

(1) 0 m/s
(2) $20\sqrt{2}$ m/s
(3) $20\sqrt{3}$ m/s
(4) 40 m/s



Sol. Answer (4)

Total work done = Area under $F - x$ curve

= ΔK.E.

$$\frac{1}{2}(4)(10) + \frac{1}{2}(4)10 + 40 = \Delta K$$

$$80\ J = \frac{1}{2}(0.1)v^2$$

$v = 40$ m/s

34. An unloaded bus can be stopped by applying brakes on straight road after covering a distance *x*. Suppose, the passenger add 50% of its weight as the load and the braking force remains unchanged, how far will the bus go after the application of the brakes? (Velocity of bus in both case is same)

(1) Zero
(2) 1.5*x*
(3) 2*x*
(4) 2.5*x*

Sol. Answer (2)

$$F.x = \frac{1}{2}mv^2$$

$$F.x^1 = \frac{1}{2}(1.5m)v^2$$

$$x^1 = 1.5\ x$$

35. Initially mass m is held such that spring is in relaxed condition. If mass m is suddenly released, maximum elongation in the spring will be

(1) $\frac{mg}{k}$ (2) $\frac{2mg}{k}$ (3) $\frac{mg}{2k}$ (4) $\frac{mg}{4k}$

Sol. Answer (2)

$$E_i = E_f$$

$$0 + mgx = \frac{1}{2}kx^2 + 0$$

$$x = \frac{2mg}{k}$$

36. The power of water pump is 4 kW. If $g = 10\ \text{ms}^{-2}$, the amount of water it can raise in 1 minute to a height of 20 m is

(1) 100 litre (2) 1000 litre (3) 1200 litre (4) 2000 litre

Sol. Answer (3)

$$Power = \frac{Work}{time} = \frac{mgh}{t}$$

$$\frac{m(10)(20)}{60} = 4000$$

$$m = 1200\ \text{kg}$$

37. A particle moves with the velocity $\vec{v} = (5\hat{i} + 2\hat{j} - \hat{k})\text{ms}^{-1}$ under the influence of a constant force, $\vec{F} = (2\hat{i} + 5\hat{j} - 10\hat{k})$ N. The instantaneous power applied is

(1) 5 W (2) 10 W (3) 20 W (4) 30 W

Sol. Answer (4)

$$P = \vec{F}\,.\,\vec{V}$$

$$= (2i + 5j - 10k)\ .\ (5i + 2j - k)$$

$$= 10 + 10 + 10 = 30\ \text{w}$$

38. A body is projected from ground obliquely. During downward motion, power delivered by gravity to it

(1) Increases (2) Decreases

(3) Remains constant (4) First decreases and then becomes constant

Sol. Answer (1)

Power = $Fv\cos\theta$ $\theta < 90°$

Velocity of particle will increase

So power will increase as F is constant

39. The blades of a wind mill sweep out a circle of area A. If wind flows with velocity v perpendicular to blades of wind mill and its density is ρ, then the mechanical power received by wind mill is

(1) $\frac{\rho A v^3}{2}$ (2) $\frac{\rho A v^2}{2}$ (3) $\rho A v^2$ (4) $2\rho A v^2$

Sol. Answer (1)

$$P = \frac{dk}{dt} = \frac{d}{dt}\left[\frac{1}{2}mv^2\right]$$

$$= \frac{1}{2}v^2\frac{dm}{dt} = \frac{PAv^3}{2}$$

40. A body of mass m accelerates uniformly from rest to velocity v_1 in time interval T_1. The instantaneous power delivered to the body as a function of time t is

(1) $\frac{mv_1^2}{T_1^2}t$ (2) $\frac{mv_1}{T_1^2}t$ (3) $\left(\frac{mv_1}{T_1}\right)^2 t$ (4) $\frac{mv_1^2}{T_1}t^2$

Sol. Answer (1)

$v_1 = u + at_1$ $\Rightarrow a = \frac{v_1}{t_1}$

again $v = u + at$

$$\Rightarrow v = 0 + \left(\frac{v_1}{T_1}\right)t$$

$$F = ma = \frac{mv_1}{T_1} \quad \Rightarrow P = \frac{mv_1}{T_1}\left(\frac{v_1}{T_1}t\right)$$

41. The power of a pump, which can pump 500 kg of water to height 100 m in 10 s is

(1) 75 kW (2) 25 kW (3) 50 kW (4) 500 kW

Sol. Answer (3)

$$P = \frac{500(1)(100)}{10} = 50{,}000 = 50\,\text{kW}$$

42. A pump is used to pump a liquid of density ρ continuously through a pipe of cross section area A. If liquid is flowing with speed V, then power of pump is

(1) $\frac{1}{3}\rho AV^2$ (2) $\frac{1}{2}\rho AV^2$ (3) $2\rho AV^2$ (4) $\frac{1}{2}\rho AV^3$

Sol. Answer (4)

$$P_{avg} = \frac{v^2}{2}\frac{dm}{dt} = \frac{1}{2}\rho Av^3$$

43. A car of mass m has an engine which can deliver power P. The minimum time in which car can be accelerated from rest to a speed v is

(1) $\frac{mv^2}{2P}$ (2) Pmv^2 (3) $2Pmv^2$ (4) $\frac{mv^2}{2}P$

Sol. Answer (1)

$$P = \frac{K.E.}{t}$$

$$Pt = \frac{m}{2}v^2$$

$$t = \frac{mv^2}{2P}$$

44. From a water fall, water is pouring down at the rate of 100 kg/s, on the blades of a turbine. If the height of the fall is 100 m, the power delivered to the turbine is approximately equal to

(1) 100 kW (2) 10 kW (3) 1 kW (4) 100 W

Sol. Answer (1)

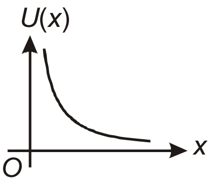
$$P_{avg} = \frac{W}{t} = \frac{mgh}{t}$$

$$= \left(\frac{m}{t}\right)gh$$

$$= 100 \times 10 \times 100 = 100 \text{ kW}$$

45. On a particle placed at origin a variable force $F = -ax$ (where a is a positive constant) is applied. If $U(0) = 0$, the graph between potential energy of particle $U(x)$ and x is best represented by

(1)



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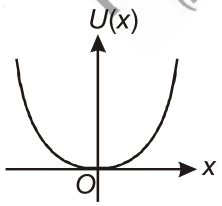

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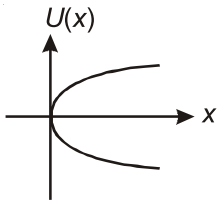

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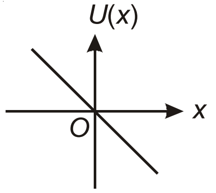
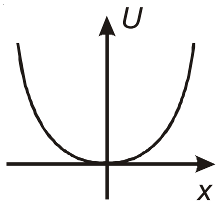


Sol. Answer (2)

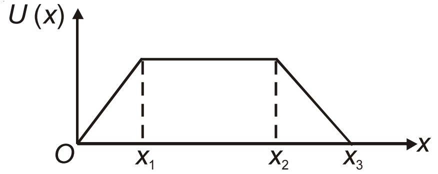


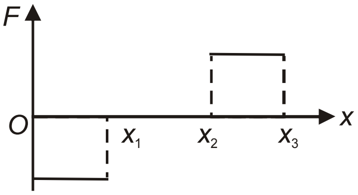
$$F = -ax = \frac{-dU}{dx}$$

Integrating both sides

$$U = \frac{ax^2}{2}$$

46. The variation of potential energy U of a system is shown in figure. The force acting on the system is best represented by



(1)


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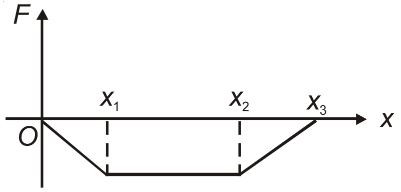
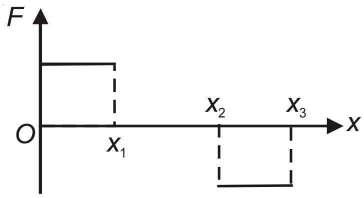


(3)


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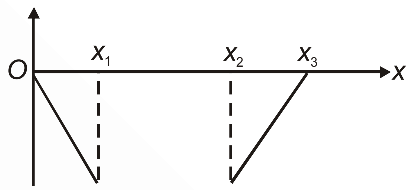


Sol. Answer (1) **.......................?**

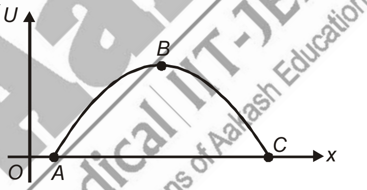
$F = \frac{-dU}{dx} \Rightarrow$ Slope of U–x curve will represent force

from 0 $\rightarrow x_1$ Slope is positive and non zero

from $x_1 \rightarrow x_2$ Slope is zero

from $x_2 \rightarrow x_3$ Slope is negative and non zero

47. The variation of potential energy U of a body moving along x-axis varies with its position (x) as shown in figure



The body is in equilibrium state at

(1) A (2) B (3) C (4) Both A & C

Sol. Answer (2)

at B, $\frac{dU}{dx} = 0$ (Slope of $U - x$ curve)

$\Rightarrow F = 0$ at B, So its a position of equilibrium

48. A particle of mass 200 g is moving in a circle of radius 2 m. The particle is just 'looping the loop'. The speed of the particle and the tension in the string at highest point of the circular path are ($g = 10\ \text{ms}^{-2}$)

(1) 4 ms^{-1}, 5 N (2) 4.47 ms^{-1}, zero (3) 2.47 ms^{-1}, zero (4) 1 ms^{-1}, zero

Sol. Answer (2)

$v = \sqrt{gL} = 4.47$ m/s

$T = 0$

49. A particle of mass 200 g, is whirled into a vertical circle of radius 80 cm using a massless string. The speed of the particle when the string makes an angle of 60° with the vertical line is 1.5 ms^{-1}. The tension in the string at this position is

(1) 1 N (2) 1.56 N (3) 2 N (4) 3 N

Sol. Answer (2)

$$T - mg\cos\theta = \frac{mv^2}{R}$$

$\theta = 60°$

Solving this

$T = 1.56\ N$

50. A stone of mass 1 kg is tied with a string and it is whirled in a vertical circle of radius 1 m. If tension at the highest point is 14 N, then velocity at lowest point will be

(1) 3 m/s (2) 4 m/s (3) 6 m/s (4) 8 m/s

Sol. Answer (4)

$$T + mg = \frac{mv^2}{R} \text{ (at the highest point)}$$

$$14 = \frac{1\left(v^2\right)}{R(1)} + 10$$

$v^2 = 4 \qquad \Rightarrow v = 2$ m/s

Using mechanical energy conservation

$$\frac{1}{2}(1)u^2 = \frac{1}{2}(1)\left(2^2\right) + 1(10)(2)$$

$u^2 = 64 \qquad \Rightarrow u = 8$ m/s

51. An object of mass 80 kg moving with velocity 2 ms^{-1} hit by collides with another object of mass 20 kg moving with velocity 4 ms^{-1}. Find the loss of energy assuming a perfectly inelastic collision

(1) 12 J (2) 24 J (3) 30 J (4) 32 J

Sol. Answer (4)

Loss in kinetic energy

$$\Delta k = \frac{m_1 m_2}{2(m_1 + m_2)}(u_1 - u_2)^2$$

$\Delta k = 32\ J$

52. A ball of mass m moving with velocity v collides head-on with the second ball of mass m at rest. If the coefficient of restitution is e and velocity of first ball after collision is v_1 and velocity of second ball after collision is v_2 then

(1) $v_1 = \frac{(1-e)u}{2}, v_2 = \frac{(1+e)u}{2}$

(2) $v_1 = \frac{(1+e)u}{2}, v_2 = \frac{(1-e)u}{2}$

(3) $v_1 = \frac{u}{2}, v_2 = -\frac{u}{2}$

(4) $v_1 = (1 + e)u, v_2 = (1 - e)u$

Sol. Answer (1)

$$e = \frac{\text{Velocity of separation}}{\text{Velocity of approach}}$$

So, $V_1 = \frac{(1-e)u}{2}, v_2 = \frac{(1+e)}{2}u$

53. Particle A makes a perfectly elastic collision with another particle B at rest. They fly apart in opposite direction with equal speeds. If their masses are m_A & m_B respectively, then

(1) $2m_A = m_B$ (2) $3m_A = m_B$ (3) $4m_A = m_B$ (4) $\sqrt{3}m_A = m_B$

Sol. Answer (2)

From conservation of momentum and mechanical energy conservation

$3m_A = m_B$

54. A shell of mass m moving with a velocity v breakes up suddenly into two pieces. The part having mass $\frac{m}{3}$ remains stationary. The velocity of the other part will be

(1) v (2) $2v$ (3) $\frac{2}{3}v$ (4) $\frac{3}{2}v$

Sol. Answer (4)

Momentum will be conserved

$P_i = P_f$

$$mv = \frac{m}{3}(0) + \frac{2m}{3}(v^1)$$

$$v^1 = \frac{3}{2}v$$

55. A particle of mass m moving towards west with speed v collides with another particle of mass m moving towards south. If two particles stich to each other, the speed of the new particle of mass 2 m will be

(1) $v\sqrt{2}$ (2) $\frac{v}{\sqrt{2}}$ (3) $\frac{v}{2}$ (4) v

Sol. Answer (2)

Using conservation of momentum

$P_i = P_f$

$mv\left(-\hat{i}\right) + mv\left(-\hat{j}\right) = 2m\,\vec{v}^1$

$\left|v^1\right| = \dfrac{v}{\sqrt{2}}$

56. A body of mass 10 kg moving with speed of 3 ms^{-1} collides with another stationary body of mass 5 kg. As a result, the two bodies stick together. The KE of composite mass will be

(1) 30 J (2) 60 J (3) 90 J (4) 120 J

Sol. Answer (1)

Using momentum conservation

10(3) = 15 V

$V = 2$ m/s

$K.E. = \dfrac{1}{2}mv^2 = \dfrac{1}{2}(15)(2)^2$

$= 30\ J$

57. A stationary particle explodes into two particles of masses x and y, which move in opposite directions with velocity v_1 and v_2. The ratio of their kinetic energies ($E_1 : E_2$) is

(1) 1 (2) $\dfrac{xv_2}{yv_1}$ (3) $\dfrac{x}{y}$ (4) $\dfrac{y}{x}$

Sol. Answer (4)

Momentum will be conserved

$0 = xv_1 + yv_2$

$-xv_1 = yv_2$ …(1)

$\dfrac{k_1}{k_2} = \dfrac{\frac{1}{2}xv_1^2}{\frac{1}{2}yv_2^2}$

Using (1) $\left(\dfrac{v_1}{v_2}\right)^2 = \dfrac{y^2}{x^2}$

$\dfrac{k_1}{k_2} = \dfrac{x}{y}\cdot\left(\dfrac{y^2}{x^2}\right)$

$= \dfrac{y}{x}$

58. Select the false statement

(1) In elastic collision, KE is not conserved during the collision

(2) The coefficient of restitution for a collision between two steel balls lies between 0 and 1

(3) The momentum of a ball colliding elastically with the floor is conserved

(4) In an oblique elastic collision between two identical bodies with one of them at rest initially, the final velocities are perpendicular

Sol. Answer (3)

Momentum will be conserved.

59. A bullet of mass *m* moving with a velocity *u* strikes a block of mass *M* at rest and gets embedded in the block. The loss of kinetic energy in the impact is

(1) $\frac{1}{2}mMu^2$ (2) $\frac{1}{2}(m+M)u^2$ (3) $\frac{mMu^2}{2(m+M)}$ (4) $\left(\frac{m+M}{2mM}\right)u^2$

Sol. Answer (3)

$$\Delta k = \frac{1}{2}\frac{m_1M_2}{(m_1+M_2)}(u_1-u_2)^2$$

$$= \frac{mMx^2}{2(m+M)}$$

60. A bullet of mass *m* moving with velocity *v* strikes a suspended wooden block of mass *M*. If the block rises to height *h*, the initial velocity of the bullet will be

(1) $\sqrt{2gh}$ (2) $\frac{M+m}{m}\sqrt{2gh}$ (3) $\frac{m}{M+m}\sqrt{2gh}$ (4) $\frac{M+m}{M}\sqrt{2gh}$

Sol. Answer (2)

$P_i = P_f$

$mv + 0 = mv^1 + Mv^1$

$mv = (m + M)v^1$

$$v^1 = \frac{mv}{m+M} = \sqrt{2gh}$$

$$v = \frac{(m+M)\sqrt{2gh}}{m}$$

61. A ball is allowed to fall from a height of 10 m. If there is 40% loss of energy due to impact, then after one impact ball will go up by

(1) 10 m (2) 8 m (3) 4 m (4) 6 m

Sol. Answer (4)

When ball just reaches the ground

$k_1 = \text{mg}\ (10)$

40 % of energy is lost after impact. Using mechanical energy conservation

$U_i + k_i = U_f + k_f$

$0 + (0.6)\ k_1 = mgh + 0$

$(0.6)\ \text{mg}\ (10) = mgh$

$h = 6\ \text{m}$

62. A bullet weighing 10 g and moving with a velocity 300 m/s strikes a 5 kg block of ice and drop dead. The ice block is kept on smooth surface. The speed of the block after the collision is

(1) 6 cm/s (2) 60 cm/s (3) 6 m/s (4) 0.6 cm/s

Sol. Answer (2)

Using conservation of momentum

$P_i = P_f$

$$\frac{10}{1000}.(300) = \left(5 + \frac{10}{1000}\right)v$$

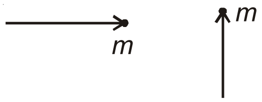
$$5 + \frac{10}{1000} \approx 5$$

So, $v = 0.6$ m/s Or 60 cm/s

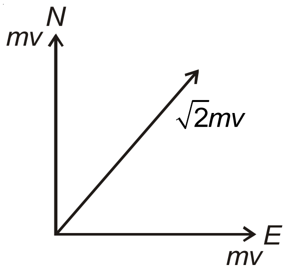
63. A particle of mass m moving eastward with a speed v collides with another particle of the same mass moving northwards with same speed v. The two particles coalesce on collision. The new particle of mass $2m$ will move with velocity

(1) $\frac{v}{2}$ North-East (2) $\frac{v}{\sqrt{2}}$ South-West (3) $\frac{v}{2}$ North-West (4) $\frac{v}{\sqrt{2}}$ North-East

Sol. Answer (4)



Using momentum conservation



$$2mv^1 = \sqrt{2}mv$$

$$v^1 = \frac{v}{\sqrt{2}} \quad \text{North-East}$$

64. Two perfectly elastic particles *A* and *B* of equal masses travelling along the line joining them with velocity 15 m/s and 10 m/s respectively, collide. Their velocities after the elastic collision will be (in m/s), respectively

(1) 0, 25 (2) 3, 20 (3) 10, 15 (4) 20, 5

Sol. Answer (3)

Velocities will interchange as mass is same and collision is elastic

$u_1 = 10$ m/s , $u_2 = 15$ m/s

$v_1 = 15$ m/s , $v_2 = 10$ m/s

65. Two balls of equal mass undergo head on collision while each was moving with speed 6 m/s. If the coefficient of restitution is $\frac{1}{3}$, the speed of each ball after impact will be

(1) 18 m/s (2) 2 m/s (3) 6 m/s (4) 4 m/s

Sol. Answer (2)

$$v = \frac{u}{2}(1-e)$$

$$= \frac{6}{2}\left(1-\frac{1}{3}\right)$$

$= 2$ m/s

66. Select the false statement

(1) In elastic collision, kinetic energy during the collision is not conserved

(2) The coefficient of restitution for a collision between two steel balls lies between zero and one

(3) The momentum of a ball colliding elastically with the floor is conserved

(4) In an oblique elastic collision between two identical bodies with initially one of them at rest, final velocities are perpendicular

Sol. Answer (3)

67. A ball of mass *M* moving with speed *v* collides perfectly inelastically with another ball of mass *m* at rest. The magnitude of impulse imparted to the first ball is

(1) Mv (2) mv (3) $\frac{Mm}{M+m}v$ (4) $\frac{M^2}{M+m}v$

Sol. Answer (3)

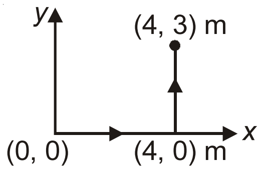
Impulse = Change in momentum of first ball

$$= \frac{Mmv}{M+m}$$

SECTION - B

Objective Type Questions

1. A force $\vec{F} = (3\vec{i} + 4\vec{j})$N acts on a particle moving in *x*-*y* plane. Starting from origin, the particle first goes along *x*-axis to the point (4, 0)m and then parallel to the *y*-axis to the point (4, 3)m. The total work done by the force on the particle is



(1) + 12 J (2) – 6 J (3) + 24 J (4) – 12 J

Sol. Answer (3)

$\vec{F} = 3\hat{i} + 4\hat{j}$

Displacement vector $(\vec{x}) = 4\hat{i} + 3\hat{j}$

$\vec{F}\,.\,\vec{x} = (3i + 4\hat{j}).(4\hat{i} + 3\hat{j})$

= 12 + 12 = 24 *J*

2. A body of mass *m* is allowed to fall with the help of string with downward acceleration $\frac{g}{6}$ to a distance *x*. The work done by the string is

(1) $\frac{mgx}{6}$ (2) $-\frac{mgx}{6}$ (3) $\frac{5mgx}{6}$ (4) $-\frac{5mgx}{6}$

Sol. Answer (4)

$mg - T = \frac{mg}{6}$

$\Rightarrow T = \frac{5}{6}mg$

$W = \frac{-5}{6}mgx$

3. A chain is on a frictionless table with one fifth of its length hanging over the edge. If the chain has length *L* and mass *M*, the work required to be done to pull the hanging part back onto the table is

(1) $\frac{MgL}{5}$ (2) $\frac{MgL}{50}$ (3) $\frac{MgL}{18}$ (4) $\frac{MgL}{10}$

Sol. Answer (2)

$\frac{1}{5}$ part is hanging, so C.M. is $\frac{L}{10}$ length below the table

$$W = \frac{m}{5}(8)\frac{L}{10} = \frac{MgL}{50}$$

4. A bullet of mass 20 g leaves a riffle at an initial speed 100 m/s and strikes a target at the same level with speed 50 m/s. The amount of work done by the resistance of air will be

(1) 100 J (2) 25 J (3) 75 J (4) 50 J

Sol. Answer (3)

W = Δk

$$W = \frac{1}{2}\frac{20}{1000}\left[(100)^2 - (50)^2\right]$$

$$= (150)\left(\frac{50}{100}\right) = 75J$$

5. A stone with weight *w* is thrown vertically upward into the air from ground level with initial speed v_0. If a constant force *f* due to air drag acts on the stone throughout its flight. The maximum height attained by the stone is

(1) $h = \frac{v_0^2}{2g\left(1+\frac{f}{w}\right)}$ (2) $h = \frac{v_0^2}{2g\left(1-\frac{f}{w}\right)}$ (3) $h = \frac{v_0^2}{2g\left(1+\frac{w}{f}\right)}$ (4) $h = \frac{v_0^2}{2g\left(1-\frac{w}{f}\right)}$

Sol. Answer (1)

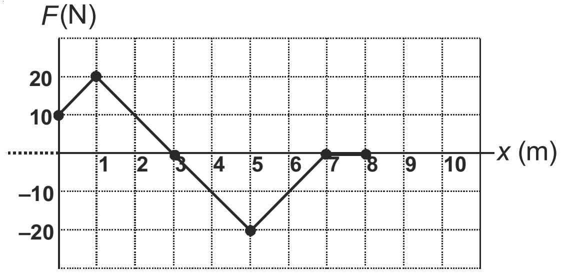
Using work energy theorem

$W_f + W_g = \Delta K$

$$-f.h - Wh = 0 - \frac{1}{2}m\,v_0^2$$

$$h = \frac{v_0^2}{2g\left(1+\frac{f}{w}\right)}$$

6. Figure shows the variation of a force *F* acting on a particle along *x*-axis. If the particle begins at rest at *x* = 0, what is the particle's coordinate when it again has zero speed?



(1) *x* = 3 (2) *x* = 6 (3) *x* = 5 (4) *x* = 7

Sol. Answer (2)

Using work energy thorem

$W_F = \Delta K$

$\int F dx = \Delta K$

Given that $\Delta K = 0$

$\Rightarrow \int F dx = 0$ (Area under $F - x$ curve)

Positive area = Negative area

So at $x = 6$ Total area = 0

7. A spring of force constant K is first stretched by distance a from its natural length and then further by distance b. The work done in stretching the part b is

(1) $\frac{1}{2}Ka(a-b)$ (2) $\frac{1}{2}Ka(a+b)$ (3) $\frac{1}{2}Kb(a-b)$ (4) $\frac{1}{2}Kb(2a+b)$

Sol. Answer (4)

$$W_1 = \frac{1}{2}kx^2 = \frac{1}{2}ka^2$$

$$W_2 = \frac{1}{2}k\left(a+b\right)^2$$

$$\Delta W = W_2 - W_1 = \frac{1}{2}kb\left(2a+b\right)$$

8. A knife of mass m is at a height x from a large wooden block. The knife is allowed to fall freely, strikes the block and comes to rest after penetrating distance y. The work done by the wooden block to stop the knife is

(1) mgx (2) $-mgy$ (3) $-mg(x+y)$ (4) $mg(x-y)$

Sol. Answer (3)

$W_{\text{all}} = \Delta K$

$W_g + W_{block} = 0$

$+mg(x+y) + W_{block} = 0$

$W_{block} = -mg(x+y)$

9. A man is running on horizontal road has half the kinetic energy of a boy of half of his mass. When man speeds up by 1 m/s, then his KE becomes equal to KE of the boy, the original speed of the man is

(1) $\sqrt{2}$ m/s (2) $\left(\sqrt{2}-1\right)$ m/s (3) 2 m/s (4) $\left(\sqrt{2}+1\right)$ m/s

Sol. Answer (4)

According to problem

$K_B = 2K_m$

$$\frac{1}{2}m_Bv_B^2 = 2\left(\frac{1}{2}m_mv_m^2\right)$$

$$\frac{1}{2}m_Bv_B^2 = 2\left(\frac{1}{2}m_m\left(v_m+1\right)^2\right)$$

Solving

$$v_m = \sqrt{2}+1 \text{ m/s}$$

10. A particle of mass m starts moving from origin along x-axis and its velocity varies with position (x) as $v = k\sqrt{x}$. The work done by force acting on it during first "t" seconds is

(1) $\frac{mk^4t^2}{4}$ (2) $\frac{mk^2t}{2}$ (3) $\frac{mk^4t^2}{8}$ (4) $\frac{mk^2t^2}{4}$

Sol. Answer (3)

$v = k\sqrt{x}$

Square both sides

$v^2 = k^2 x$ ...(1)

$v^2 = (0)^2 + 2ax$ ...(2)

Compare (1) and (2)

$2a = k^2$

$$a = \frac{k^2}{2}$$

Displacement $x = \frac{1}{2}at^2$

$$= \frac{1}{2}\frac{k^2}{2}t^2$$

W = Fx

= ma x

$$= \frac{mk^2}{2}.\frac{1}{2}\frac{k^2}{2}t^2$$

$$= \frac{mk^4t^2}{8}$$

11. A particle is moving in a circular path of radius r under the action of a force F. If at an instant velocity of particle is v, and speed of particle is increasing, then

(1) $\vec{F}.\vec{v} = 0$ (2) $\vec{F}.\vec{v} > 0$ (3) $\vec{F}.\vec{v} < 0$ (4) $\vec{F}.\vec{v} \geq 0$

Sol. Answer (2)

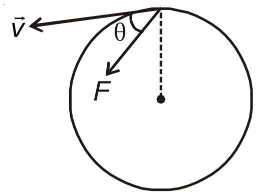
Net force will be in the direction of net acceleration.

Here accelerations are of two types

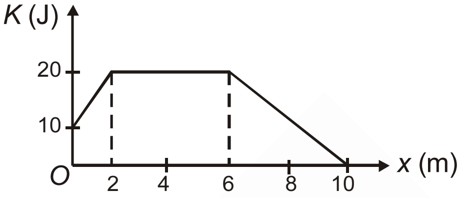
(i) Centripetal (ii) Tangential

$\theta < 90°$ always

$\Rightarrow \vec{F}\,.\,\vec{v} > 0$



12. The kinetic energy *K* of a particle moving along *x*-axis varies with its position (*x*) as shown in figure



The magnitude of force acting on particle at *x* = 9 m is

(1) Zero (2) 5 N (3) 20 N (4) 7.5 N

Sol. Answer (2)

Slope of *K*–*x* curve is *F*

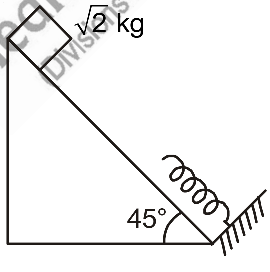
$Fdx = dK$

$F = \frac{dK}{dx}$

at *x* = 9 m, Slope of the curve is 5

Hence *F* = 5 *N*

13. A block of mass $\sqrt{2}$ kg is released from the top of an inclined smooth surface as shown in figure. If spring constant of spring is 100 N/m and block comes to rest after compressing the spring by 1 m, then the distance travelled by block before it comes to rest is



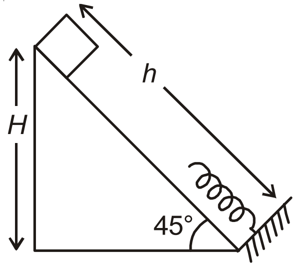
(1) 1 m (2) 1.25 m (3) 2.5 m (4) 5 m

Sol. Answer (4)

$U_i + k_i = U_f + k_f$

$(mgh \sin 45°) + 0 = \frac{1}{2}k(1)^2 + 0$

by solving *h* = 5m



14. If net force on a system is zero then

(1) Its momentum is conserved

(2) Its kinetic energy may increase

(3) The acceleration of its a constituent particle may be non-zero

(4) All of these

Sol. Answer (4)

Due to internal forces kinetic energy or acceleration of its constituent particle may be non-zero.

15. Internal forces acting within a system of particles can alter

(1) The linear momentum as well as the kinetic energy of the system

(2) The linear momentum of the system, but not the kinetic energy of the system

(3) The kinetic energy of the system, but not the linear momentum of the system

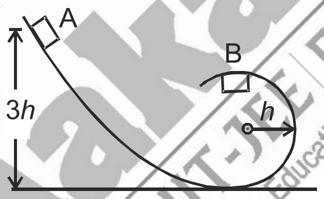
(4) Neither linear momentum nor kinetic energy of the system

Sol. Answer (3)

The kinetic energy of the system, but not the linear momentum of the system as

$F_{ext} = 0$. So momentum will be conserved

16. In the figure shown, a particle is released from the position A on a smooth track. When the particle reaches at B, then normal reaction on it by the track is



(1) mg (2) $2mg$ (3) $\frac{2}{3}mg$ (4) $\frac{m^2g}{h}$

Sol. Answer (1)

Using Mechanical energy conservation

$$mg(3h) = mg(2h) + \frac{1}{2}mu^2$$

$$mgh = \frac{1}{2}mv^2$$

$$v^2 = 2gh$$

$$mg + N = \frac{mv^2}{h} = \frac{m(2gh)}{h}$$

$N = mg$

17. A particle of mass m is projected with speed u at angle θ with horizontal from ground. The work done by gravity on it during its upward motion is

(1) $\frac{-mu^2\sin^2\theta}{2}$ (2) $\frac{mu^2\cos^2\theta}{2}$ (3) $\frac{mu^2\sin^2\theta}{2}$ (4) Zero

Sol. Answer (1)

Height covered by projectile $= \frac{u^2\sin^2\theta}{2g}$

$$W = -mg\left(\frac{u^2\sin^2\theta}{2g}\right)$$

$$= \frac{-mu^2\sin^2\theta}{2}$$

18. A shell at rest on *a* smooth horizontal surface explodes into two fragments of masses m_1 and m_2. If just after explosion m_1 move with speed u, then work done by internal forces during explosion is

(1) $\frac{1}{2}(m_1+m_2)\frac{m_2}{m_1}u^2$ (2) $\frac{1}{2}(m_1+m_2)u^2$ (3) $\frac{1}{2}m_1u^2\left(1+\frac{m_1}{m_2}\right)$ (4) $\frac{1}{2}(m_2-m_1)u^2$

Sol. Answer (3)

Using momentum conservation

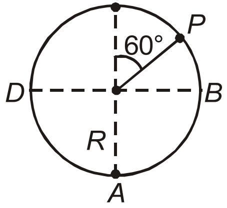
$m_1u = m_2v$

Now using work energy theorem

$$W = \frac{P_1^2}{2m_1}+\frac{P_2^2}{2m_2}$$

$$W = \frac{m_1^2u^2}{2}\left(\frac{m_1+m_2}{m_1m_2}\right)$$

19. A particle is moving along a vertical circle of radius R. At P, what will be the velocity of particle (assume critical condition at C)?



(1) $\sqrt{gR}$ (2) $\sqrt{2gR}$ (3) $\sqrt{3gR}$ (4) $\sqrt{\frac{3}{2}gR}$

Sol. Answer (2)

At critical condition at C

$$v = \sqrt{gR}$$

Using mechanical energy conservation between points P and C (taking P.E. = 0 at P)

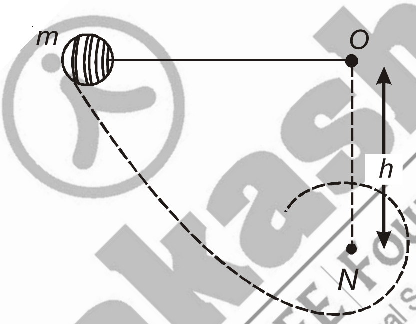
$$U_i + k_i = U_f + k_f$$

$$0 + \frac{1}{2}mv^2 = mgR(1 - \cos 60^\circ) + \frac{1}{2}m\left(\sqrt{gR}\right)^2$$

$$\frac{1}{2}mv^2 = \frac{mgR}{2} + \frac{mgR}{2}$$

$$v = \sqrt{2gR}$$

20. A particle of mass m attached to the end of string of length l is released from the horizontal position. The particle rotates in a circle about O as shown. When it is vertically below O, the string makes contact with a nail N placed directly below O at a distance h and rotates around it. For the particle to swing completely around the nail in a circle,



(1) $h < \frac{3}{5}l$ (2) $h \geq \frac{3}{5}l$ (3) $h < \frac{2}{5}l$ (4) $h \geq \frac{2}{5}l$

Sol. Answer (2)

Using mechanical energy conservation

$$mgl = \frac{1}{2}m\left(\sqrt{5g(l-h)}\right)^2$$

$$gl = \frac{5g(l-h)}{2}$$

$$2gl = 5gl - 5gh$$

$$h = \frac{3l}{5}$$

21. If $F = 2x^2 - 3x - 2$, then select the correct statement

(1) $x = -\frac{1}{2}$ is the position of stable equilibrium (2) $x = 2$ is the position of stable equilibrium

(3) $x = -\frac{1}{2}$ is the position of unstable equilibrium (4) $x = 2$ is the position of neutral equilibrium

Sol. Answer (1)

$F = 2x^2 - 3x - 2$

Putting $F = 0$

$2x^2 - 3x - 2 = 0$

$2x^2 - 4x + x - 2 = 0$

$2x(x - 2) + (x - 2) = 0$

$(x - 2)(2x + 1) = 0$

$$\Rightarrow x = 2, \quad x = \frac{-1}{2}$$

$$\frac{d^2v}{dx^2} = \frac{-dF}{dx} = -(4x - 3)$$

at $x = \frac{-1}{2}$

$$\frac{d^2v}{dx^2} > 0 \quad \Rightarrow \text{ Stable equilibrium}$$

22. When a conservative force does positive work on a body, then the

(1) Potential energy of body increases (2) Potential energy of body decreases

(3) Total mechanical energy of body increases (4) Total mechanical energy of body decreases

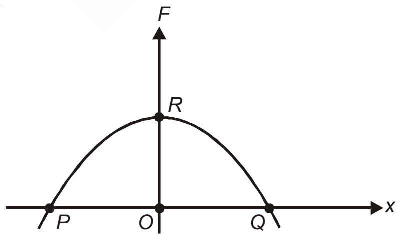
Sol. Answer (2)

$$F = \frac{-dU}{dx}$$

$$\int dU = -\int F dr$$

$\Rightarrow$ U will decrease

23. The variation of force F acting on a body moving along x-axis varies with its position (x) as shown in figure



The body is in stable equilibrium state at

(1) P (2) Q (3) R (4) Both P & Q

Sol. Answer (2)

$$F = \frac{-dU}{dx} \Rightarrow \frac{dF}{dx} = \frac{-d^2U}{dx^2}$$

If $\frac{dF}{dx} < O \Rightarrow \frac{d^2U}{dx^2} > O$ Point of minima and stable equilibrium

at $Q \frac{dF}{dx} < 0$ (Slope of $F - x$ curve)

So Q is point of stable equilibrium

24. A particle located in one dimensional potential field has potential energy function $U(x) = \frac{a}{x^2} - \frac{b}{x^3}$, where a and b are positive constants. The position of equilibrium corresponds to x =

(1) $\frac{3a}{2b}$ (2) $\frac{2b}{3a}$ (3) $\frac{2a}{3b}$ (4) $\frac{3b}{2a}$

Sol. Answer (4)

$$U = \frac{a}{x^2} - \frac{b}{x^3}$$

$$F = \frac{-dU}{dx} = 0 \text{ at equilibrium}$$

$$\frac{dU}{dx} = \frac{-2a}{x^3} + \frac{3b}{x^4} = 0$$

$$x = \frac{3b}{2a}$$

25. The force required to row a boat at constant velocity is proportional to square of its speed. If a speed of v km/h requires 4 kW, how much power does a speed of $2v$ km/h require?

(1) 8 kW (2) 16 kW (3) 24 kW (4) 32 kW

Sol. Answer (4)

$F \alpha v^2$

$P = F.\, v$, So $P \alpha v^3$

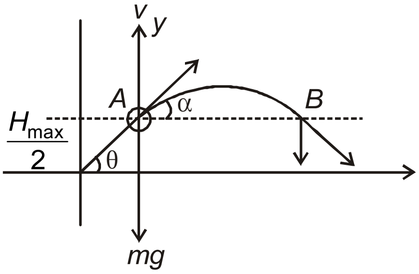
$$\frac{P_1}{P_2} = \frac{4}{P_2} = \frac{v^3}{8v^3}$$

$\Rightarrow P_2 = 32$ kW

26. A body of mass m is projected from ground with speed u at an angle θ with horizontal. The power delivered by gravity to it at half of maximum height from ground is

(1) $\frac{mgu\cos\theta}{\sqrt{2}}$ (2) $\frac{mgu\sin\theta}{\sqrt{2}}$ (3) $\frac{mgu\cos(90+\theta)}{\sqrt{2}}$ (4) Both (2) & (3)

Sol. Answer (4)



$$H_{max} = \frac{u^2 \sin^2\theta}{2g}$$

$$v_y^2 = (u\sin\theta)^2 - \frac{2gu^2\sin^2\theta}{4g}$$

$$v_y = \frac{u\sin\theta}{\sqrt{2}}$$

At point A,

$$\vec{P} = \vec{F}\,.\vec{V} = (mg)\left(\frac{u\sin\theta}{\sqrt{2}}\right)\cos\pi = \frac{-mgu\sin\theta}{\sqrt{2}}$$

At point *B*,

$$\vec{P} = \frac{+umg\sin\theta}{\sqrt{2}}$$

27. A particle of mass *m* moves in a circular path of radius *r*, under the action of force which delivers it constant power *p* and increases its speed. The angular acceleration of particle at time (*t*) is proportional

(1) $\frac{1}{\sqrt{t}}$ (2) $\sqrt{t}$ (3) t^0 (4) $t^{3/2}$

Sol. Answer (1)

Work = *Pt*

Using *W* = Δ*K*

$$Pt = \frac{1}{2}m(rw)^2$$

$$Pt = \frac{1}{2}mr^2w^2$$

$$Pt = \frac{1}{2}mr^2\alpha^2t^2 \qquad \left(\because \alpha = \frac{w}{t}\right)$$

So $\alpha^2 \propto \frac{1}{t} \Rightarrow \alpha \propto \frac{1}{\sqrt{t}}$

28. The rate of doing work by force acting on a particle moving along x-axis depends on position x of particle and is equal to $2x$. The velocity of particle is given by expression

(1) $\left[\dfrac{3x^2}{m}\right]^{1/3}$ (2) $\left[\dfrac{3x^2}{2m}\right]^{1/3}$ (3) $\left(\dfrac{2mx}{9}\right)^{1/2}$ (4) $\left[\dfrac{mx^2}{3}\right]^{1/2}$.

Sol. Answer (1)

$$P = \frac{F.dx}{dt}$$

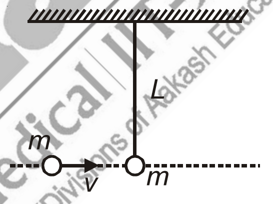
$$= m\left(\frac{vdv}{dx}\right)v = 2x$$

$$m\int v^2 dv = \int 2x dx$$

$$\frac{mv^3}{3} = x^2$$

$$v = \left(\frac{3x^2}{m}\right)^{\frac{1}{3}}$$

29. A small ball of mass m moving with speed v $(< \sqrt{2gL})$ undergoes an elastic head on collision with a stationary bob of identical mass of a simple pendulum of length L. The maximum height h, from the equilibrium position, to which the bob rises after collision is



(1) $\dfrac{v^2}{2g}$ (2) $\dfrac{v^2}{4g}$ (3) $\dfrac{v^2}{8g}$ (4) $\dfrac{3v^2}{8g}$

Sol. Answer (1)

$$\frac{1}{2}mv^2 = mgh$$

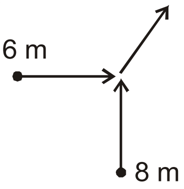
$$h = \frac{v^2}{2g}$$

30. Two balls of masses m each are moving at right angle to each other with velocities 6 m/s and 8 m/s respectively. If collision between them is perfectly inelastic, the velocity of combined mass is

(1) 15 m/s (2) 10 m/s (3) 5 m/s (4) 2.5 m/s

Sol. Answer (3)

Using momentum conservation



$m\sqrt{6^2+8^2} = 2mv^1$

v^1 = 5 m/s

31. A sphere of mass *m* moving with a constant velocity *u* hits another stationary sphere of the same mass. If *e* is the coefficient of restitution, then ratio of velocities of the two spheres after collision will be

(1) $\frac{1-e}{1+e}$ (2) $\frac{2+e}{2-e}$ (3) $\left(\frac{1+e}{1-e}\right)^2$ (4) $\left(\frac{1-e}{1+e}\right)^2$

Sol. Answer (1)

$v_1 = \frac{u}{2}(1+e)$

$v_2 = \frac{u}{2}(1-e)$

$\frac{v_2}{v_1} = \frac{1-e}{1+e}$

32. A neutron travelling with a velocity collides elastically, head on, with a nucleus of an atom of mass number *A* at rest. The fraction of total energy retained by neutron is

(1) $\left(\frac{A-1}{A+1}\right)^2$ (2) $\left(\frac{A+1}{A-1}\right)^2$ (3) $\left(\frac{A-1}{A}\right)^2$ (4) $\left(\frac{A+1}{A}\right)^2$

Sol. Answer (1)

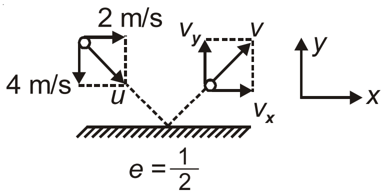
$v_1 = \left(\frac{m_1-m_2}{m_1+m_2}\right)u = v\left(\frac{A-1}{A+1}\right)$

Initial energy = $\frac{1}{2}(1)v^2$

Final energy = $\frac{1}{2}(1)v_1^2 = \frac{1}{2}(1)\left(\frac{A-1}{A+1}\right)^2$

Fraction of total energy retained = $\frac{\textit{Final energy}}{\textit{Initial energy}}$

33. In the figure shown, a small ball hits obliquely a smooth and horizontal surface with speed u whose x and y components are indicated. If the coefficient of restitution is $\frac{1}{2}$, then its x and y components v_x and v_y just after collision are respectively



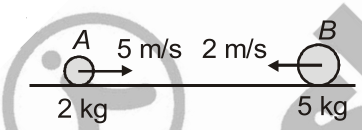
(1) 4 m/s, 1 m/s (2) 2 m/s, 1 m/s (3) 2 m/s, 2 m/s (4) 4 m/s, 2 m/s

Sol. Answer (3)

$v_y = eu_y = \frac{1}{2} \times 4 = 2\text{ m/s}$

$v_x = u_x = 2$ m/s

34. Velocity of the ball A after collision with the ball B as shown in the figure is (Assume perfectly inelastic and head-on collision)



(1) $\frac{3}{7}$ m/s (2) $\frac{5}{7}$ m/s (3) $\frac{1}{7}$ m/s (4) Zero

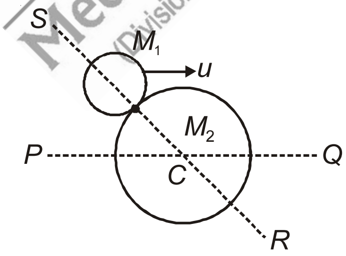
Sol. Answer (4)

Using momentum conservation

$10 - 10 = 2\, mv^1$

$\Rightarrow v^1 = 0$

35. An object of mass M_1 moving horizontally with speed u collides elastically with another object of mass M_2 at rest. Select correct statement.



(1) The momentum of system is conserved only in direction PQ

(2) Momentum of M_1 is conserved in direction perpendicular to SR

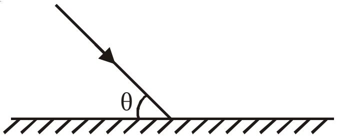
(3) Momentum of M_2 will change in direction normal to CR

(4) All of these

Sol. Answer (2)

Momentum $(\vec{P})$ of mass M_1 is conserved in direction $\perp$ to SR

36. A ball of mass m moving with speed u collides with a smooth horizontal surface at angle θ with it as shown in figure. The magnitude of impulse imparted to surface by ball is [Coefficient of restitution of collision is e]



(1) $mu(1 + e)\cos\theta$ (2) $mu(1 - e)\sin\theta$ (3) $mu(1 - e)\cos\theta$ (4) $mu(1 + e)\sin\theta$

Sol. Answer (4)

$$u_y = -u\sin\theta\hat{j}$$

$$\vec{v}_y = +eu\sin\theta\hat{j}$$

$$\vec{I} = m\left(\vec{v}_y - \vec{u}_y\right)$$

$$= mu(e + 1)\sin\theta$$

37. A body of mass m falls from height h on ground. If e be the coefficient of restitution of collision between the body and ground, then the distance travelled by body before it comes to rest is

(1) $h\left\{\frac{1+e^2}{1-e^2}\right\}$ (2) $h\left\{\frac{1-e^2}{1+e^2}\right\}$ (3) $\frac{2eh}{1+e^2}$ (4) $\frac{2eh}{1-e^2}$

Sol. Answer (1)

$S = h + 2e^2h + 2e^4h + ...$

$S = h + 2h\ [e^2 + e^4 + e^6 + ...]$

$$S = h + 2h\left[\frac{e^2}{1-e^2}\right]$$

Solving

$$S = \frac{h\left(1+e^2\right)}{\left(1-e^2\right)}$$

38. The PE of a 2 kg particle, free to move along x-axis is given by $V(x) = \left(\frac{x^3}{3} - \frac{x^2}{2}\right)$ J. The total mechanical energy of the particle is 4 J. Maximum speed (in ms^{-1}) is

(1) $\frac{1}{\sqrt{2}}$ (2) $\sqrt{2}$ (3) $\frac{3}{\sqrt{2}}$ (4) $\frac{5}{\sqrt{6}}$

Sol. Answer (4)

$$U(x)=\frac{x^3}{3}-\frac{x^2}{2} \qquad \ldots(1)$$

$$F=\frac{-dU}{dx}=\frac{3x^2}{3}-\frac{2x}{2}=0$$

$x^2 - x = 0$

$\Rightarrow x = 1, 0$

Potential energy is minimum at x = 1 m and the value of this minimum P.E. will be

U = $\frac{-1}{6}J$ (Putting x = 1 in (1))

Now, $E = U + K$

Kinetic energy will be maximum, when potential energy will be minimum

$$4=\frac{-1}{6}+K$$

$$K=\frac{25}{6}$$

$$\frac{1}{2}mv_m^2=\frac{25}{6}$$

$$v_m=\frac{5}{\sqrt{6}}$$

39. A bullet of mass *m* moving with velocity *v* strikes a suspended wooden block of mass *M*. If the block rises to height *h*, then the initial velocity *v* of the bullet must have been

(1) $\sqrt{2gh}$ (2) $\frac{M+m}{m}\sqrt{2gh}$ (3) $\frac{m}{M+m}\sqrt{2gh}$ (4) $\frac{M+m}{M}\sqrt{2gh}$

Sol. Answer (2)

Using momentum conservation

$mu + 0 = (M + m)\, v^1$

$$v^1=\frac{mu}{M+m}$$

Now block reaches to height *h*, using energy conservation.

$v^1=\sqrt{2gh}$

So in (1) $u=\frac{M+m}{m}\sqrt{2gh}$

SECTION - C

Previous Years Questions

1. The angle between the two vectors $\vec{A} = 3\hat{i} + 4\hat{j} + 5\hat{k}$ and $\vec{B} = 3\hat{i} + 4\hat{j} - 5\hat{k}$ will be

(1) 90° (2) 180° (3) Zero (4) 45°

Sol. Answer (1)

$$cos\theta = \frac{\vec{a}.\vec{b}}{|\vec{a}||\vec{b}|}$$

$$\vec{A}.\vec{B} = \left(3\hat{i} + 4\hat{j} + 5\hat{k}\right).\left(3\hat{i} + 4\hat{j} - 5\hat{k}\right)$$

$= 9 + 16 – 25 = 0$

$\Rightarrow$ *A* and *B* are perpendicular

2. Vectors $\vec{A}, \vec{B}$ and $\vec{C}$ are such that $\vec{A}\cdot\vec{B} = 0$ and $\vec{A}\cdot\vec{C} = 0$. Then the vector parallel to $\vec{A}$ is

(1) $\vec{B}$ and $\vec{C}$ (2) $\vec{A}\times\vec{B}$ (3) $\vec{B}+\vec{C}$ (4) $\vec{B}\times\vec{C}$

Sol. Answer (4)

Given that

$\vec{A}\,.\,\vec{B} = 0,\ \vec{A}\,.\,\vec{C} = 0$

$\Rightarrow$ A is perpendicular to both $\vec{B}$ and $\vec{C}$ and $\vec{B}\times\vec{C}$ will be a vector which is perpendicular to both $\vec{B}$ and $\vec{C}$, hence $\vec{A} \parallel \vec{B}\times\vec{C}$

3. If a unit vector is represented by $0.5\hat{i} - 0.8\hat{j} + c\hat{k}$ then the value of *c* is

(1) $\sqrt{0.01}$ (2) $\sqrt{0.11}$ (3) 1 (4) $\sqrt{0.39}$

Sol. Answer (2)

Magnitude of unit vector will be 1

$$\sqrt{(0.5)^2 + (0.8)^2 + c^2} = 1$$

$0.25 + 0.64 + c^2 = 1$

$c^2 = 0.11$

$c = \sqrt{0.11}$

4. If a vector $2\hat{i} + 3\hat{j} + 8\hat{k}$ is perpendicular to the vector $4\hat{j} - 4\hat{i} + \alpha\hat{k}$, then the value of α is

(1) $\frac{1}{2}$ (2) $-\frac{1}{2}$ (3) 1 (4) –1

Sol. Answer (2)

$\vec{a}.\vec{b} = 0$

$8 - 12 + 8\alpha = 0$

$\alpha = -\frac{1}{2}$

5. A uniform force of $\left(3\hat{i} + \hat{j}\right)$ newton acts on a particle of mass 2 kg. Hence the particle is displaced from position $\left(2\hat{i} + \hat{k}\right)$ metre to position $\left(4\hat{i} + 3\hat{j} - \hat{k}\right)$ metre. The work done by the force on the particle is

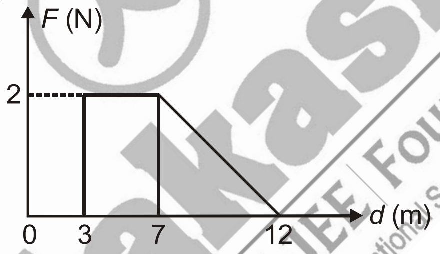
(1) 6 J (2) 13 J (3) 15 J (4) 9 J

Sol. Answer (4)

$W = \left(3\hat{i} + \hat{j}\right).\left(2i + 3\hat{j} - 2\hat{k}\right)$

$= 6 + 3 = 9$

6. Force *F* on a particle moving in a straight line varies with distance *d* as shown in the figure. The work done on the particle during its displacement of 12 m is



(1) 13 J (2) 18 J (3) 21 J (4) 26 J

Sol. Answer (1)

Work done will be area under *F*-*x* curve

$W = \frac{1}{2} \times 5(2) + 4 \times 2$

$= 13$ J

7. The work done by an applied variable force $F = x + x^3$ from $x = 0$ m to $x = 2$ m, where x is displacement, is

(1) 6 J (2) 8 J (3) 10 J (4) 12 J

Sol. Answer (1)

$F = x + x^3$

$$W = \int_0^2 \left(x + x^3\right).dx = \left[\frac{x^2}{2} + \frac{x^4}{4}\right]^2$$

$= 6$ J

8. When a body moves with a constant speed along a circle

(1) No work is done on it (2) No acceleration is produced in it

(3) Its velocity remains constant (4) No force acts on it

Sol. Answer (1)

Displacement is zero, hence no work is done.

9. A position dependent force, $F = (7 - 2x + 3x^2)$ N acts on a small body of mass 2 kg and displaces it from $x = 0$ to $x = 5$ m. The work done in joules is

(1) 135 (2) 270 (3) 35 (4) 70

Sol. Answer (1)

$$W = \int F.dx = \int\left(7 - 2x + 3x^2\right).dx$$

$$= \left[7x - \frac{2x^2}{2} + \frac{3x^3}{3}\right]_0^5 = 135 \text{ J}$$

10. A body, constrained to move in y-direction, is subjected to a force given by $\vec{F} = \left(-2\hat{i} + 15\hat{j} + 6\hat{k}\right)$N. The work done by this force in moving the body through a distance of 10 m along positive y-axis, is

(1) 150 J (2) 20 J (3) 190 J (4) 160 J

Sol. Answer (1)

$$\vec{F} = -2\hat{i} + 15\hat{j} + 6\hat{k}$$

$$\vec{S} = 10\hat{j}$$

$$W = \vec{F}.\vec{S}$$

$$= \left(-2i + 15\hat{j} + 6\hat{k}\right).\left(10\hat{j}\right)$$

$$= 150 \text{ J}$$

11. A body moves a distance of 10 m along a straight line under the action of a 5 N force. If the work done is 25 J, then angle between the force and direction of motion of the body is

(1) 60° (2) 75° (3) 30° (4) 45°

Sol. Answer (1)

$Fs \cos\theta = 25$

$5(10) \cos\theta = 25$

$$\cos\theta = \frac{1}{2}$$

$\theta = 60°$

12. A force acts on a 3 g particle in such a way that the position of the particle as a function of time is given by $x = 3t - 4t^2 + t^3$, where x is in metres and t is in seconds. The work done during the first 4 second is

(1) 490 mJ (2) 450 mJ (3) 576 mJ (4) 528 mJ

Sol. Answer (4)

$x = 3t - 4t^2 + t^3$

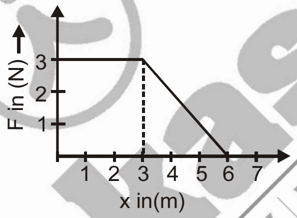
$$\frac{dx}{dt} = v = 3 - 8t + 3t^2$$

$W = \Delta K$

$$W = \frac{1}{2} \times \frac{3}{1000}\left[3 - 8(4) + 3(4)^2\right]^2$$

$= 528$ mJ

13. A force F acting on an object varies with distance x as shown here. The force is in N and x in m. The work done by the force in moving the object from $x = 0$ to $x = 6$ m is



(1) 18.0 J (2) 13.5 J (3) 9.0 J (4) 4.5 J

Sol. Answer (2)

Work will be area under F-x curve

So, $W = 3(3) + \frac{1}{2}(3)(3) = 13.5$ J

14. A body of mass 3 kg is under a constant force which causes a displacement s in metres in it, given by the relation $s = \frac{1}{3}t^2$, where t is in second. Work done by the force in 2 second is

(1) $\frac{19}{5}$ J (2) $\frac{5}{19}$ J (3) $\frac{3}{8}$ J (4) $\frac{8}{3}$ J

Sol. Answer (4)

$$S = \frac{1}{3}t^2 \qquad \Rightarrow v = \frac{2t}{3}$$

$$W = \frac{1}{2} \times 3\left(\frac{4}{3}\right)^2 = \frac{8}{3}\text{ J}$$

15. 300 J of work is done in sliding a 2 kg block up an inclined plane of height 10 m. Taking g = 10 m/s^2, work done against friction is

(1) 1000 J (2) 200 J (3) 100 J (4) Zero

Sol. Answer (3)

$3w = w_f + 2\,(10)\,(10)$

$w_f = 100$ J

16. Two bodies of masses m and $4m$ are moving with equal K.E. The ratio of their linear momenta is

(1) 1 : 2 (2) 1 : 4 (3) 4 : 1 (4) 1 : 1

Sol. Answer (1)

$$P = \sqrt{2mk}$$

$$\frac{P_1}{P_2} = \sqrt{\frac{m}{4m}} = 1:2$$

17. One kilowatt hour is equal to

(1) 36 × 10^{-5} J (2) 36 × 10^5 J (3) 36 × 10^7 J (4) 36 × 10^3 J

Sol. Answer (2)

1 kW hr = 36 × 10^5 J

18. Two bodies with kinetic energies in the ratio of 4 : 1 are moving with equal linear momentum. The ratio of their masses is

(1) 4 : 1 (2) 1 : 1 (3) 1 : 2 (4) 1 : 4

Sol. Answer (4)

$$\frac{K_1}{K_2} = \frac{P_1^2.2m_2}{2m_1.P_2^2} \qquad (P_1 = P_2 \text{ given})$$

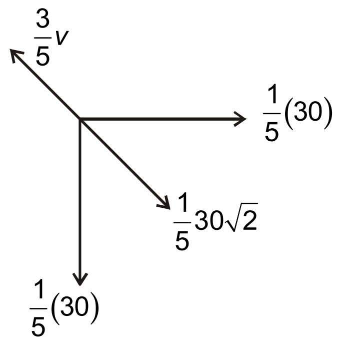
$$\Rightarrow \frac{K_1}{K_2} = \frac{m_2}{m_1} = \frac{4}{1} \quad \Rightarrow \frac{m_1}{m_2} = \frac{1}{4}$$

19. A 1 kg stationary bomb is exploded in three parts having masses in ratio 1 : 1 : 3 respectively. Parts having same mass move in perpendicular direction with velocity 30 m/s, then the velocity of bigger part will be

(1) $10\sqrt{2}$ m/s (2) $\frac{10}{\sqrt{2}}$ m/s (3) $15\sqrt{2}$ m/s (4) $\frac{15}{\sqrt{2}}$ m/s

Sol. Answer (1)

Momentum will be conserved.



$$\frac{3}{5}v = \frac{30}{5}\sqrt{2}$$

20. If kinetic energy of a body is increased by 300% then percentage change in momentum will be

(1) 100% (2) 150% (3) 265% (4) 73.2%

Sol. Answer (1)

$$k^1 = 4k = \frac{\left(P^1\right)^2}{2m}$$

$P^1 = 2P$

$\Rightarrow$ 100% increase

21. A stationary particle explodes into two particles of masses m_1 and m_2 which move in opposite directions with velocities v_1 and v_2. The ratio of their kinetic energies $\frac{E_1}{E_2}$ is

(1) $\frac{m_2}{m_1}$ (2) $\frac{m_1}{m_2}$ (3) 1 (4) $\frac{m_1 v_2}{m_2 v_1}$

Sol. Answer (1)

22. A particle of mass m_1 is moving with a velocity v_1 and another particle of mass m_2 is moving with a velocity v_2. Both of them have the same momentum but their different kinetic energies are E_1 and E_2 respectively. If $m_1 > m_2$, then

(1) $E_1 < E_2$ (2) $\frac{E_1}{E_2} = \frac{m_1}{m_2}$ (3) $E_1 > E_2$ (4) $E_1 = E_2$

Sol. Answer (1)

$E \propto \frac{1}{m}$ $\qquad m_1 > m_2 \Rightarrow E_1 < E_2$

23. A bomb of mass 30 kg at rest explodes into two pieces of masses 18 kg and 12 kg. The velocity of 18 kg mass is 6 ms^{-1}. The kinetic energy of the other mass is

(1) 324 J (2) 486 J (3) 256 J (4) 524 J

Sol. Answer (2)

Using momentum conservation

$0 = 18(6) + 12\,(v)$

$$v = \frac{-18(6)}{12} = -9 \text{ m/s}$$

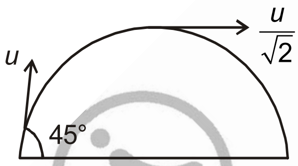
$$K.E. = \frac{1}{2}(12)(9)^2 = 486 \text{ J}$$

24. A ball whose kinetic energy is E is thrown at an angle of 45° with the horizontal. Its K.E. at the highest point of its flight will be

(1) $\frac{E}{\sqrt{2}}$ (2) Zero (3) E (4) $\frac{E}{2}$

Sol. Answer (4)

$$E = \frac{1}{2}mu^2$$



$$E^1 = \frac{1}{2}m\left(\frac{u}{\sqrt{2}}\right)^2$$

$$= \frac{E}{2}$$

25. A shell of mass 200 gm is ejected from a gun of mass 4 kg by an explosion that generates 1.05 kJ of energy. The initial velocity of the shell is

(1) 120 ms^{-1} (2) 100 ms^{-1} (3) 80 ms^{-1} (4) 40 ms^{-1}

Sol. Answer (2)

Using momentum conservation

$0 = (0.2)v + 4v_1$

$$v_1 = \frac{-0.2v}{4}$$

Total energy produced = 1.05 kJ

$$\frac{1}{2}(0.2)v^2 + \frac{1}{2}(4)v_1^2 = 1050$$

$$\frac{1}{2}(0.2)v^2 + \frac{1}{2}(4)\left(\frac{0.2v}{4}\right)^2 = 1050$$

$\Rightarrow v = 100$ m/s

26. A body dropped from a height h with initial velocity zero, strikes the ground with a velocity 3 m/s. Another body of same mass is thrown from the same height h with an initial velocity of 4 m/s. Find the final velocity of second mass, with which it strikes the ground.

(1) 5 m/s (2) 12 m/s (3) 3 m/s (4) 4 m/s

Sol. Answer (3)

$$v = \sqrt{2gh} \qquad h = \frac{v^2}{20} = \frac{9}{20}$$

Now for second case

$$v^2 = u^2 - 2gh = 16 - 20.\frac{9}{20} = 9$$

$v = 3$ m/s

27. A particle with total energy E is moving in a potential energy region $U(x)$. Motion of the particle is restricted to the region when

(1) $U(x) > E$ (2) $U(x) < E$ (3) $U(x) = 0$ (4) $U(x) \le E$

Sol. Answer (4)

Particle will be restricted to the region till when K.E. > 0

Using mechanical energy conservation

$E = k + U$

$E - U = k \ge 0$

$E \ge U$

28. The potential energy of a system increases if work is done

(1) Upon the system by a conservative force (2) Upon the system by a non-conservative force

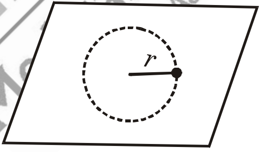
(3) By the system against a conservative force (4) By the system against a non-conservative force

Sol. Answer (3)

$$dU = -\int \vec{F}_c .dx$$

where $\vec{F}_c$ is conservative force.

29. A small mass attached to a string rotates on a frictionless table top as shown. If the tension in the string is increased by pulling the string causing the radius of the circular motion to decrease by a factor of 2, the kinetic energy of the mass will



(1) Increase by a factor of 4 (2) Decrease by a factor of 2

(3) Remain constant (4) Increase by a factor of 2

Sol. Answer (1)

Using angular momentum conservation

$I_1 w_1 = I_2 w_2$

$$mr^2 w = m\left(\frac{r}{2}\right)^2 w_2$$

$w_2 = 4\,w$

$$E = \frac{1}{2}mr^2w^2, \qquad E^1 = \frac{1}{2}m\frac{r^2}{4}\left(16w^2\right)$$

$E^1 = 4E$

30. The kinetic energy acquired by a mass m in travelling distance d, starting from rest, under the action of a constant force is directly proportional to

(1) m (2) m^0 (3) $\sqrt{m}$ (4) $1/\sqrt{m}$

Sol. Answer (2)

$v^2 = u^2 + 2as$

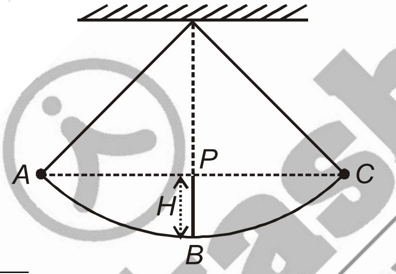
$u = 0,\ a = \frac{F}{m}$

$v^2 = \frac{2F}{m}d$

$K.E. = \frac{1}{2}mv^2 = \frac{1}{2}.m\frac{2F}{m}d = Fd$

So $K.E. \propto m^0$

31. A simple pendulum with a bob of mass m oscillates from A to C and back to A such that PB is H. If the acceleration due to gravity is g, then the velocity of the bob as it passes through B is



(1) mgH (2) $\sqrt{2gH}$ (3) Zero (4) $2gH$

Sol. Answer (2)

Using energy conservation

$\frac{1}{2}mv^2 = mgH$

$v = \sqrt{2gH}$

32. A car moving with a speed of 40 km/h can be stopped by applying brakes after at least 2 m. If the same car is moving with a speed of 80 km/h, what is the minimum stopping distance?

(1) 4 m (2) 6 m (3) 8 m (4) 2 m

Sol. Answer (3)

$v^2 = u^2 - 2as$

$0 = 1600 - 2a\,(2)$

$a = \frac{1600}{4}\left(\frac{5}{18}\right)^2$ ...(1)

Again using $v^2 = u^2 - 2as$

Using a from (1)

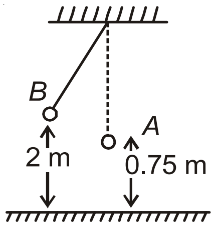
$S = 8\text{m}$

33. A child is sitting on a swing. Its minimum and maximum heights from the ground are 0.75 m and 2 m respectively, its maximum speed will be

(1) 10 m/s (2) 5 m/s (3) 8 m/s (4) 15 m/s

Sol. Answer (2)

Using energy conservation at *A* and *B*



$U_i + k_i = U_f + k_f$

$$0+\frac{1}{2}mv^2 = mg(2-0.75)+0$$

$v^2 = 2g\ (1.25)$

$v^2 = 25 \quad \Rightarrow \quad v = 5$ m/s

34. When a long spring is stretched by 2 cm, its potential energy is *U*. If the spring is stretched by 10 cm, the potential energy stored in it will

(1) $\frac{U}{5}$ (2) 5*U* (3) 10*U* (4) 25*U*

Sol. Answer (4)

$$U = \frac{1}{2}kx^2$$

$$U = \frac{1}{2}k(4) \Rightarrow k = \frac{U}{2}$$

$$U' = \frac{1}{2}k(10)^2$$

$$= \frac{1}{2}\cdot\frac{U}{2}\cdot 100$$

= 25 U

35. A ball of mass 2 kg and another of mass 4 kg are dropped together from a 60 feet tall building. After a fall of 30 feet each towards earth, their respective kinetic energies will be in the ratio of

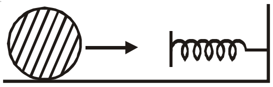
(1) $\sqrt{2}:1$ (2) 1 : 4 (3) 1 : 2 (4) $1:\sqrt{2}$

Sol. Answer (3)

$$\frac{v_1}{v_2} = \frac{\sqrt{2gh}}{\sqrt{2gh}} \Rightarrow v_1 = v_2$$

$$\frac{K.E_1}{k.E_2} = \frac{\frac{1}{2}m_1v_1^2}{\frac{1}{2}m_2v_2^2} = \frac{2}{4} = \frac{1}{2}$$

36. A mass of 0.5 kg moving with a speed of 1.5 m/s on a horizontal smooth surface, collides with a nearly weightless spring of force constant k = 50 N/m. The maximum compression of the spring would be



(1) 0.15 m (2) 0.12 m (3) 1.5 m (4) 0.5 m

Sol. Answer (1)

$U_i + k_i = U_f + k_f$

$$0+\frac{1}{2}(0.5)(1.5)^2=\frac{1}{2}(50)x^2+0$$

x = 0.15 m

37. A vertical spring with force constant k is fixed on a table. A ball of mass m at a height h above the free upper end of the spring falls vertically on the spring so that the spring is compressed by a distance d. The net work done in the process is

(1) $mg(h+d)-\frac{1}{2}kd^2$ (2) $mg(h-d)-\frac{1}{2}kd^2$ (3) $mg(h-d)+\frac{1}{2}kd^2$ (4) $mg(h+d)+\frac{1}{2}kd^2$

Sol. Answer (1)

$W = W_g + W_{spring}$

$= mg(h + d) - \frac{1}{2}kd^2$

38. A body of mass 1 kg is thrown upwards with a velocity 20 m/s. It momentarily comes to rest after attaining a height of 18 m. How much energy is lost due to air friction? (g = 10 m/s^2)

(1) 10 J (2) 20 J (3) 30 J (4) 40 J

Sol. Answer (2)

$W_{all} = \Delta k$

$$W_f+W_g=\frac{1}{2}(1)(20)^2$$

$W_f + mg(18) = 200$

$W_f = 200 - 180$

$= 20$ J

39. Water falls from a height of 60 m at the rate of 15 kg/s to operate a turbine. The losses due to frictional forces are 10% of energy. How much power is generated by the turbine? (g = 10 m/s^2)

(1) 7.0 kW (2) 8.1 kW (3) 10.2 kW (4) 12.3 kW

Sol. Answer (2)

Energy per unit time on the turbine = $\left(\frac{dm}{dt}\right)60(g)$

= 15(60)(10)

= 9000 J/s

Losses per second = $9000\times\frac{10}{100}$ = 900 J/s

So, net power supplied = 9000 – 900 = 8100 J/s

= 8.1 kW

40. One coolie takes 1 minute to raise a suitcase through a height of 2 m but the second coolie takes 30 s to raise the same suitcase to the same height. The powers of two coolies are in the ratio

(1) 1 : 2 (2) 1 : 3 (3) 2 : 1 (4) 3 : 1

Sol. Answer (1)

$$\frac{P_1}{P_2}=\frac{\frac{W}{t_1}}{\frac{W}{t_2}}=\frac{t_2}{t_1}=\frac{1}{2}$$

41. A car of mass *m* starts from rest and accelerates so that the instantaneous power delivered to the car has a constant magnitude P_0. The instantaneous velocity of this car is proportional to

(1) t^2P_0 (2) $t^{1/2}$ (3) $t^{-1/2}$ (4) $\frac{t}{\sqrt{m}}$

Sol. Answer (2)

$$W=Pt=\frac{1}{2}mv^2$$

$$v^2\propto t\Rightarrow v\propto t^{\frac{1}{2}}$$

42. A body projected vertically from the earth reaches a height equal to earth's radius before returning to the earth. The power exerted by the gravitational force is greatest

(1) At the instant just after the body is projected

(2) At the highest position of the body

(3) At the instant just before the body hits the earth

(4) It remains constant all through

Sol. Answer (3)

At the instant of projection velocity will be maximum and will be same just before the body hits the earth. But initially power will be negative, whereas the time of hitting it will be positive.

43. If a force of 9 N is acting on a body, then find instantaneous power supplied to the body when its velocity is 5 m/s in the direction of force

(1) 195 watt (2) 45 watt (3) 75 watt (4) 100 watt

Sol. Answer (2)

$P = FV = 9(5) = 45$ W

44. An engine pumps water through a hose pipe. Water passes through the pipe and leaves it with a velocity of 2 m/s. The mass per unit length of water in the pipe is 100 kg/m. What is the power of the engine?

(1) 800 W (2) 400 W (3) 200 W (4) 100 W

Sol. Answer (1)

$$P = FV = v^2\frac{dm}{dt} = (2)^2(100\times 2) = 800\text{ W}$$

45. A particle of mass M starting from rest undergoes uniform acceleration. If the speed acquired in time T is V, the power delivered to the particle is

(1) $\frac{MV^2}{T}$ (2) $\frac{1}{2}\frac{MV^2}{T^2}$ (3) $\frac{MV^2}{T^2}$ (4) $\frac{1}{2}\frac{MV^2}{T}$

Sol. Answer (4)

$$W = \frac{1}{2}mv^2$$

$$\frac{W}{T} = \frac{1}{2}\frac{mv^2}{T}$$

$$P = \frac{mv^2}{2T}$$

46. An engine pumps water continuously through a hose. Water leaves the hose with a velocity v and m is the mass per unit length of the water jet. What is the rate at which kinetic energy is imparted to water?

(1) $\frac{1}{2}m^2v^2$ (2) $\frac{1}{2}mv^3$ (3) mv^3 (4) $\frac{1}{2}mv^2$

Sol. Answer (3)

$$F = \frac{dP}{dt} = \frac{vdM}{dt}$$

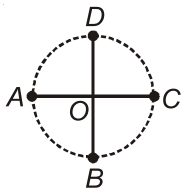
$$F.v = v^2\frac{dM}{dt}$$

$$= v^2\rho A\left(\frac{dx}{dt}\right) \quad (M = \rho Ax)$$

$$= v^3\rho A$$

$$= \frac{v^3\rho A(l)}{l} = mv^3 = \frac{dK}{dt} \quad \left\{\begin{matrix}\because \frac{dW}{dt} = \frac{dK}{dt} \\ = P\end{matrix}\right\} \quad (m : \text{mass per unit length})$$

47. As shown in figure, a particle of mass m is performing vertical circular motion. The velocity of the particle is increased, then at which point will the string break?



(1) A (2) B (3) C (4) D

Sol. Answer (2)

Tension will be maximum at B

So increasing velocity increases centripetal force and tension.

48. The bob of simple pendulum having length l, is displaced from mean position to an angular position θ with respect to vertical. If it is released, then velocity of bob at equilibrium position

(1) $\sqrt{2gl(1-\cos\theta)}$ (2) $\sqrt{2gl(1+\cos\theta)}$ (3) $\sqrt{2gl\cos\theta}$ (4) $\sqrt{2gl}$

Sol. Answer (1)

Using energy conservation

$$mgl\left(1-\cos\theta\right)=\frac{1}{2}mv^2$$

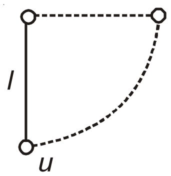
$$v=\sqrt{2gl\left(1-\cos\theta\right)}$$

49. A stone is tied to a string of length 'l' and is whirled in a vertical circle with the other end of the string as the centre. At a certain instant of time, the stone is at its lowest position and has a speed 'u'. The magnitude of the change in velocity as it reaches a position where the string is horizontal (g being acceleration due to gravity) is

(1) $\sqrt{2(u^2-gl)}$ (2) $\sqrt{u^2-gl}$ (3) $u-\sqrt{u^2-2gl}$ (4) $\sqrt{2gl}$

Sol. Answer (1)

Using conservation of energy



$U_i + k_i + U_f + k_f$

$$0+\frac{1}{2}mu^2=mgl+\frac{1}{2}mv'^2$$

$$\sqrt{u^2-2gl}=v'$$

Change in velocity (Δv) = $v'\hat{j}-u\hat{i}$

$$|\Delta v|=\sqrt{v'^2+u^2}$$

$$=\sqrt{u^2-2gl+u^2}$$

$$=\sqrt{2\left(u^2-gl\right)}$$

50. The potential energy of a particle in a force field is $U = \frac{A}{r^2} - \frac{B}{r}$, where A and B are positive constants and r is the distance of particle from the centre of the field. For stable equilibrium, the distance of the particle is

(1) $\frac{A}{B}$ (2) $\frac{B}{A}$ (3) $\frac{B}{2A}$ (4) $\frac{2A}{B}$

Sol. Answer (4)

$$U = \frac{A}{r^2} - \frac{B}{r}$$

$$F = \frac{-dU}{dr} = 0$$

$$= \frac{-2A}{r^3} + \frac{B}{r^2} = 0$$

$$r = \frac{2A}{B}$$

51. The potential energy between two atoms, in a molecule, is given by $U(x) = \frac{a}{x^{12}} - \frac{b}{x^6}$; where a and b are positive constants and x is the distance between the atoms. The atom is in stable equilibrium, when

(1) $x = \left(\frac{2a}{b}\right)^{1/6}$ (2) $x = \left(\frac{11a}{5b}\right)^{1/6}$ (3) $x = 0$ (4) $x = \left(\frac{a}{2b}\right)^{1/6}$

Sol. Answer (1)

$$U = \frac{a}{x^{12}} - \frac{b}{x^6}$$

$$F = \frac{-dU}{dx} = 0$$

$$\frac{-12a}{x^{13}} + \frac{6b}{x^7} = 0$$

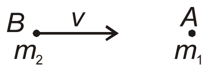
$$x = \left(\frac{2a}{b}\right)^{\frac{1}{6}}$$

52. Two spheres A and B of masses m_1 and m_2 respectively collide. A is at rest initially and B is moving with velocity v along x-axis. After collision B has a velocity $\frac{v}{2}$ in a direction perpendicular to the original direction. The mass A moves after collision in the direction

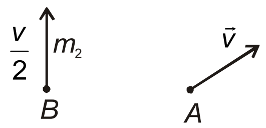
(1) $\theta = \tan^{-1}\left(\frac{1}{2}\right)$ to the x-axis (2) $\theta = \tan^{-1}\left(-\frac{1}{2}\right)$ to the x-axis

(3) Same as that of B (4) Opposite to that of B

Sol. Answer (1)



Before collision



After collision

Using momentum conservation

$$m_2v\hat{i} + 0 = -m_2\frac{v}{2}\hat{j} + m_1\vec{v}$$

$$m_1\vec{v} = m_2v\hat{i} + m_2\frac{v}{2}\hat{j}$$

$$\theta = \tan^{-1}\left(\frac{v}{2v}\right) = \tan^{-1}\left(\frac{1}{2}\right)$$

angle is from *x*-axis

53. The coefficient of restitution, *e*, for a perfectly elastic collision is

(1) 0 (2) –1 (3) 1 (4) ∞

Sol. Answer (3)

e = 1

54. A particle of mass m_1 moves with velocity v_1 and collides with another particle at rest of equal mass. The velocity of the second particle after the elastic collision is

(1) $2v_1$ (2) v_1 (3) $-v_1$ (4) 0

Sol. Answer (2)

Velocity will be interchanged as mass of colliding particles is same.

55. Two identical balls *A* and *B* collide head-on elastically. If velocities of *A* and *B*, before the collision, are + 0.5 m/s and - 0.3 m/s respectively then their velocities, after the collision, are respectively

(1) – 0.5 m/s and + 0.3 m/s (2) + 0.5 m/s and + 0.3 m/s

(3) + 0.3 m/s and – 0.5 m/s (4) – 0.3 m/s and + 0.5 m/s

Sol. Answer (4)

Velocities will be exchanged

$u_1 = 0.5$ m/s $u_2 = -0.3$ m/s

$v_1 = -0.3$ m/s $v_2 = 0.5$ m/s

56. *A* moving body of mass *m* and velocity 3 km/h collides with a rest body of mass 2*m* and sticks to it. Now the combined mass starts to move. What will be the combined velocity?

(1) 3 km/h (2) 4 km/h (3) 1 km/h (4) 2 km/h

Sol. Answer (3)

Using momentum conservation

$m(3) + 0 = 3mv$

$v = 1$ km/h

57. A rubber ball is dropped from a height of 5 m on a plane, where the acceleration due to gravity is not known. On bouncing, it rises to 1.8 m. The ball loses its velocity on bouncing by a factor of

(1) $\frac{3}{5}$ (2) $\frac{2}{5}$ (3) $\frac{16}{25}$ (4) $\frac{9}{25}$

Sol. Answer (2)

$h_2 = e^2 h_1$

$1.8 = e^2 (5)$

$$e^2 = \frac{18}{50} = \frac{9}{25} \Rightarrow e = \frac{3}{5}$$

$v = eu$

$$= \frac{3}{5}u$$

Velocity lost = $u - v = u - \frac{3u}{5} = \frac{2u}{5}$

Lost by a factor $\dfrac{\frac{2u}{5}}{u} = \frac{2}{5}$

58. A ball moving with velocity 2 m/s collides head on with another stationary ball of double the mass. If the coefficient of restitution is 0.5 then their velocities (in m/s) after collision will be

(1) 0, 2 (2) 0, 1 (3) 1, 1 (4) 1, 0.5

Sol. Answer (2)

Using momentum conservation

$2m = mv_1 + 2mv_2$

and $e = \frac{v_2 - v_1}{2}$

Solving (1) and (2)

$v_1 = 0,$ $v_2 = 1$

59. A metal ball of mass 2 kg moving with speed of 36 km/h has a head on collision with a stationary ball of mass 3 kg. If after collision, both the balls move together, then the loss in K.E. due to collision is

(1) 100 J (2) 140 J (3) 40 J (4) 60 J

Sol. Answer (4)

$$\Delta K = \frac{1}{2}\frac{m_1 m_2}{m_1 + m_2}(u_1 - u_2)^2$$

$$= \frac{1}{2}\frac{(2)(3)}{(2+3)}(10)^2$$

= 60 J

60. Two springs A and B having spring constant K_A and K_B ($K_A = 2K_B$) are stretched by applying force of equal magnitude. If energy stored in spring A is E_A then energy stored in B will be

(1) $2E_A$ (2) $\frac{E_A}{4}$ (3) $\frac{E_A}{2}$ (4) $4E_A$

Sol. Answer (1)

$K_A = 2K_B$

$$x_A = \frac{F}{K_A} \quad , \quad x_B = \frac{F}{K_B}$$

$$v_A = \frac{1}{2}K_A \frac{F^2}{K_A^2}$$

$$v_B = \frac{1}{2}K_B \frac{F^2}{K_B^2} = \frac{F^2}{K_A}$$

$\Rightarrow U_B = 2U_A$

61. The potential energy of a long spring when stretched by 2 cm is U. If the spring is stretched by 8 cm the potential energy stored in it is

(1) $\frac{U}{4}$ (2) $4U$ (3) $8U$ (4) $16U$

Sol. Answer (4)

$$U = \frac{1}{2}K(2)^2 = 2K$$

$$U' = \frac{1}{2}K(8)^2 = 32K = 16U$$

SECTION - D

Assertion-Reason Type Questions

1. A : The work done by a force during round trip is always zero.

R : The average value of force in round trip is zero.

Sol. Answer (4)

2. A : The change in kinetic energy of a particle is equal to the work done on it by the net force.

R : The work-energy theorem can be used only in conservative field.

Sol. Answer (3)

3. A : Internal forces can change the kinetic energy but not the momentum of the system.

R : The net internal force on a system is always zero.

Sol. Answer (1)

4. A : The potential energy can be defined only in conservative field.

R : The value of potential energy depends on the reference level (level of zero potential energy).

Sol. Answer (2)

5. A : When a body moves in a circle the work done by the centripetal force is always zero.

R : Centripetal force is perpendicular to displacement at every instant.

Sol. Answer (1)

6. A : If net force acting on a system is zero, then work done on the system may be nonzero.

R : Internal forces acting on a system can increase its kinetic energy.

Sol. Answer (1)

7. A : During collision between two objects, the momentum of colliding objects is conserved only in direction perpendicular to line of impact.

R : The force on colliding objects in direction perpendicular to line of impact is zero.

Sol. Answer (1)

8. A : The potential energy of a system increases when work is done by conservative force.

R : Kinetic energy can change into potential energy and vice-versa.

Sol. Answer (2)

9. A : In inelastic collision, a part of kinetic energy convert into heat energy, sound energy and light energy etc.

R : The force of interaction in an inelastic collision is non-conservative in nature.

Sol. Answer (1)

10. A : Energy dissipated against friction depends on the path followed.

R : Friction force is non-conservative force.

Sol. Answer (1)

11. A : Work done by the frictional force can't be positive.

R : Frictional force is a conservative force.

Sol. Answer (4)

12. A : Impulse generated on one body by another body in a perfectly elastic collision is not zero.

R : In a perfectly elastic collision, momentum of the system is always conserved and not the momentum of the individual bodies.

Sol. Answer (1)

13. A : Power of the gravitational force on the body in a projectile motion is zero, once during its motion.

R : At the highest point only, the component of velocity along the gravitational force is zero.

Sol. Answer (1)

14. A : Power delivered by the tension in the wire to a body in vertical circle is always zero.

    R : Tension in the wire is equal to the centripetal force acting on the body doing vertical circular motion.

Sol. Answer (3)

15. A : When a man is walking on a rough road, the work done by frictional force is zero.

    R : Frictional force acts in the direction of the motion of the man in this case.

Sol. Answer (2)

❑ ❑ ❑

Chapter 7

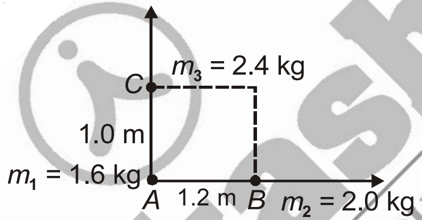
System of Particles & Rotational Motion

Solutions

SECTION - A

Objective Type Questions

1. Three point masses m_1, m_2 and m_3 are placed at the corners of a thin massless rectangular sheet (1.2 m × 1.0 m) as shown. Centre of mass will be located at the point



(1) (0.8, 0.6) m (2) (0.6, 0.8) m (3) (0.4, 0.4) m (4) (0.5, 0.6) m

Sol. Answer (3)

$$x_{cm} = \frac{m_1x_1 + m_2x_2 + m_3x_3}{m_1 + m_2 + m_3}$$

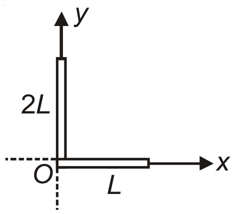
$$y_{cm} = \frac{m_1y_1 + m_2y_2 + m_3y_3}{m_1 + m_2 + m_3}$$

$$x_{cm} = \frac{(1.6)(0)+(2.4)(0)+2(1.2)}{1.6+2.4+2} = 0.4 \text{ m}$$

$$y_{cm} = \frac{(1.6)(0)+(2.4)1+2(0)}{1.6+2.4+2} = 0.4 \text{ m}$$

So, (x_{cm}, y_{cm}) = (0.4, 0.4) m

2. Figure shows a composite system of two uniform rods of lengths as indicated. Then the coordinates of the centre of mass of the system of rods are



(1) $\left(\frac{L}{2}, \frac{2L}{3}\right)$ (2) $\left(\frac{L}{4}, \frac{2L}{3}\right)$ (3) $\left(\frac{L}{6}, \frac{2L}{3}\right)$ (4) $\left(\frac{L}{6}, \frac{L}{3}\right)$

Sol. Answer (3)

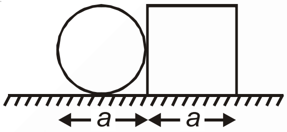
Centre of mass of the uniform rod will lie at its centre

$$x_{\text{cm}} = \frac{m_1x_1 + m_2x_2}{m_1 + m_2}$$

$$x_{\text{cm}} = \frac{m\left(\frac{L}{2}\right) + 2m(0)}{3m}, \quad y_{\text{cm}} = \frac{2m(L) + m(0)}{3m}$$

$$x_{\text{cm}} = \frac{L}{6} \quad , \quad y_{\text{cm}} = \frac{2L}{3}$$

3. A circular plate of diameter '*a*' is kept in contact with a square plate of side *a* as shown. The density of the material and the thickness are same everywhere. The centre of mass of composite system will be



(1) Inside the circular plate (2) Inside the square plate

(3) At the point of contact (4) Outside the system

Sol. Answer (2)

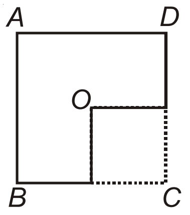
$$x_{cm} = \frac{A_1x_1 + A_2x_2}{A_1 + A_2} \qquad \text{[taking origin at contact point]}$$

$$= \frac{\frac{\pi a^2}{4}\left(\frac{-a}{2}\right) + a^2\left(\frac{a}{2}\right)}{\frac{\pi a^2}{4} + a^2} = \frac{a^3\left(1 - \frac{\pi}{4}\right)}{2a^2\left(a + \frac{\pi}{4}\right)}$$

$$= \frac{a\left(1 - \frac{\pi}{4}\right)}{2\left(1 + \frac{\pi}{4}\right)} > 0$$

$\Rightarrow x_{cm}$ is inside the square plate

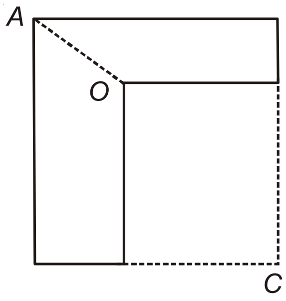
4. From a uniform square plate, one-fourth part is removed as shown. The centre of mass of remaining part will lie on



(1) *OC* (2) *OA* (3) *OB* (4) *OD*

Sol. Answer (2)

Centre of mass will lie on the line of symmetry



OA is the line of symmetry of the remaining part

5. Two particles *A* and *B* initially at rest move towards each other under a mutual force of attraction. At the instant when velocity of *A* is v and that of *B* is $2v$, the velocity of centre of mass of the system

(1) v (2) $2v$ (3) $3v$ (4) Zero

Sol. Answer (4)

If $F_{ext} = 0$

v_{cm} is at rest initially so $v_{cm} = 0$

as $F_{ext} = 0 \quad \Rightarrow \; a_{cm} = 0$

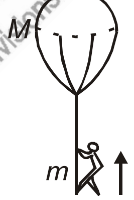
6. A shell following a parabolic path explodes somewhere in its flight. The centre of mass of fragments will move in

(1) Vertical direction (2) Any direction (3) Horizontal direction (4) Same parabolic path

Sol. Answer (4)

The path of centre of mass will not change due to internal forces

7. A man of mass m is suspended in air by holding the rope of a balloon of mass M. As the man climbs up the rope, the balloon



(1) Moves upward (2) Moves downward (3) Remains stationary (4) Cannot say

Sol. Answer (2)

Net external force is zero, and centre of mass of the system is initially at rest. So position of centre of mass will not change. So to have x_{cm} = constant the balloon will move downwards

8. A ball of mass m is thrown upward and another ball of same mass is thrown downward so as to move freely under gravity. The acceleration of centre of mass is

(1) g (2) $\frac{g}{2}$ (3) $2g$ (4) 0

Sol. Answer (1)

$$a_{cm} = \frac{m(-g)+m(-g)}{m+m}$$

$$a_{cm} = -g$$

9. A man of mass m starts moving on a plank of mass M with constant velocity v with respect to plank. If the plank lies on a smooth horizontal surface, then velocity of plank with respect to ground is

(1) $\frac{-Mv}{m+M}$ (2) $\frac{-mv}{M}$ (3) $\frac{-Mv}{m}$ (4) $\frac{-mv}{m+M}$

Sol. Answer (4)

Velocity of man w.r.t plank $v_{MP} = v$, Velocity of plank w.r.t. earth $v_{PE} = v'$

Velocity of man w.r.t. earth $v_{ME} = v_{MP} + v_{PE} = v + v'$

Applying conservation of linear momentum w.r.t. earth frame

$$O = m(v + v') + Mv' \Rightarrow v' = \frac{-mv}{M+m}$$

10. The moment of inertia of a body depends on

(1) The mass of the body (2) The distribution of the mass in the body

(3) The axis of rotation of the body (4) All of these

Sol. Answer (4)

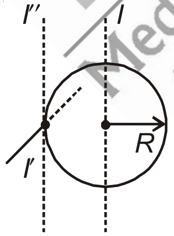
$I = mr^2$

11. The moment of inertia of a thin uniform circular disc about one of its diameter is I. Its moment of inertia about an axis tangent to it and perpendicular to its plane is

(1) $\frac{2I}{3}$ (2) $2I$ (3) $\frac{I}{2}$ (4) $6I$

Sol. Answer (4)

$$I = \frac{MR^2}{4}$$



Using parallel axis theorem

$$I'' = \frac{MR^2}{4} + MR^2$$

Now perpendicular axis theorem

$I' = I'' + I$

$$= \frac{MR^2}{4} + MR^2 + \frac{MR^2}{4}$$

$$= \frac{3}{2}MR^2$$

$$= \frac{3}{2}.(4I) = 6I$$

12. The two spheres, one of which is hollow and other solid, have identical masses and moment of inertia about their respective diameters. The ratio of their radii is given by

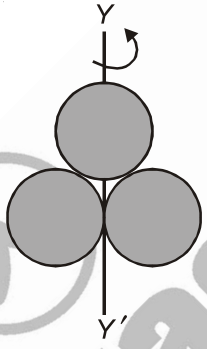
(1) 5 : 7 (2) 3 : 5 (3) $\sqrt{3}:\sqrt{5}$ (4) 3 : 7

Sol. Answer (3)

$$\frac{2}{3}mr_1^2=\frac{2}{5}mr_2^2$$

$$\frac{r_1}{r_2}=\sqrt{\frac{3}{5}}$$

13. Three solid spheres each of mass P and radius Q are arranged as shown in fig. The moment of inertia of the arrangement about YY' axis



(1) $\frac{7}{5}PQ^2$ (2) $\frac{14}{5}PQ^2$ (3) $\frac{16}{5}PQ^2$ (4) $\frac{5}{14}PQ^2$

Sol. Answer (3)

$$I=\left(\frac{2}{5}mR^2\right)+\left(\frac{2}{5}mR^2+mR^2\right)+\left(\frac{2}{5}mR^2+mR^2\right)$$

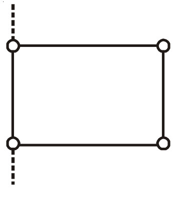
$$=\frac{16}{5}mR^2$$

14. Four spheres of diameter 2a and mass M are placed with their centres on the four corners of a square of side b. Then moment of inertia of the system about an axis about one of the sides of the square is

(1) Ma^2+2Mb^2 (2) Ma^2 (3) Ma^2+4Mb^2 (4) $\frac{8}{5}Ma^2+2Mb^2$

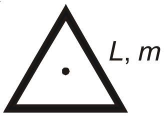
Sol. Answer (4)

$$I=4\left(\frac{2}{5}Ma^2\right)+2Mb^2$$



$$=\frac{8}{5}Ma^2+2Mb^2$$

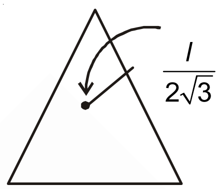
15. Three rods each of mass m and length L are joined to form an equilateral triangle as shown in the figure. What is the moment of inertia about an axis passing through the centre of mass of the system and perpendicular to the plane?



(1) $2\ mL^2$ (2) $\frac{mL^2}{2}$ (3) $\frac{mL^2}{3}$ (4) $\frac{mL^2}{6}$

Sol. Answer (2)

Using parallel axis theorem for one rod



$$I = \frac{ml^2}{12} + m\left(\frac{l}{2\sqrt{3}}\right)^2$$

For all three rods

$I' = 3I$

$$= 3ml^2\left[\frac{1}{12} + \frac{1}{12}\right]$$

$$= \frac{ml^2}{2}$$

16. A circular disc is to be made by using iron and aluminium so that it possesses maximum moment of inertia about geometrical axis. It is possible with

(1) Aluminium at interior and iron surrounding it

(2) Iron at interior surrounded by aluminium

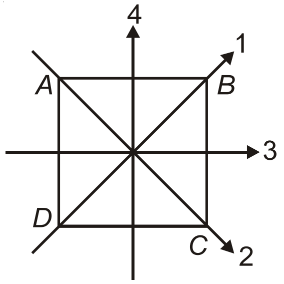
(3) Using iron and aluminium layers in alternate order

(4) Sheet of iron is used at both external surfaces and aluminium as interior layer

Sol. Answer (1)

Iron is much denser than Aluminium. To have the maximum moment of inertia, material having higher density should be placed farther from the rotational axis.

17. The moment of inertia of a thin square plate $ABCD$ of uniform thickness about an axis passing through the centre O and perpendicular to the plane of the plate is I. Which of the following is false?



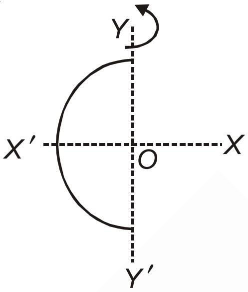
(1) $I = I_1 + I_2$ (2) $I = I_1 + I_3$ (3) $I = I_4 + I_2$ (4) $I = I_1 + I_2 + I_3 + I_4$

Sol. Answer (4)

Using perpendicular axis theorem

$I \neq I_1 + I_2 + I_3 + I_4$

18. A thin wire of length ℓ and mass m is bent in the form of a semicircle as shown. Its moment of inertia about an axis joining its free ends will be



(1) $m\ell^2$ (2) Zero (3) $\frac{m\ell^2}{\pi^2}$ (4) $\frac{m\ell^2}{2\pi^2}$

Sol. Answer (4)

$\ell = \pi R \quad \Rightarrow \quad R = \frac{\ell}{\pi}$

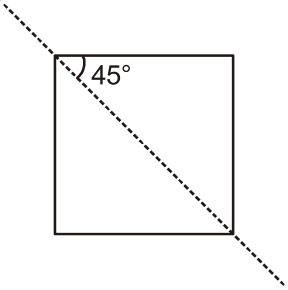
$I = \frac{mr^2}{2}$

$I = \frac{1}{2}m\left(\frac{\ell}{\pi}\right)^2 \quad \Rightarrow \quad I = \frac{m\ell^2}{2\pi^2}$

19. Four thin uniform rods each of length L and mass m are joined to form a square. The moment of inertia of square about an axis along its one diagonal is

(1) $\frac{mL^2}{6}$ (2) $\frac{2}{3}mL^2$ (3) $\frac{3\,mL^2}{4}$ (4) $\frac{4\,mL^2}{3}$

Sol. Answer (2)



$I = 4\left(\frac{mL^2 \sin^2 45^\circ}{3}\right)$

$= \frac{4mL^2}{6}$

$= \frac{2}{3}mL^2$

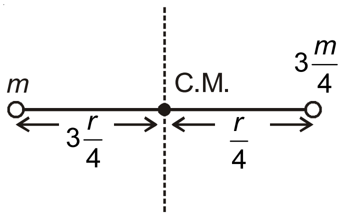
20. Two point masses *m* and 3*m* are placed at distance *r*. The moment of inertia of the system about an axis passing through the centre of mass of system and perpendicular to the line joining the point masses is

(1) $\frac{3}{5}mr^2$ (2) $\frac{3}{4}mr^2$ (3) $\frac{3}{2}mr^2$ (4) $\frac{6}{7}mr^2$

Sol. Answer (2)

$$I = m\left(\frac{3r}{4}\right)^2 + 3m\left(\frac{r}{4}\right)^2$$

$$= \frac{3}{4}mr^2$$



21. A wheel starts from rest and attains an angular velocity of 20 radian/s after being uniformly accelerated for 10 s. The total angle in radian through which it has turned in 10 second is

(1) 20 π (2) 40 π (3) 100 (4) 100 π

Sol. Answer (3)

$\omega_f = \omega_i + \alpha t$

$20 = 0 + \alpha(10)$

$\alpha = 2$ rad/s^2

Now, $\theta = \omega_i t + \frac{1}{2}\alpha t^2$

$\theta = \frac{1}{2}(2)(100)$

= 100 radian

22. An angular impulse of 20 Nms is applied to a hollow cylinder of mass 2 kg and radius 20 cm. The change in its angular speed is

(1) 25 rad/s (2) 2.5 rad/s (3) 250 rad/s (4) 2500 rad/s

Sol. Answer (3)

$$20 = 2\left(\frac{1}{2}\right)(2)\left(\frac{20}{100}\right)^2\Delta\omega \quad \begin{bmatrix}\text{Angular impulse} \\ = \text{Change in angular momentum}\end{bmatrix}$$

$$\Delta\omega = \frac{500}{2} = 250 \text{ rad/s}$$

23. A hollow sphere of mass 1 kg and radius 10 cm is free to rotate about its diameter. If a force of 30N is applied tangentially to it, its angular acceleration is (in rad/s^2)

(1) 5000 (2) 450 (3) 50 (4) 5

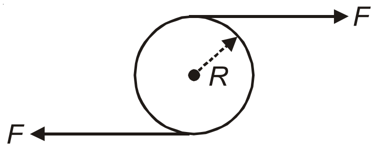
Sol. Answer (2)

Use $\tau = I\alpha$

$$30\left(\frac{10}{100}\right) = \frac{2}{3}(1)\left(\frac{10}{100}\right)^2\alpha$$

$\alpha = 450$ rad/s^2

24. Two equal and opposite forces are applied tangentially to a uniform disc of mass M and radius R as shown in the figure. If the disc is pivoted at its centre and free to rotate in its plane, the angular acceleration of the disc is



(1) $\frac{F}{MR}$ (2) $\frac{2F}{3MR}$ (3) $\frac{4F}{MR}$ (4) Zero

Sol. Answer (3)

$$2FR = \frac{1}{2}MR^2\alpha$$

$$\alpha = \frac{4F}{MR}$$

25. A wheel having moment of inertia 4 kg m^2 about its symmetrical axis, rotates at rate of 240 rpm about it. The torque which can stop the rotation of the wheel in one minute is

(1) $\frac{5\pi}{7}$Nm (2) $\frac{8\pi}{15}$Nm (3) $\frac{2\pi}{9}$Nm (4) $\frac{3\pi}{7}$Nm

Sol. Answer (2)

$$w = w_0 - \alpha t$$

$$\alpha = \frac{w_0}{t} = \frac{2\pi(240)}{60 \times 60}$$

$$\alpha = \frac{8\pi}{60}\ \text{rad/s}^2$$

$$\tau = I\alpha$$

$$= 4\frac{8\pi}{60} = \frac{8\pi}{15}\ \text{N} - \text{m}$$

26. A force $\vec{F} = (2\hat{i} + 3\hat{j} - 5\hat{k})$ N acts at a point $\vec{r}_1 = (2\hat{i} + 4\hat{j} + 7\hat{k})$ m. The torque of the force about the point $\vec{r}_2 = (\hat{i} + 2\hat{j} + 3\hat{k})\,m$ is

(1) $(17\hat{j} + 5\hat{k} - 3\hat{i})$ Nm (2) $(2\hat{i} + 4\hat{j} - 6\hat{k})$ Nm (3) $(12\hat{i} - 5\hat{j} + 7\hat{k})$ Nm (4) $(13\hat{j} - 22\hat{i} - \hat{k})$ Nm

Sol. Answer (4)

$$\vec{r} = \vec{r}_1 - \vec{r}_2 = (2i + 4j + 7k) - (i + 2j + 3k)$$

$$= \hat{i} + 2\hat{j} + 4\hat{k}$$

$\vec{F} = 2\hat{i} + 3\hat{j} - 5\hat{k}$

$$\tau = \vec{r} \times \vec{F} = \begin{vmatrix} i & j & k \\ 1 & 2 & 4 \\ 2 & 3 & -5 \end{vmatrix}$$

$$= -22\hat{i} + 13\hat{j} - \hat{k}$$

27. Two like parallel forces 20 N and 30 N act at the ends *A* and *B* of a rod 1.5 m long. The resultant of the forces will act at the point

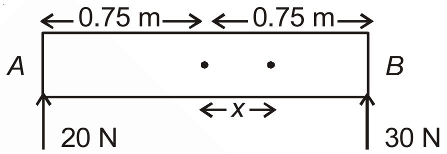
(1) 90 cm from *A* (2) 75 cm from *B* (3) 20 cm from *B* (4) 85 cm from *A*

Sol. Answer (1)

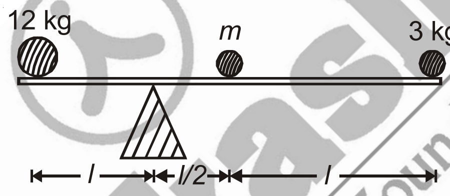
Net torque should be same for the new point

20(0.75) + 30(0.75) = 50(*x*)

Solve for *x*



28. For equilibrium of the system, value of mass *m* should be



(1) 9 kg (2) 15 kg (3) 21 kg (4) 1 kg

Sol. Answer (2)

Net torque = 0 for equilibrium

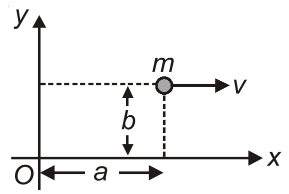
$$12l = m\left(\frac{l}{2}\right) + 3\left(\frac{3l}{2}\right)$$

$$12\,l - 4.5l = \frac{ml}{2}$$

$$7.5l = \frac{ml}{2}$$

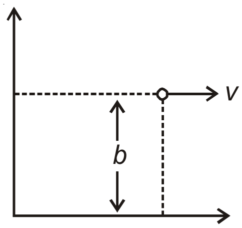
m = 15 kg

29. A particle of mass *m* is moving with constant velocity *v* parallel to the *x*-axis as shown in the figure. Its angular momentum about origin *O* is



(1) mvb (2) mva (3) $mv\sqrt{a^2 + b^2}$ (4) $mv(a + b)$

Sol. Answer (1)

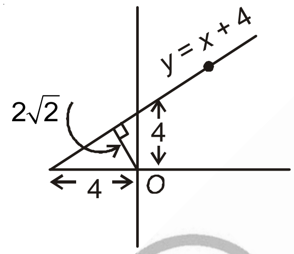


$|L| = mbv$

30. A particle of mass 5 kg is moving with a uniform speed $3\sqrt{2}$ in *XOY* plane along the line $Y = X + 4$. The magnitude of its angular momentum about the origin is

(1) 40 units (2) 60 units (3) Zero (4) $40\sqrt{2}$ units

Sol. Answer (2)

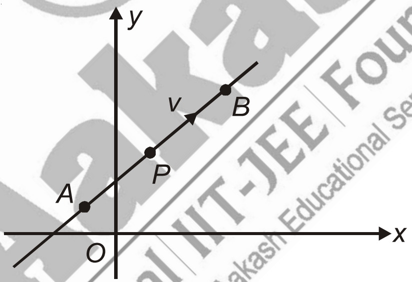


$L = mvr$

$= (5)(3\sqrt{2})(2\sqrt{2})$

= 60 units

31. A particle *P* is moving along a straight line as shown in the figure. During the motion of the particle from *A* to *B* the angular momentum of the particle about *O*



(1) Increases (2) Decreases

(3) Remains constant (4) First increases and then decreases

Sol. Answer (3)

$L = mvr_{\perp}$

$r_{\perp}$ is constant so L = constant

32. The angular momentum of a particle performing uniform circular motion is *L*. If the kinetic energy of partical is doubled and frequency is halved, then angular momentum becomes

(1) $\frac{L}{2}$ (2) $2L$ (3) $\frac{L}{4}$ (4) $4L$

Sol. Answer (4)

$L = I\omega$

$K = \frac{1}{2}I\omega^2$

$$2K = \frac{1}{2}I'\left(\frac{\omega}{2}\right)^2$$

$$\frac{1}{2} = \frac{I}{I'}(4)$$

$I' = 8I$

$$L' = (8I)\left(\frac{\omega}{2}\right) = 4I\omega$$

$\Rightarrow L' = 4\ L$

33. A solid sphere, a spherical shell, a ring and a disc of same radius and mass are allowed to roll down an inclined plane without slipping. The one which reaches the bottom first is

(1) Solid sphere (2) Spherical shell (3) Ring (4) Disc

Sol. Answer (1)

Body of smaller $\frac{K^2}{R^2}$ will take less time so solid sphere will reach the ground first.

34. If torque acting upon a system is zero, the quantity that remains constant is

(1) Force (2) Linear momentum (3) Angular momentum (4) Angular velocity

Sol. Answer (3)

35. A constant torque acting on a uniform circular wheel changes its angular momentum from A_0 to $4A_0$ in 4 seconds. The magnitude of this torque is

(1) $\frac{3A_0}{4}$ (2) A_0 (3) $4A_0$ (4) $12A_0$

Sol. Answer (1)

$$\tau = \frac{\Delta L}{\Delta t}$$

$$\tau = \frac{4A_0 - A_0}{4} = \frac{3A_0}{4}$$

36. A meter stick is held vertically with one end on the floor and is allowed to fall. The speed of the other end when it hits the floor assuming that the end at the floor does not slip is (g = 9.8 m/s^2)

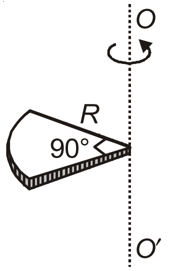
(1) 3.2 m/s (2) 5.4 m/s (3) 7.6 m/s (4) 9.2 m/s

Sol. Answer (2)

$$\frac{mgl}{2} = \frac{1}{2}\frac{ml^2}{3}\omega^2$$

$$\omega^2 = \frac{3g}{\ell} \Rightarrow \omega = \sqrt{\frac{3g}{l}} = \sqrt{30}$$

37. A quarter disc of radius R and mass m is rotating about the axis OO' (perpendicular to the plane of the disc) as shown. Rotational kinetic energy of the quarter disc is



(1) $\frac{1}{2}mR^2\omega^2$ (2) $\frac{1}{4}mR^2\omega^2$ (3) $\frac{1}{8}mR^2\omega^2$ (4) $\frac{1}{16}mR^2\omega^2$

Sol. Answer (2)

$$k = \frac{1}{2}I\omega^2$$

$$= \frac{1}{2}\left(\frac{mr^2}{2}\right)\omega^2$$

$$k = \frac{1}{4}mr^2\omega^2$$

38. A uniform rod of mass m and length l is suspended by two strings at its ends as shown. When one of the strings is cut, the rod starts falling with an initial angular acceleration

(1) $\frac{g}{l}$ (2) $\frac{g}{2l}$ (3) $\frac{3g}{2l}$ (4) $\frac{3g}{4l}$

Sol. Answer (3)

$$\tau = I\alpha$$

$$\frac{mgl}{2} = \frac{ml^2}{3}\alpha$$

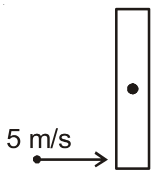
$$\alpha = \frac{3g}{2l} \quad \text{and} \quad a = \alpha r$$

$$= \frac{l}{2}.\frac{3g}{2l} = \frac{3g}{4}$$

39. A metre stick is pivoted about its centre. A piece of wax of mass 20 g travelling horizontally and perpendicular to it at 5 m/s strikes and adheres to one end of the stick so that the stick starts to rotate in a horizontal circle. Given the moment of inertia of the stick and wax about the pivot is 0.02 kg m^2, the initial angular velocity of the stick is

(1) 1.58 rad/s (2) 2.24 rad/s (3) 2.50 rad/s (4) 5.00 rad/s

Sol. Answer (3)



$L = I\omega$

$$\frac{20}{1000}\times 5\times\frac{l}{2} = 0.02\ \omega$$

$\omega = 2.5$ rad/s

40. A circular disc of mass 2 kg and radius 10 cm rolls without slipping with a speed 2 m/s. The total kinetic energy of disc is

(1) 10 J (2) 6 J (3) 2 J (4) 4 J

Sol. Answer (2)

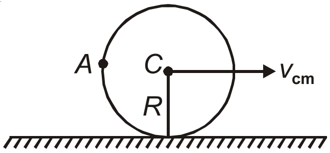
$$k = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$$

$$= \frac{1}{2}mv^2 + \frac{1}{2}\frac{ml^2}{2}.\frac{v^2}{l^2}$$

$$= \frac{3}{4}(2)(2)^2$$

$$= 6\text{ J}$$

41. In case of pure rolling, what will be the velocity of point A of the ring of radius R ?

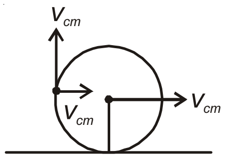


(1) v_{cm} (2) $\sqrt{2}v_{cm}$ (3) $\frac{v_{cm}}{2}$ (4) $2v_{cm}$

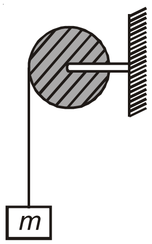
Sol. Answer (2)

$$v_{net} = \sqrt{v_{cm}^2 + v_{cm}^2}$$

$$= v_{cm}\sqrt{2}$$



42. A disc of mass m and radius r is free to rotate about its centre as shown in the figure. A string is wrapped over its rim and a block of mass m is attached to the free end of the string. The system is released from rest. The speed of the block as it descends through a height h, is



(1) $\sqrt{2gh}$ (2) $\sqrt{\frac{2}{3}gh}$ (3) $2\sqrt{\frac{gh}{3}}$ (4) $\frac{1}{2}\sqrt{3gh}$

Sol. Answer (3)

Using Mechanical energy conservation

$$mgh = \frac{1}{2}mv^2 + \frac{1}{2}\left(\frac{1}{2}\right)mr^2.\frac{v^2}{r^2}$$

$$mgh = \frac{3}{4}mv^2$$

$$v^2 = \frac{4gh}{3}$$

$$v = \sqrt{\frac{4gh}{3}}$$

43. When a body is rolling without slipping on a rough horizontal surface, the work done by friction is

(1) Always zero (2) May be zero (3) Always positive (4) Always negative

Sol. Answer (1)

44. A solid spherical ball is rolling without slipping down an inclined plane. The fraction of its total energy associated with rotation is

(1) $\frac{2}{5}$ (2) $\frac{2}{7}$ (3) $\frac{3}{5}$ (4) $\frac{3}{7}$

Sol. Answer (2)

$$K_R = \frac{1}{2}\left(\frac{2}{5}mr^2\right)\frac{v^2}{r^2}$$

$$K_R = \frac{1}{5}mv^2$$

$$K_{Tr} = \frac{1}{2}mv^2$$

$$K_{Total} = \frac{1}{5}mv^2 + \frac{1}{2}mv^2$$

$$= \frac{7}{10}mv^2$$

$$\frac{K_R}{K_{Total}} = \frac{\frac{1}{5}mv^2}{\frac{7}{10}mv^2}$$

$$= \frac{2}{7}$$

45. A solid cylinder of mass M and radius R rolls down an inclined plane of height h without slipping. The speed of its centre of mass when it reaches the bottom is

(1) $\sqrt{2gh}$

(2) $\sqrt{\frac{4}{3}gh}$

(3) $\sqrt{\frac{3}{4}gh}$

(4) $\sqrt{\frac{4g}{h}}$

Sol. Answer (2)

$$Mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$$

$$= \frac{1}{2}mv^2 + \frac{1}{2}\frac{ml^2}{2}.\frac{v^2}{l^2}$$

Solving,

$$v = \sqrt{\frac{4gh}{3}}$$

46. An inclined plane makes an angle of 30° with the horizontal. A solid sphere rolling down this inclined plane from rest without slipping has a linear acceleration equal to

(1) $\frac{g}{3}$

(2) $\frac{2g}{3}$

(3) $\frac{5g}{7}$

(4) $\frac{5g}{14}$

Sol. Answer (4)

$$\tau = I\alpha$$

$$\alpha = \frac{\tau}{I} = \frac{mgr\sin\theta}{\frac{2}{5}mr^2 + mr^2}$$

$$a = \alpha r = \frac{mgr^2\sin\theta}{\frac{2}{5}mr^2 + mr^2}$$

$$a = \frac{5g\sin 30^\circ}{7} = \frac{5g}{14}$$

47. What is the minimum coefficient of friction for a solid sphere to roll without slipping on an inclined plane of inclination θ?

(1) $\frac{2}{7}\tan\theta$ (2) $\frac{1}{3}g\tan\theta$ (3) $\frac{1}{2}\tan\theta$ (4) $\frac{2}{5}\tan\theta$

Sol. Answer (1)

$$\mu = \frac{I\tan\theta}{I+mr^2} = \frac{\frac{2}{5}mr^2\tan\theta}{\frac{2}{5}mr^2+mr^2}$$

$$= \frac{2\tan\theta}{7}$$

48. An object slides down a smooth incline and reaches the bottom with velocity v. If same mass is in the form of a ring and it rolls down an inclined plane of same height and angle of inclination, then its velocity at the bottom of inclined plane will be

(1) v (2) $\frac{v}{\sqrt{2}}$ (3) $2v$ (4) $\sqrt{2}v$

Sol. Answer (2)

$$v = \sqrt{2gh}$$

$$mgh = \frac{1}{2}mv^2 + \frac{1}{2}mr^2\frac{v^2}{r^2}$$

$$v' = \sqrt{gh}$$

$$v' = \frac{v}{\sqrt{2}}$$

49. A swimmer while jumping into river from a height easily forms a loop in air if

(1) He pulls his arms and legs in (2) He spreads his arms and legs

(3) He keeps himself straight (4) None of these

Sol. Answer (1)

Using angular momentum conservation, by pulling his arms and legs in, Moment of inertia will decrease hence ω will increase.

50. A thin circular ring of mass M and radius r is rotating about its axis with a constant angular velocity ω. Two objects, each of mass m are attached gently to the opposite ends of a diameter of the ring. The ring now rotates with an angular velocity

(1) $\frac{\omega M}{m+M}$ (2) $\frac{\omega(M-2m)}{M+2m}$ (3) $\frac{\omega M}{M+2m}$ (4) $\omega\left(\frac{M+2m}{M}\right)$

Sol. Answer (3)

$I_1\omega_1 = I_2\omega_2$

$Mr^2\omega = (M + 2m)\, r^2\omega'$

$$\omega' = \frac{M\omega}{M+2m}$$

51. A horizontal disc rotating freely about a vertical axis through its centre makes 90 revolutions per minute. A small piece of wax of mass *m* falls vertically on the disc and sticks to it at a distance *r* from the axis. If the number of revolutions per minute reduce to 60, then the moment of inertia of the disc is

(1) mr^2 (2) $\frac{3}{2}mr^2$ (3) $2\,mr^2$ (4) $3\,mr^2$

Sol. Answer (3)

$$w_1 = \frac{2\pi 90}{60} = 3\pi \text{ rps}$$

$$w_2 = \frac{2\pi 60}{60} = 2\pi \text{ rps}$$

Using angular momentum conservation

$I(1.5) = (I + mr^2)\,(1)$

$$\frac{I}{2} = mr^2$$

$$I = 2mr^2$$

52. If two discs of moment of inertia I_1 and I_2 rotating about collinear axis passing through their centres of mass and perpendicular to their plane with angular speeds ω_1 and ω_2 respectively in opposite directions are made to rotate combinedly along same axis, then the magnitude of angular velocity of the system is

(1) $\frac{I_1\omega_1 + I_2\omega_2}{I_1 + I_2}$ (2) $\frac{I_1\omega_1 - I_2\omega_2}{I_1 + I_2}$ (3) $\frac{I_1\omega_1 + I_2\omega_2}{\omega_1 + \omega_2}$ (4) $\frac{I_1\omega_1 - I_2\omega_2}{\omega_1 - \omega_2}$

Sol. Answer (2)

Using angular momentum conservation

$I_1\omega_1 + I_2\omega_2 = (I_1 + I_2)\omega$

$$\omega = \frac{I_1\omega_1 + I_2\omega_2}{I_1 + I_2}$$

SECTION - B

Objective Type Questions

1. The linear mass density(λ) of a rod of length L kept along x-axis varies as $\lambda = \alpha + \beta x$; where α and β are positive constants. The centre of mass of the rod is at

(1) $\dfrac{(2\beta+3\alpha L)L}{2(2\beta+\alpha L)}$ (2) $\dfrac{(3\alpha+2\beta L)L}{3(2\alpha+\beta L)}$ (3) $\dfrac{(3\beta+2\alpha L)L}{3(2\beta+\alpha L)}$ (4) $\dfrac{(3\beta+2\alpha L)L}{3\beta+2\alpha}$

Sol. Answer (2)

$\lambda = \alpha + \beta x$

$dm = (\alpha + \beta x)dx$

$$x_{cm} = \frac{\int_0^L x(\alpha+\beta x)\,dx}{\int_0^L (\alpha+\beta x)dx}$$

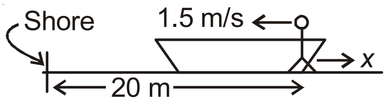
$$= \frac{\alpha\int_0^L xdx + \beta\int_0^L x^2dx}{\alpha\int_0^L dx + \beta\int_0^L xdx}$$

$$x_{cm} = \frac{\frac{\alpha L^2}{2} + \frac{\beta L^3}{3}}{\alpha L + \frac{\beta L^2}{2}}$$

2. A man of mass 60 kg is standing on a boat of mass 140 kg, which is at rest in still water. The man is initially at 20 m from the shore. He starts walking on the boat for 4 s with constant speed 1.5 m/s towards the shore. The final distance of the man from the shore is

(1) 15.8 m (2) 4.2 m (3) 12.6 m (4) 14.1 m

Sol. Answer (1)



Distance travelled by the man on boat in 4 second = (1.5) × 4

= 6.0 m

$140x = 60(6 - x)$

$140x = 360 - 60x$

$x = 1.8$ m

So final distance of the man from the shore will be 20 – (6 – 1.8) = 15.8 m

3. A bomb of mass m is projected from the ground with speed v at angle θ with the horizontal. At the maximum height from the ground it explodes into two fragments of equal mass. If one fragment comes to rest immediately after explosion, then the horizontal range of centre of mass is

(1) $\dfrac{v^2\sin^2\theta}{g}$ (2) $\dfrac{v^2\sin\theta}{g}$ (3) $\dfrac{v^2\sin\theta}{2g}$ (4) $\dfrac{v^2\sin 2\theta}{g}$

Sol. Answer (4)

Path of the centre of mass will not change due to internal forces

$$R_{cm} = \frac{v^2 \sin 2\theta}{g}$$

4. Two blocks of masses 5 kg and 2 kg are connected by a spring of negilible mass and placed on a frictionless horizontal surface. An impulse gives a velocity of 7 m/s to the heavier block in the direction of the lighter block. The velocity of the centre of mass is

(1) 30 m/s (2) 20 m/s (3) 10 m/s (4) 5 m/s

Sol. Answer (4)

$$v_{cm} = \frac{m_1 v_1 + m_2 v_2}{m_1 + m_2}$$

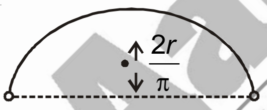
$$= \frac{5(7) + 2(0)}{7} = 5 \text{ m/s}$$

5. The moment of inertia of a uniform semicircular wire of mass *m* and radius *r*, about an axis passing through its centre of mass and perpendicular to its plane is

(1) $\frac{mr^2}{2}$ (2) mr^2 (3) $mr^2\left(1-\frac{4}{\pi^2}\right)$ (4) $mr^2\left(1+\frac{4}{\pi^2}\right)$

Sol. Answer (3)

$$mr^2 = I_{cm} + m\left(\frac{2r}{\pi}\right)^2$$



$$I_{cm} = mr^2\left[1 - \frac{4}{\pi^2}\right]$$

6. A hot solid sphere is rotating about a diameter at an angular velocity ω_0. If it cools so that its radius reduces to $\frac{1}{\eta}$ of its original value, its angular velocity becomes

(1) $\eta\omega_0$ (2) $\frac{\omega_0}{\eta}$ (3) $\frac{\omega_0}{\eta^2}$ (4) $\eta^2\omega_0$

Sol. Answer (4)

Angular momentum will be conserved

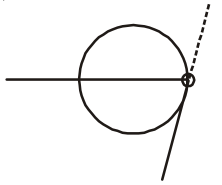
$$\frac{2}{5}mr^2\omega_0 = \frac{2}{5}m\left(\frac{r}{\eta}\right)^2 \omega'$$

$$w' = \eta^2\omega_0$$

7. Moment of inertia of a uniform circular disc about its diameter is I. Its moment of inertia about an axis parallel to its plane and passing through a point on its rim will be

(1) $3I$ (2) $4I$ (3) $5I$ (4) $6I$

Sol. Answer (4)



$$I = \frac{1}{4}mr^2$$

$$I' = \frac{1}{2}mr^2 + mr^2$$

$$I' = \frac{3}{2}mr^2$$

$$I' = \frac{3}{2}(4I)$$

$$= 6I$$

8. Two discs of same mass and same thickness have densities as 17 g/cm³ and 51 g/cm³. The ratio of their moment of inertia about their central axes is

(1) $\frac{1}{3}$ (2) $\frac{2}{3}$ (3) $\frac{3}{1}$ (4) $\frac{3}{2}$

Sol. Answer (3)

$$I = \frac{1}{2}V\rho r^2$$

$$I = \frac{1}{2}\pi r^2 t\rho r^2$$

$$I = \frac{\pi r^4 t\rho}{2}$$

$$\pi r_1^2 t\rho_1 = \pi r_2^2 t\rho_2$$

$$r_1^4\rho_1^2 = r_2^4\rho_2^2$$

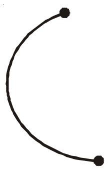
$$\frac{r_1^4}{r_2^4} = \frac{\rho_2^2}{\rho_1^2}$$

So, $$\frac{I_1}{I_2} = \frac{\pi r_1^4 t\rho_1}{\pi r_2^4 t\rho_2} = \frac{\rho_2^2}{\rho_1^2}.\frac{\rho_1}{\rho_2} = \frac{\rho_2}{\rho_1} = 3$$

9. A thin wire of length l and mass m is bent in the form of a semicircle. The moment of inertia about an axis perpendicular to its plane and passing through the end of the wire is

(1) $\frac{ml^2}{2}$ (2) $2ml^2$ (3) $\frac{ml^2}{\pi^2}$ (4) $\frac{2ml^2}{\pi^2}$

Sol. Answer (4)



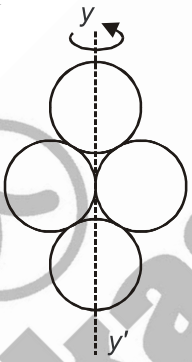
$$\ell = \pi r$$

$$r = \frac{l}{\pi}$$

$$I = 2m\left(\frac{l}{\pi}\right)^2$$

$$= \frac{2ml^2}{\pi^2}$$

10. Four rings each of mass *M* and radius *R* are arranged as shown in the figure. The moment of inertia of the system about the axis *yy'* is



(1) $2MR^2$ (2) $3MR^2$ (3) $4MR^2$ (4) $5MR^2$

Sol. Answer (3)

For upper and lower rings

$$I_1 = \frac{Mr^2}{2}$$

For middle rings, using parallel axis theorem

$$I_2 = \frac{Mr^2}{2} + Mr^2$$

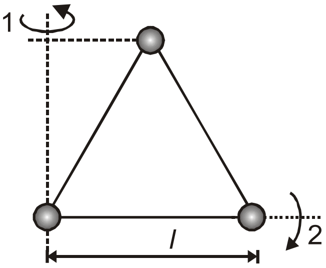
$$= \frac{3}{2}Mr^2$$

$$I = 2I_1 + 2I_2$$

$$= Mr^2 + 3Mr^2$$

$$= 4Mr^2$$

11. Three particles each of mass m are placed at the corners of equilateral triangle of side l



Which of the following is /are correct?

(1) Moment of inertia about axis ‘1’ is $\frac{5}{4}ml^2$

(2) Moment of inertia about axis ‘2’ is $\frac{3}{4}ml^2$

(3) Moment of inertia about an axis passing through one corner and perpendicular to the plane is $2ml^2$

(4) All of these

Sol. Answer (4)

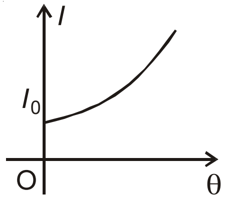
$$I_1 = ml^2 + m\left(\frac{l}{2}\right)^2 \qquad I_2 = m\left(\frac{l\sqrt{3}}{2}\right)^2$$

$$I_1 = \frac{5ml^2}{4}, \quad I_2 = \frac{3ml^2}{4}, \quad I_3 = ml^2 + ml^2$$

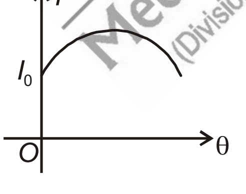
$= 2ml^2$

12. A square plate has a moment of inertia I_0 about an axis lying in its plane, passing through its centre and making an angle θ with one of the sides. Which graph represents the variation of I with θ?

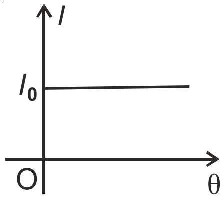
(1)



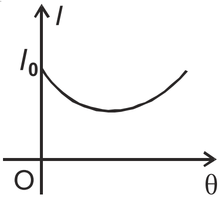
(2)



(3)

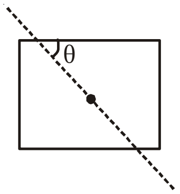


(4)



Sol. Answer (3)

Using perpendicular axis theorem

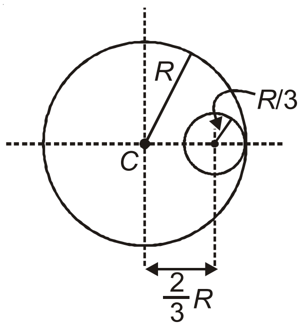


$I_z = I_x + I_y$

$I = 2I'$

$I' = \frac{I}{2}$ = Constant

13. From a uniform disc of radius R and mass 9 M, a small disc of radius $\frac{R}{3}$ is removed as shown. What is the moment of inertia of remaining disc about an axis passing through the centre of disc and perpendicular to its plane?



(1) $\frac{32}{9}MR^2$ (2) 10 MR^2 (3) $\frac{40}{9}MR^2$ (4) 4 MR^2

Sol. Answer (2)

$$I_1 = \frac{1}{2}(9M)\left(R^2\right) = \frac{9MR^2}{2}$$

$$I_2 = \frac{1}{2}M\left(\frac{R}{3}\right)^2 + M\left(\frac{2R}{3}\right)^2$$

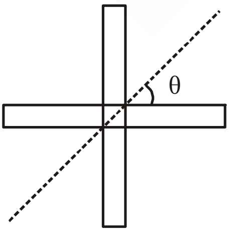
$$= \frac{MR^2}{18} + \frac{4MR^2}{9} = \frac{9MR^2}{18} = \frac{MR^2}{2}$$

$I = I_1 - I_2 = 4MR^2$

14. Two rods of equal lengths(l) and equal mass M are kept along x and y axis respectively such that their centre of mass lie at origin. The moment of inertia about an line $y = x$, is

(1) $\frac{ml^2}{3}$ (2) $\frac{ml^2}{4}$ (3) $\frac{ml^2}{12}$ (4) $\frac{ml^2}{6}$

Sol. Answer (2)



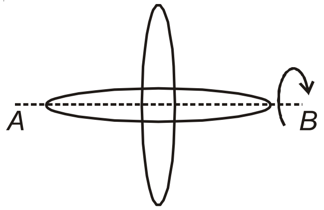
$$I_{\text{Total}} = 2\left(\frac{ml^2}{12}\sin^2 45°\right)$$

$$\frac{2ml^2}{12}.\frac{1}{2} = \frac{ml^2}{12}$$

15. Two rings of same mass and radius R are placed with their planes perpendicular to each other and centres at a common point. The radius of gyration of the system about an axis passing through the centre and perpendicular to the plane of one ring is

(1) $2R$ (2) $\frac{R}{\sqrt{2}}$ (3) $\sqrt{\frac{3}{2}}R$ (4) $\frac{\sqrt{3}R}{2}$

Sol. Answer (4)



$$I_{AB} = mr^2 + \frac{mr^2}{2}$$

$$= \frac{3mr^2}{2}$$

$$\frac{3mr^2}{2} = 2mk^2$$

$$k = \frac{\sqrt{3}}{2}R$$

16. A thin uniform wire of mass *m* and length *l* is bent into a circle. The moment of inertia of the wire about an axis passing through its one end and perpendicular to the plane of the circle is

(1) $\frac{2mL^2}{\pi^2}$ (2) $\frac{mL^2}{\pi^2}$ (3) $\frac{mL^2}{2\pi^2}$ (4) $\frac{mL^2}{3\pi^2}$

Sol. Answer (3)

$2\pi r = L$

$$r = \frac{L}{2\pi}, \quad I = 2mr^2 = 2m\left(\frac{L}{2\pi}\right)^2$$

17. The angular velocity of a body changes from ω_1 to ω_2 without applying a torque but by changing the moment of inertia about its axis of rotation. The ratio of its corresponding radii of gyration is

(1) $\omega_1 : \omega_2$ (2) $\sqrt{\omega_1} : \sqrt{\omega_2}$

(3) $\omega_2 : \omega_1$ (4) $\sqrt{\omega_2} : \sqrt{\omega_1}$

Sol. Answer (4)

Using angular momentum conservation

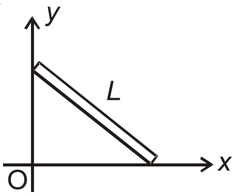
$$I_1\omega_1 = I_2\omega_2$$

$$\frac{I_1}{I_2} = \frac{\omega_2}{\omega_1}$$

$$\frac{mk_1^2}{mk_2^2} = \frac{\omega_2}{\omega_1}$$

$$\frac{k_1}{k_2} = \sqrt{\frac{\omega_2}{\omega_1}}$$

18. A rod of length L leans against a smooth vertical wall while its other end is on a smooth floor. The end that leans against the wall moves uniformly vertically downward. Select the correct alternative



(1) The speed of lower end increases at a constant rate

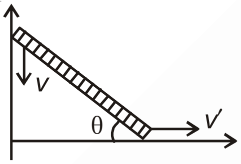
(2) The speed of the lower end decreases but never becomes zero

(3) The speed of the lower end gets smaller and smaller and vanishes when the upper end touches the ground

(4) The speed of the lower end remain constant till upper end touches the ground

Sol. Answer (3)

Using constraint motion relation



$v'\cos\theta = v\sin\theta$

$v' = v\tan\theta$

As θ keeps on decreasing, tanθ will also decrease and at last θ will become zero and $v' = 0$

19. A thin rod of mass m and length l is suspended from one of its ends. It is set into oscillation about a horizontal axis. Its angular speed is ω while passing through its mean position. How high will its centre of mass rise from its lowest position?

(1) $\frac{\omega^2 l^2}{2g}$ (2) $\frac{\omega^2 l^2}{3g}$ (3) $\frac{\omega^2 l^2}{g}$ (4) $\frac{\omega^2 l^2}{6g}$

Sol. Answer (4)

$$\frac{1}{2}\frac{ml^2}{3}.\omega^2 = mgh \quad \text{(Energy conservation)}$$

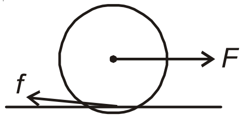
$$h = \frac{l^2\omega^2}{6g}$$

20. A force F is applied at the centre of a disc of mass M. The minimum value of coefficient of friction of the surface for rolling is

(1) $\frac{F}{2Mg}$ (2) $\frac{F}{3Mg}$ (3) $\frac{2F}{5Mg}$ (4) $\frac{2F}{7Mg}$

Sol. Answer (2)

$F - f = Ma$ …(1)



$fr = \frac{1}{2}Mr^2\frac{a}{r}$ …(2)

Using (1) and (2), $F = \frac{3}{2}Ma$

$$a = \frac{2F}{3M}$$

$$f = \frac{1}{2}M \cdot \frac{2F}{3M}$$

$$f = \frac{F}{3} = \mu Mg$$

$$\Rightarrow \mu = \frac{F}{3Mg}$$

21. A solid body rotates about a fixed axis such that its angular velocity depends on θ as $\omega = k\theta^{-1}$ where k is a positive constants. At $t = 0$, $\theta = 0$, then time dependence of θ is given as

(1) $\theta = kt$ (2) $\theta = 2kt$ (3) $\theta = \sqrt{kt}$ (4) $\theta = \sqrt{2kt}$

Sol. Answer (4)

$$\omega = \frac{k}{\theta}$$

$$\frac{d\theta}{dt} = \frac{k}{\theta}$$

$$\int \theta d\theta = k\int dt$$

$$\frac{\theta^2}{2} = kt$$

$$\theta = \sqrt{2kt}$$

22. A particle starts from the point (0, 8) metre and moves with uniform velocity of $\vec{v} = 3\hat{i}$ m/s. What is the angular momentum of the particle after 5 s about origin (mass of particle is 1 kg)?

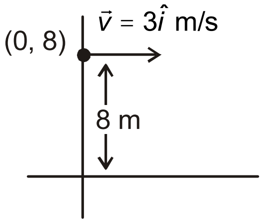
(1) $-12\hat{k}$ kg m^2/s (2) $-24\hat{k}$ kg m^2/s (3) $-32\hat{k}$ kg m^2/s (4) $-36\hat{k}$ kg m^2/s

Sol. Answer (2)

$L = mvr_{\perp}$

$= (1)(3)(8)$

$= 24(-\hat{k})$ kgm^2/s



23. A ball of mass 1 kg is projected with a velocity of $20\sqrt{2}$ m/s from the origin of an *xy* co-ordinate axis system at an angle 45° with *x*-axis (horizontal). The angular momentum [In SI units] of the ball about the point of projection after 2 s of projection is [take g = 10 m/s^2] (*y*-axis is taken as vertical)

(1) $-400\ \hat{k}$ (2) $200\ \hat{i}$ (3) $300\ \hat{j}$ (4) $-350\ \hat{j}$

Sol. Answer (1)

Time of flight $T = \dfrac{2u\sin\theta}{g} = \dfrac{2\left(20\sqrt{2}\right)\frac{1}{\sqrt{2}}}{10} = 4$ second

$\Rightarrow$ After 2 second particle will be at maximum height of the projectile

$L = mvr_\perp$

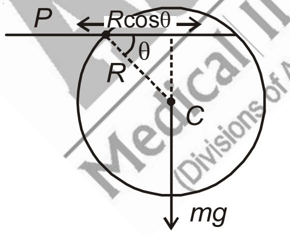
$r_\perp = H_{\text{max}} = \dfrac{u^2\sin^2\theta}{2g} = 20$ m

So $L = (1)\,(20)\,(20) = 400\left(-\hat{k}\right)$

24. A uniform disc of mass *m* and radius *R* is pivoted at point *P* and is free to rotate in vertical plane. The centre *C* of disc is initially in horizontal position with *P* as shown in figure. If it is released from this position, then its angular acceleration when the line PC is inclined to the horizontal at an angle θ is

(1) $\dfrac{2g\cos\theta}{3R}$ (2) $\dfrac{g\sin\theta}{2R}$ (3) $\dfrac{2g\sin\theta}{R}$ (4) $\dfrac{2g\sin\theta}{3R}$

Sol. Answer (1)

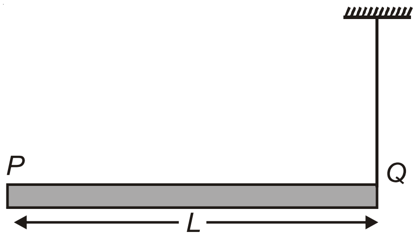


$\tau = I\alpha$

$mg\left(R\cos\theta\right) = \dfrac{3}{2}mr^2\alpha$

$\alpha = \dfrac{2g\cos\theta}{3r}$

25. A rod *PQ* of mass *M* and length *L* is hinged at end *P*. The rod is kept horizontal by a massless string tied to point *Q* as shown in figure. When string is cut, the initial angular acceleration of the rod is



(1) $\dfrac{g}{L}$ (2) $\dfrac{2g}{L}$ (3) $\dfrac{2g}{3L}$ (4) $\dfrac{3g}{2L}$

Sol. Answer (4)

$\tau_{cm} = I\alpha$

$$\frac{mgL}{2} = \frac{mL^2}{3}.\alpha$$

$$\alpha = \frac{3g}{2L}$$

26. A particle undergoes uniform circular motion. About which point in the plane of the circle, will the angular momentum of the particle remain conserved?

(1) Centre of the circle (2) On the circumference of the circle

(3) Inside the circle other than centre (4) Outside the circle

Sol. Answer (1)

External torque about centre will always be zero hence angular momentum of the particle will remain conserved

27. When a planet moves around sun, then its

(1) Angular velocity is constant (2) Areal velocity is constant

(3) Linear velocity is constant (4) Linear momentum is conserved

Sol. Answer (2)

28. When a rolling body enters onto a smooth horizontal surface, it will

(1) Continue rolling (2) Starts slipping

(3) Come to rest (4) Slipping as well as rolling

Sol. Answer (1)

Smooth surface won't be able to change *w* or *v* of the body. So to conserve its angular momentum it will continue to roll on the smooth surface.

29. A hollow sphere of mass *m* and radius *R* is rolling downward on a rough inclined plane of inclination θ. If the coefficient of friction between the hollow sphere and incline is μ, then

(1) Friction opposes its translation (2) Friction supports rotation motion

(3) On decreasing θ, frictional force decreases (4) All of these

Sol. Answer (4)

30. A heavy solid sphere is thrown on a horizontal rough surface with initial velocity *u* without rolling. What will be its speed, when it starts pure rolling motion?

(1) $\frac{3u}{5}$ (2) $\frac{2u}{5}$ (3) $\frac{5u}{7}$ (4) $\frac{2u}{7}$

Sol. Answer (3)

Using angular momentum conservation

$$mur = mvr + \frac{2}{5}mr^2\left(\frac{v}{r}\right)$$

$$u = 7\frac{v}{5}$$

$$v = \frac{5u}{7}$$

31. A cylinder rolls down two different inclined planes of the same height but of different inclinations
    (1) In both cases the speed and time of descent will be different
    (2) In both cases the speed and time of descent will be same
    (3) The speed will be different but time of descent will be same
    (4) The time of descent will be different but speed will be same

Sol. Answer (4)

32. A disc of mass 3 kg rolls down an inclined plane of height 5 m. The translational kinetic energy of the disc on reaching the bottom of the inclined plane is
    (1) 50 J (2) 100 J (3) 150 J (4) 175 J

Sol. Answer (2)

Using mechanical energy conservation

$$mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$$

$$3(5)(10) = \frac{1}{2}mv^2 + \frac{1}{2}ml^2\left(\frac{v^2}{l^2}\right)$$

$$150 = \frac{3}{4}mv^2$$

$mv^2 = 200$

$$\frac{1}{2}mv^2 = 100\text{ J} = \text{K.E.}_{\text{Translation}}$$

SECTION - C

Previous Years Questions

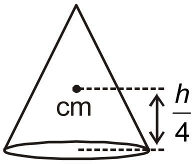
1. Two persons of masses 55 kg and 65 kg respectively, are at the opposite ends of a boat. The length of the boat is 3.0 m and weighs 100 kg. The 55 kg man walks up to the 65 kg man and sits with him. If the boat is in still water the center of mass of the system shifts by
    (1) Zero (2) 0.75 m (3) 3.0 m (4) 2.3 m

Sol. Answer (1)

Net external force on the man and boat is zero and centre of mass is initially at rest. So centre of mass will not move.

2 The centre of mass of a solid cone along the line from the center of the base to the vertex is at
    (1) One-fourth of the height (2) One-third of the height
    (3) One-fifth of the height (4) None of these

Sol. Answer (1)



One fourth of the height

3. The centre of mass of a system of particles does not depend on

(1) Position of the particles (2) Relative distances between the particles

(3) Masses of the particles (4) Forces acting on the particles

Sol. Answer (4)

$$x_{cm} = \frac{m_1x_1 + m_2x_2}{m_1 + m_2}$$

So x_{cm} or y_{cm} does not depend upon force acting on the particles.

4. Consider a system of two particles having masses m_1 and m_2. If the particle of mass m_1 is pushed towards m_2 through a distance d, by what distance should be particle of mass m_2 be moved so as to keep the centre of mass of the system of particles at the original position?

(1) $\frac{m_1}{m_1 + m_2}d$ (2) $\frac{m_1}{m_2}d$ (3) d (4) $\frac{m_2}{m_1}d$

Sol. Answer (2)

$m_1d = m_2x$

$$x = \frac{m_1d}{m_2}$$

5. Three masses are placed on the x-axis ; 300 g at origin, 500 g at x = 40 cm and 400 g at x = 70 cm. The distance of the centre of mass from the origin is

(1) 40 cm (2) 45 cm (3) 50 cm (4) 30 cm

Sol. Answer (1)

$$x_{cm} = \frac{m_1x_1 + m_2x_2 + m_3x_3}{m_1 + m_2 + m_3}$$

$$= \frac{300(0) + 500(40) + 400(70)}{1200}$$

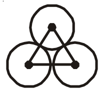
= 40 cm

6. Three identical metal balls, each of the radius r are placed touching each other on a horizontal surface such that an equilateral triangle is formed when centres of three balls are joined. The centre of the mass of the system is located at

(1) Line joining centres of any two balls (2) Centre of one of the balls

(3) Horizontal surface (4) Point of intersection of the medians

Sol. Answer (4)



Centre of mass will lie on the centroid of this triangle i.e. point of intersection of the medians.

7. Two bodies of mass 1 kg and 3 kg have position vectors $\hat{i}+2\hat{j}+\hat{k}$ and $-3\hat{i}-2\hat{j}+\hat{k}$, respectively. The centre of mass of this system has a position vector

(1) $-\hat{i}+\hat{j}+\hat{k}$ (2) $-2\hat{i}+2\hat{k}$ (3) $-2\hat{i}-\hat{j}+\hat{k}$ (4) $2\hat{i}-\hat{j}-2\hat{k}$

Sol. Answer (3)

$$\vec{r}_{cm}=\frac{m_1\vec{r}_1+m_2\vec{r}_2}{m_1+m_2}$$

$$=\frac{(i+2j+k)+(-9i-6j+3k)}{4}$$

$$=\frac{-8\hat{i}-4\hat{j}+4\hat{k}}{4}$$

$$\vec{r}_{cm}=-2\hat{i}-\hat{j}+\hat{k}$$

8. A rod of length 3 m has its mass per unit length directly proportional to distance x from one of its ends then its centre of gravity from that end will be at

(1) 1.5 m (2) 2 m (3) 2.5 m (4) 3.0 m

Sol. Answer (2)

$dm = kxdx$ $\{\text{as } \lambda = kx\}$

$$x_{cm}=\frac{\int x\,dm}{\int dm}=\frac{\int_0^3 x\,kxdx}{\int_0^3 kxdx}=\frac{\left[\frac{kx^3}{3}\right]_0^3}{\left[\frac{kx^2}{2}\right]_0^3}$$

$$=\frac{2}{3}(3)=2\text{ m}$$

9. Two particles which are initially at rest, move towards each other under the action of their internal attraction. If their speeds are v and $2v$ at any instant, then the speed of centre of mass of the system will be

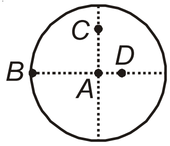
(1) v (2) $2\,v$ (3) Zero (4) $1.5\,v$

Sol. Answer (3)

$$\vec{F}_{ext}=0 \;\Rightarrow\; \vec{a}_{cm}=0$$

$$\Rightarrow (v_{cm})_i=(v_{cm})_f=0$$

10. The moment of inertia of a uniform circular disc is maximum about an axis perpendicular to the disc and passing through



(1) B (2) C (3) D (4) A

Sol. Answer (1)

$I_{new} = I_{cm} + md^2$ (parallel axis theorem)

I_{cm} is same for all points but d is maximum for B

11. The moment of inertia of a thin uniform rod of mass M and length L about an axis passing through its midpoint and perpendicular to its length is I_0. Its moment of inertia about an axis passing through one of its ends and perpendicular to its length is

(1) $I_0 + ML^2$ (2) $I_0 + \frac{ML^2}{2}$ (3) $I_0 + \frac{ML^2}{4}$ (4) $I_0 + 2ML^2$

Sol. Answer (3)

$$I_0 = \frac{ML^2}{12}$$

$$I = I_0 + M\left(\frac{L}{2}\right)^2 = I_0 + \frac{ML^2}{4}$$

12. The ratio of radii of gyration of a circular ring and a circular disc, of the same mass and radius, about an axis passing through their centres and perpendicular to their planes are

(1) $\sqrt{2}:1$ (2) $1:\sqrt{2}$ (3) 3 : 2 (4) 2 : 1

Sol. Answer (1)

$$\frac{M_1K_1^2}{M_2K_2^2} = \frac{I_1}{I_2} = \frac{M_1r^2}{\left(\frac{M_1r^2}{2}\right)}$$

$M_1 = M_2$ given

So $\frac{K_1}{K_2} = \frac{1}{\sqrt{2}}$

13. The ratio of the radii of gyration of a circular disc to that of a circular ring, each of same mass and radius, around their respective axes is

(1) $\sqrt{2}:\sqrt{3}$ (2) $\sqrt{3}:\sqrt{2}$ (3) $1:\sqrt{2}$ (4) $\sqrt{2}:1$

Sol. Answer (3)

$$\frac{M_1K_1^2}{M_2K_2^2} = \frac{\frac{M_1r^2}{2}}{M_2r^2}$$

Given $M_1 = M_2$

$$\frac{K_1}{K_2} = \frac{1}{\sqrt{2}}$$

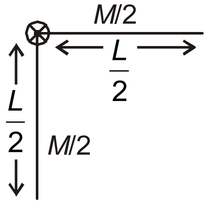
14. A thin rod of length L and mass M is bent at its midpoint into two halves so that the angle between them is 90°. The moment of inertia of the bent rod about an axis passing through the bending point and perpendicular to the plane defined by the two halves of the rod is

(1) $\frac{\sqrt{2}\,ML^2}{24}$ (2) $\frac{ML^2}{24}$ (3) $\frac{ML^2}{12}$ (4) $\frac{ML^2}{6}$

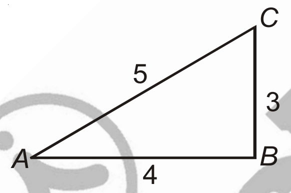
Sol. Answer (3)

$I = 2I$

$$= \frac{2\frac{M}{2}\left(\frac{L}{2}\right)^2}{3} = \frac{ML^2}{12}$$



15. The ABC is a triangular plate of uniform thickness. The sides are in the ratio shown in the figure. I_{AB}, I_{BC} and I_{CA} are the moments of inertia of the plate about AB, BC and CA respectively. Which one of the following relations is correct?



(1) $I_{AB} + I_{BC} = I_{CA}$ (2) I_{CA} is maximum (3) $I_{AB} > I_{BC}$ (4) $I_{BC} > I_{AB}$

Sol. Answer (4)

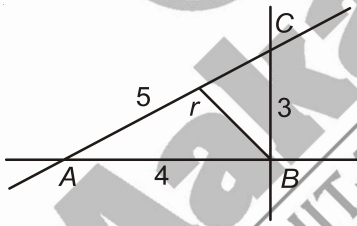
$I_{AB} = m(3)^2$

$I_{BC} = m(4)^2$

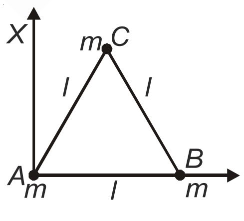
$I_{CA} = mr^2$

$r < 4$

$\Rightarrow I_{BC} > I_{AB}$



16. Three particles, each of mass m gram, are situated at the vertices of an equilateral triangle ABC of side l cm (as shown in the figure). The moment of inertia of the system about a line AX perpendicular to AB and in the plane of ABC, in gcm^2 units will be

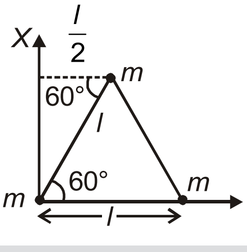


(1) $\frac{3}{4}ml^2$ (2) $2ml^2$ (3) $\frac{5}{4}ml^2$ (4) $\frac{3}{4}ml^2$

Sol. Answer (3)

$I = I_1 + I_2 + I_3$

$$= 0 + m\left(\frac{l}{2}\right)^2 + ml^2 = \frac{5ml^2}{4}$$



17. The moment of inertia of a uniform circular disc of radius R and mass M about an axis passing from the edge of the disc and normal to the disc is

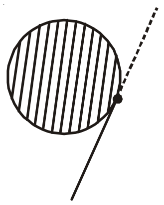
(1) MR^2 (2) $\frac{1}{2}MR^2$ (3) $\frac{3}{2}MR^2$ (4) $\frac{7}{2}MR^2$

Sol. Answer (3)

$I = I_{cm} + MR^2$

$= \frac{MR^2}{2} + MR^2$

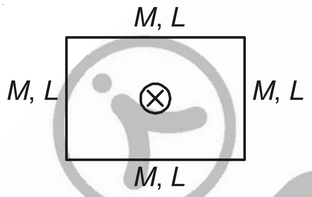
$= \frac{3}{2}MR^2$



18. Four identical thin rods each of mass M and length l, form a square frame. Moment of inertia of this frame about an axis through the centre of the square and perpendicular to its plane is

(1) $\frac{1}{3}Ml^2$ (2) $\frac{4}{3}Ml^2$ (3) $\frac{2}{3}Ml^2$ (4) $\frac{13}{3}Ml^2$

Sol. Answer (2)



$I = I_{cm} + Md^2$

$I_{Total} = 4I$

$= 4\left[\frac{Ml^2}{12} + M\left(\frac{l}{2}\right)^2\right]$

$= \frac{4Ml^2}{3}$

19. From a circular disc of radius R and mass $9M$, a small disc of mass M and radius $\frac{R}{3}$ is removed concentrically. The moment of inertia of the remaining disc about an axis perpendicular to the plane of the disc and passing through its centre is

(1) $\frac{40}{9}MR^2$ (2) MR^2 (3) $4\,MR^2$ (4) $\frac{4}{9}MR^2$

Sol. Answer (1)

$I_1 = \frac{1}{2}(9M)R^2 = \frac{9MR^2}{2}$

$I_2 = \frac{1}{2}M\left(\frac{R}{3}\right)^2 = \frac{MR^2}{18}$

$I = I_1 - I_2$

$= \frac{9MR^2}{2} - \frac{MR^2}{18} = \frac{40MR^2}{9}$

20. (a) Centre of gravity (C.G.) of a body is the point at which the weight of the body acts

(b) Centre of mass coincides with the centre of gravity if the earth is assumed to have infinitely large radius

(c) To evaluate the gravitational field intensity due to any body at an external point, the entire mass of the body can be considered to be concentrated at its C.G.

(d) The radius of gyration of any body rotating about an axis is the length of the perpendicular dropped from the C.G. of the body to the axis

Which one of the following pairs of statements is correct?

(1) (d) and (a) (2) (a) and (b) (3) (b) and (c) (4) (c) and (d)

Sol. Answer (1)

21. A circular disc is to be made by using iron and aluminium so that it acquires maximum moment of inertia about geometrical axis. It is possible with

(1) Aluminium at interior and iron surround to it

(2) Iron at interior and aluminium surround to it

(3) Using iron and aluminium layers in alternate order

(4) Sheet of iron is used at both external surface and aluminium sheet as interna layers

Sol. Answer (1)

As density of iron is higher than Aluminium. So iron should be farther from the rotational axis.

22. The ratio of the radii of gyration of a circular disc about a tangential axis in the plane of the disc and of a circular ring of the same radius about a tangential axis in the plane of the ring is

(1) 2 : 3 (2) 2 : 1 (3) $\sqrt{5}:\sqrt{6}$ (4) $1:\sqrt{2}$

Sol. Answer (3)

For disc, using parallel axis theorem first and then using perpendicular axis theorem

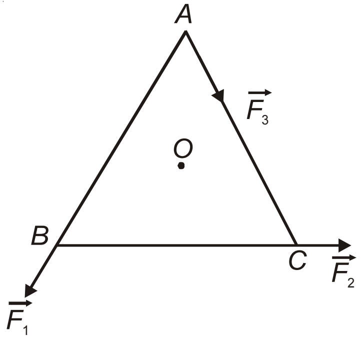
$$I_{disc} = \frac{5}{4}Mr^2$$

$$I_{ring} = \frac{3}{2}Mr^2$$

$$\frac{I_{disc}}{I_{ring}} = \frac{5(2)}{4(3)} = \frac{5}{6} = \frac{K_1^2}{K_2^2}$$

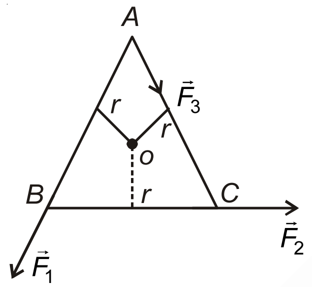
$$\Rightarrow \frac{K_1}{K_2} = \sqrt{\frac{5}{6}}$$

23. ABC is an equilateral triangle with O as its centre. $\vec{F}_1, \vec{F}_2$ and $\vec{F}_3$ represent three forces acting along the sides AB, BC and AC respectively. If the total torque about O is zero then the magnitude of $\vec{F}_3$ is



(1) $\frac{F_1 + F_2}{2}$ (2) $2(F_1 + F_2)$ (3) $F_1 + F_2$ (4) $F_1 - F_2$

Sol. Answer (3)



$F_1r + F_2r = F_3r$

$F_3 = F_1 + F_2$

24. When a mass is rotating in a plane about a fixed point, its angular momentum is directed along

(1) The radius

(2) The tangent to the orbit

(3) A line perpendicular to the plane of rotation

(4) The line making an angle of 45° to the plane of rotation

Sol. Answer (3)

25. The reduced mass of two particles having masses m and $2m$ is

(1) $2m$ (2) $3m$ (3) $\frac{2m}{3}$ (4) $\frac{m}{2}$

Sol. Answer (3)

Reduced mass $\mu = \frac{m_1 m_2}{m_1 + m_2} = \frac{m(2m)}{m + 2m} = \frac{2m}{3}$

26. What is the torque of the force $\vec{F} = 2\hat{i} - 3\hat{j} + 4\hat{k}$ N acting at the point $\vec{r} = 3\hat{i} + 2\hat{j} + 3\hat{k}$ m about origin?

(1) $-6\hat{i} + 6\hat{j} - 12\hat{k}$ (2) $-17\hat{i} + 6\hat{j} + 13\hat{k}$ (3) $6\hat{i} - 6\hat{j} + 12\hat{k}$ (4) $17\hat{i} - 6\hat{j} - 13\hat{k}$

Sol. Answer (4)

$$\tau = \vec{r} \times \vec{F}$$

$$= \begin{vmatrix} i & j & k \\ 3 & 2 & 3 \\ 2 & -3 & 4 \end{vmatrix}$$

$$\hat{i}(17) - \hat{j}(6) + \hat{k}(-13)$$

$$17\hat{i} - 6\hat{j} - 13\hat{k}$$

27. A couple produces

(1) Linear and rotational motion
(2) No motion
(3) Purely linear motion
(4) Purely rotational motion

Sol. Answer (4)

28. The instantaneous angular position of a point on a rotating wheel is given by the equation $\theta(t) = 2t^3 - 6t^2$. The torque on the wheel becomes zero at

(1) $t = 2$ s
(2) $t = 1$ s
(3) $t = 0.2$ s
(4) $t = 0.25$ s

Sol. Answer (2)

$$\theta = 2t^3 - 6t^2$$

$$\omega = \frac{d\theta}{dt} = 6t^2 - 12t$$

$$\alpha = \frac{d\omega}{dt} = 12t - 12$$

$$\alpha = 0 \quad \Rightarrow \quad 12t - 12 = 0 \quad \Rightarrow t = 1\text{s}$$

29. The angular speed of a fly-wheel making 120 revolutions/minute is

(1) 4π rad/s
(2) $4\pi^2$ rad/s
(3) π rad/s
(4) 2π rad/s

Sol. Answer (1)

$$120 \text{ rev/min} = \frac{2\pi(120)}{60} = 4\pi \text{ rad/s}$$

30. Two discs are rotating about their axes, normal to the discs and passing through the centres of the discs. Disc D_1 has 2 kg mass and 0.2 m radius and initial angular velocity of 50 rad s^{-1}. Disc D_2 has 4kg mass, 0.1 m radius and initial angular velocity of 200 rad s^{-1}. The two discs are brought in contact face to face, with their axes of rotation coincident. The final angular velocity (in rad.s^{-1}) of the system is

(1) 40
(2) 60
(3) 100
(4) 120

Sol. Answer (3)

Using angular momentum conservation

$$I_1 \omega_1 + I_2 \omega_2 = (I_1 + I_2)\omega$$

$$\frac{1}{2}(2)(0.2)^2(50)+\frac{1}{2}4(0.1)^2(200)$$

$$=\left[\frac{1}{2}(2)(0.2)^2+\frac{1}{2}(4)(0.1)^2\right]\omega$$

$$6=\frac{6}{100}\omega$$

ω = 100 rad/s

31. A wheel having moment of inertia 2 kgm^2 about its vertical axis, rotates at the rate of 60 rpm about this axis. The torque which can stop the wheel's rotation in one minute would be

(1) $\frac{2\pi}{15}$Nm (2) $\frac{\pi}{12}$Nm (3) $\frac{\pi}{15}$Nm (4) $\frac{\pi}{18}$Nm

Sol. Answer (3)

$$\alpha=\frac{0-\frac{60\times 2\pi}{60}}{60}$$

$$=\frac{-2\pi}{60}\text{ rad/s}^2$$

$$\tau=I\alpha=(2)\left(\frac{\pi}{30}\right)=\frac{\pi}{15}\text{ Nm}$$

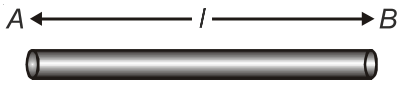
32. Two bodies have their moments of inertia I and $2I$ respectively about their axis of rotation. If their kinetic energies of rotation are equal, their respective angular momenta will be in the ratio

(1) 2 : 1 (2) 1 : 2 (3) $\sqrt{2}$: 1 (4) 1 : $\sqrt{2}$

Sol. Answer (4)

$$\frac{L_1}{L_2}=\frac{\sqrt{2IK}}{\sqrt{2(2I)K}}=\frac{1}{\sqrt{2}}$$

33. A uniform rod of length l and mass m is free to rotate in a vertical plane about A. The rod initially in horizontal position is released. The initial angular acceleration of the rod is (moment of inertia of the rod about A is $\frac{ml^2}{3}$)



(1) $mg\frac{l}{2}$ (2) $\frac{3g}{2l}$ (3) $\frac{2l}{3g}$ (4) $\frac{3g}{2l^2}$

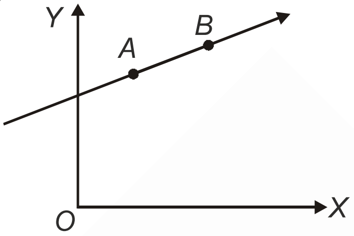
Sol. Answer (2)

$$\tau = I\alpha$$

$$\frac{mgl}{2} = \frac{ml^2}{3}\alpha$$

$$\alpha = \frac{3g}{2l}$$

34. A particle of mass *m* moves in the *XY* plane with a velocity *v* along the straight line *AB.* If the angular momentum of the particle with respect to origin *O* is L_A, when it is at *A* and L_B when it is at *B,* then



(1) $L_A = L_B$

(2) The relationship between L_A and L_B depends upon the slope of the line *AB*

(3) $L_A < L_B$

(4) $L_A > L_B$

Sol. Answer (1)

Perpendicular distance from *O* of line *AB* will be constant. Hence angular momentum will be constant.

35. What is the value of linear velocity, if $\vec{\omega} = 3\hat{i} - 4\hat{j} + \hat{k}$ and $\vec{r} = 5\hat{i} - 6\hat{j} + 6\hat{k}$?

(1) $4\hat{i} - 13\hat{j} + 6\hat{k}$ (2) $-18\hat{i} - 13\hat{j} + 2\hat{k}$ (3) $6\hat{i} + 2\hat{j} + 3\hat{k}$ (4) $6\hat{i} - 2\hat{j} + 8\hat{k}$

Sol. Answer (2)

$$\vec{v} = \vec{\omega} \times \vec{r}$$

$$= \begin{vmatrix} i & j & k \\ 3 & -4 & 1 \\ 5 & -6 & 6 \end{vmatrix}$$

$$i(-18) - j(13) + k(2)$$

$$= -18i - 13\hat{j} + 2\hat{k}$$

36. If $|\vec{A} \times \vec{B}| = \sqrt{3}\vec{A}.\vec{B}$ then the value of $|\vec{A} + \vec{B}|$ is

(1) $(A^2 + B^2 + AB)^{1/2}$ (2) $\left(A^2 + B^2 + \frac{AB}{\sqrt{3}}\right)^{1/2}$ (3) $A + B$ (4) $(A^2 + B^2\sqrt{3} + AB)^{1/2}$

Sol. Answer (1)

$$\left|\vec{A}\right|\left|\vec{B}\right|\sin\theta = \sqrt{3}\left|\vec{A}\right|\left|\vec{B}\right|\cos\theta$$

$$\tan\theta = \sqrt{3}$$

$\theta = 60°$

$$\left|\vec{A}+\vec{B}\right|^2 = \left|\vec{A}\right|^2 + \left|\vec{B}\right|^2 + 2\vec{A}\vec{B}$$

$$= \left(A^2 + B^2 + AB\right)^{\frac{1}{2}}$$

37. If the angle between the vectors $\vec{A}$ and $\vec{B}$ is θ, the value of the product $(\vec{B}\times\vec{A})\cdot\vec{A}$ is equal to

(1) $BA^2\sin\theta$ (2) $BA^2\cos\theta$ (3) $BA^2\sin\theta\cos\theta$ (4) Zero

Sol. Answer (4)

$\left(\vec{B}\times\vec{A}\right)$ and $\vec{A}$ will be perpendicular to each other so cross product will be zero

38. If $\vec{F}$ is the force acting on a particle having position vector $\vec{r}$ and $\vec{\tau}$ be the torque of this force about the origin, then

(1) $\vec{r}\cdot\vec{\tau}=0$ and $\vec{F}\cdot\vec{\tau}\neq 0$ (2) $\vec{r}\cdot\vec{\tau}\neq 0$ and $\vec{F}\cdot\vec{\tau}=0$

(3) $\vec{r}\cdot\vec{\tau}>0$ and $\vec{F}\cdot\vec{\tau}<0$ (4) $\vec{r}\cdot\vec{\tau}=0$ and $\vec{F}\cdot\vec{\tau}=0$

Sol. Answer (4)

$\vec{\tau}$ will be perpendicular to $\vec{F}$ and $\vec{r}$ as $\vec{\tau}=\vec{r}\times\vec{F}$

39. A circular platform is mounted on a frictionless vertical axle. Its radius R = 2 m and its moment of inertia about the axle is 200 kg m^2. It is initially at rest. A 50 kg man stands on the edge of the platform and begins to walk along the edge at the speed of 1 ms^{-1} relative to the ground. Time taken by the man to complete one revolution is

(1) π s (2) $\frac{3\pi}{2}$ s (3) 2π s (4) $\frac{\pi}{2}$ s

Sol. Answer (3)

$0 = (50)(1)(2) - 200\,\omega$

$$\omega = \frac{1}{2}\text{ rad/s}$$

$$v_{rel} = 1 + 2\left(\frac{1}{2}\right) = 2$$

$$T = \frac{(2\pi)(2)}{2} = 2\pi\text{ s}$$

40. A thin circular ring of mass M and radius r is rotating about its axis with a constant angular velocity ω. Two objects each of mass m are attached gently to the opposite ends of a diameter of the ring. The ring will now rotate with an angular velocity

(1) $\frac{\omega(M+2m)}{M}$ (2) $\frac{\omega M}{M+2m}$ (3) $\frac{\omega(M-2M)}{M+2m}$ (4) $\frac{\omega M}{M+m}$

Sol. Answer (2)

Using angular momentum conservation

$(Mr^2\omega) = (M+2m)r^2\omega'$

$$\omega' = \frac{M}{M+2m}\omega$$

41. A round disc of moment of inertia I_1 about its axis perpendicular to its plane and passing through its centre is placed over another disc of moment of inertia I_2 rotating with an angular velocity ω about the same axis. The final angular velocity of the combination of discs is

(1) $\frac{I_2\omega}{I_1+I_2}$ (2) ω (3) $\frac{I_1\omega}{I_1+I_2}$ (4) $\frac{(I_1+I_2)\omega}{I_1}$

Sol. Answer (1)

Using angular momentum conservation

$$I_1(0) + I_2(\omega) = (I_1+I_2)\omega'$$

$$\omega' = \frac{I_2\omega}{I_1+I_2}$$

42. A circular disk of moment of inertia I_t is rotating in a horizontal plane, about its symmetry axis, with a constant angular speed ω_i. Another disk of moment of inertia I_b is dropped coaxially onto the rotating disk. Initially the second disk has zero angular speed. Eventually both the disks rotate with a constant angular speed ω_f. The energy lost by the initially rotating disc to friction is

(1) $\frac{1}{2}\frac{I_bI_t}{(I_t+I_b)}\omega_i^2$ (2) $\frac{1}{2}\frac{I_b^2}{(I_t+I_b)}\omega_i^2$ (3) $\frac{1}{2}\frac{I_t^2}{(I_t+I_b)}\omega_i^2$ (4) $\frac{I_b-I_t}{(I_t+I_b)}\omega_i^2$

Sol. Answer (1)

$$\text{Energy lost} = \frac{1}{2}\frac{I_t+I_b}{I_t+I_b}\omega_i^2\left(\text{Same as }\frac{1}{2}\frac{m_1m_2}{(m_1+m_2)}.u^2\right)$$

43. A disc is rotating with angular speed ω. If a child sits on it, what is conserved?

(1) Linear momentum (2) Angular momentum (3) Kinetic energy (4) Potential energy

Sol. Answer (2)

44. A solid cylinder is rolling without slipping on a plane having inclination θ and the coefficient of static friction μ_s. The relation between θ and μ_s is

(1) $\tan\theta > 3\mu_s$ (2) $\tan\theta \le 3\mu_s$ (3) $\tan\theta < 3\mu_s^2$ (4) None of these

Sol. Answer (2)

$$\mu_s \ge \frac{\frac{1}{2}mr^2\tan\theta}{\frac{1}{2}mr^2+mr^2}$$

$$\mu_s \ge \frac{\tan\theta}{3}$$

$$3\mu \ge \tan\theta$$

45. A solid spherical ball rolls on a table. Ratio of its rotational kinetic energy to total kinetic energy is (1)

$\frac{1}{2}$ (2) $\frac{1}{6}$ (3) $\frac{7}{10}$ (4) $\frac{2}{7}$

Sol. Answer (4)

46. A small object of uniform density rolls up a curved surface with an initial velocity v'. It reaches up to a maximum height of $\frac{3v^2}{4g}$ with respect to the initial position. The object is

(1) Solid sphere (2) Hollow sphere (3) Disc (4) Ring

Sol. Answer (3)

$U_i + k_i = U_f + k_f$

$$0+\left(\frac{1}{2}mv^2+\frac{1}{2}I\left(\frac{v}{r}\right)^2\right)=mg\left(\frac{3v^2}{4g}\right)+0$$

Solving this, we get

$I=\frac{Mr^2}{2}\Rightarrow$ body is disc

47. A hollow cylinder and a solid cylinder are rolling without slipping down an inclined plane, then which of these reaches earlier?

(1) Solid cylinder (2) Hollow cylinder

(3) Both simultaneously (4) Can't say anything

Sol. Answer (1)

Body of smaller $\frac{K^2}{R^2}$ will take less time. Solid cylinder has smaller $\frac{K^2}{R^2}$

48. A disc is rolling such that the velocity of its centre of mass is v_{cm}. Which one will be correct?

(1) The velocity of highest point is 2 v_{cm} and point of contact is zero

(2) The velocity of highest point is v_{cm} and point of contact is v_{cm}

(3) The velocity of highest point is $2v_{cm}$ and point of contact is v_{cm}

(4) The velocity of highest point is $2v_{cm}$ and point of contact is $2v_{cm}$

Sol. Answer (1)

49. A solid sphere of radius R is placed on a smooth horizontal surface. A horizontal force F is applied at height h from the lowest point. For the maximum acceleration of centre of mass, which is correct?

(1) $h = R$

(2) $h = 2R$

(3) $h = 0$

(4) Centre of mass has same acceleration in each case

Sol. Answer (4)

Acceleration of CM is independent of point of application of force.

50. A point P is the contact point of a wheel on ground which rolls on ground without slipping. The value of displacement of the point P when wheel completes half of rotation (If radius of wheel is 1 m)

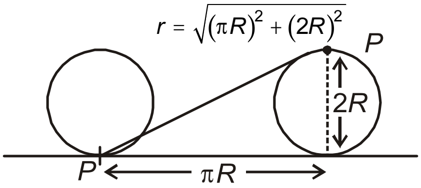
(1) 2 m (2) $\sqrt{\pi^2+4}$ m (3) π m (4) $\sqrt{\pi^2+2}$ m

Sol. Answer (2)

Use pythagoras theorem

$$r = R\sqrt{\pi^2+4}$$

$$= \sqrt{\pi^2+4}\ \text{m}$$



51. A solid cylinder of mass M and radius R rolls without slipping down an inclined plane of length L and height h. What is the speed of its centre of mass when the cylinder reaches its bottom?

(1) $\sqrt{2gh}$ (2) $\sqrt{\frac{3}{4}gh}$ (3) $\sqrt{\frac{4}{3}gh}$ (4) $\sqrt{4gh}$

Sol. Answer (3)

Using mechanical energy conservation

$$Mgh = \frac{1}{2}mv^2 + \frac{1}{2}\left(\frac{1}{2}MR^2\right)\frac{v^2}{R^2}$$

$$Mgh = \frac{3}{4}Mv^2$$

$$v = \sqrt{\frac{4gh}{3}}$$

52. A solid cylinder and a hollow cylinder, both of the same mass and same external diameter are released from the same height at the same time on a inclined plane. Both roll down without slipping. Which one will reach the bottom first?

(1) Both together only when angle of inclination of plane is 45°

(2) Both together

(3) Hollow cylinder

(4) Solid cylinder

Sol. Answer (4)

$a = r\alpha$

$$= \frac{r\tau}{I} \quad (\because \tau = I\alpha)$$

So $a = \dfrac{mgr^2 \sin\theta}{I + mr^2}$

If I is less , a is more, t is less

53. A drum of radius R and mass M, rolls down without slipping along an inclined plane of angle θ. The frictional force

(1) Dissipates energy as heat (2) Decreases the rotational motion

(3) Decreases the rotational and translational motion (4) Converts translational energy to rotational energy

Sol. Answer (4)

54. A ball rolls without slipping. The radius of gyration of the ball about an axis passing through its centre of mass is K. If radius of the ball be R, then the fraction of total energy associated with its rotational energy will be

(1) $\frac{K^2+R^2}{R^2}$ (2) $\frac{K^2}{R^2}$ (3) $\frac{K^2}{K^2+R^2}$ (4) $\frac{R^2}{K^2+R^2}$

Sol. Answer (3)

$$K_{Rot} = \frac{1}{2}MK^2\frac{v^2}{R^2}$$

$$K_{Total} = \frac{1}{2}MK^2\frac{v^2}{R^2}+\frac{1}{2}Mv^2$$

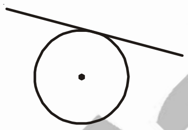
$$\frac{K_{Rot}}{K_{Total}} = \frac{\frac{K^2}{R^2}}{1+\frac{K^2}{R^2}} = \frac{K^2}{K^2+R^2}$$

55. The moment of inertia of a disc of mass M and radius R about an axis, which is tangential to the circumference of the disc and parallel to its diameter is

(1) $\frac{5}{4}MR^2$ (2) $\frac{2}{3}MR^2$ (3) $\frac{3}{2}MR^2$ (4) $\frac{1}{2}MR^2$

Sol. Answer (1)

$$I = \frac{MR^2}{4}+MR^2$$



$$= \frac{5MR^2}{4}$$

SECTION - D

Assertion - Reason Type Questions

1. A : Centre of mass of a system may or may not lie inside the system.
R : The position of centre of mass depends on distribution of mass within the system.

Sol. Answer ((1)

2. A : The position of centre of mass relative to body is independent of the choice of coordinate system.
R : Centre of mass does not shift its position in the absence of an external force.

Sol. Answer (3)

3. A : A bomb at rest explodes. The centre of mass of fragments moves along parabolic path.
R : Under the effect of gravity only the path followed by centre of mass is always parabolic.

Sol. Answer (4)

4. A : If an object is taken to the centre of earth, then its centre of gravity cannot be defined.
R : At the centre of earth acceleration due to gravity is zero.

Sol. Answer (1)

5. A : It is very difficult to open or close a door if force is applied near the hinge.
   R : The moment of applied force is minimum near the hinge.

Sol. Answer (1)

6. A : The moment of force is maximum for a point if force applied on it and its position vector w.r.t. the point of rotation are perpendicular.
   R : The magnitude of torque is independent of the direction of application of force.

Sol. Answer (3)

7. A : If angular momentum of an object is constant about a point, then net torque on it about that point is zero.
   R : Torque is equal to the rate of change of angular momentum.

Sol. Answer (1)

8. A : Two rings of equal mass and radius made of different materials, will have same moment of inertia.
   R : Moment of inertia depends on mass as well as distribution of mass in the object.

Sol. Answer (1)

9. A : In pure rolling motion all the points of a rigid body have same linear velocity.
   R : Rolling motion is not possible on smooth surface.

Sol. Answer (4)

10. A : For an object in rolling motion rotational kinetic energy is always equal to translational kinetic energy.
    R : For an object in rolling motion magnitude of linear speed and angular speed are equal.

Sol. Answer (4)

11. A : The work done by friction force on an object during pure rolling motion is zero.
    R : In pure rolling motion, there is relative motion at the point of contact.

Sol. Answer (3)

12. A : When a rigid body rotates about any fixed axis, then all the particles of it move in circles of different radii but with same angular velocity.
    R : In rigid body relative position of particles are fixed.

Sol. Answer (1)

13. A : A rigid body can't be in a pure rolling on a rough inclined plane without giving any external force.
    R : Since there is no torque providing force acting on the body in the above case, the body can't come in a rolling condition.

Sol. Answer (4)

14. A : When a ring moves in pure rolling condition on ground, it has 50% translational and 50% rotational energy.

    R : $\dfrac{\text{KE}_{\text{trans}}}{\text{KE}_{\text{rot}}} = \dfrac{\frac{1}{2}MV^2}{\frac{1}{2}I\omega^2} = \dfrac{\frac{1}{2}MV^2}{\frac{1}{2}(MR^2)\frac{V^2}{R^2}} = 1:1.$

Sol. Answer (1)

15. A : For a body to be in rotational equilibrium the net torque acting on the body about any point is zero.
    R : For net torque to be zero, net force should also be zero.

Sol. Answer (3)

❑ ❑ ❑

Chapter 8

Gravitation

Solutions

SECTION - A

Objective Type Questions

1. According to Kepler, planets move in

   (1) Circular orbits around the sun

   (2) Elliptical orbits around the sun with sun at exact centre

   (3) Straight lines with constant velocity

   (4) Elliptical orbits around the sun with sun at one of its foci

Sol. Answer (4)

Kepler's first law,

Law of Orbits : All planets move in elliptical orbits, with the sun at one of the foci of the ellipse.

2. The minimum and maximum distances of a planet revolving around sun are r and R. If the minimum speed of planet on its trajectory is v_0, its maximum speed will be

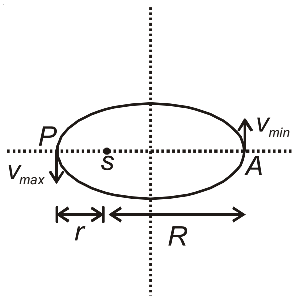
   (1) $\frac{v_0 R}{r}$ (2) $\frac{v_0 r}{R}$ (3) $\frac{v_0 R^2}{r^2}$ (4) $\frac{v_0 r^2}{R^2}$

Sol. Answer (1)

According to Kepler's second law.

Low of Areas : The line that joins any planet to the sun sweeps out equal areas in equal intervals of time. Thus planets appear to move slower when they are farther from sun than when they are nearer.

Now, for planets moving around the sun in an elliptical orbit, Angular momentum is conserved.



$$\Rightarrow \quad |\overrightarrow{L_P}| = |\overrightarrow{L_A}|$$

$$mv_{\text{max}}r = mv_0R$$

$$v_{\text{max}} = \frac{v_0R}{r}$$

3. A planet of mass m moves around the sun of mass M in an elliptical orbit. The maximum and minimum distances of the planet from the sun are r_1 and r_2 respectively. The time period of the planet is proportional to

(1) $r_1^{3/2}$ (2) $r_2^{3/2}$ (3) $(r_1 + r_2)^{3/2}$ (4) $(r_1 - r_2)^{3/2}$

Sol. Answer (3)

Law of periods : The square of the time period of revolution of a planet is proportional to the cube of the semi-major axis of the ellipse traced out by the planet.

$T^2 \alpha\ a^3$

where,

T = Time period of revolution of a planet.

a = Semi-major axis of the elliptical orbit traced by the planet.

$r_1 = a + ae$

$r_2 = a - ae$

$r_1 + r_2 = 2a$

$$\Rightarrow\ T^2\ \alpha \left(\frac{(r_1 + r_2)}{2}\right)^3$$

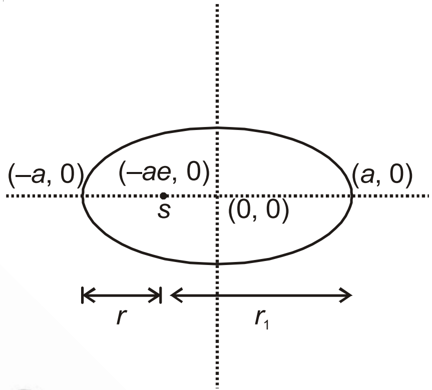
$$\Rightarrow\ T\ \alpha\ (r_1 + r_2)^{3/2}$$

Alternatively,

From figure, $r_1 + r_2 = 2a$

$$\Rightarrow\ T^2 \alpha \left(\frac{r_1 + r_2}{2}\right)^3$$

$$\Rightarrow\ T\ \alpha\ (r_1 + r_2)^{3/2}$$



4. In a satellite if the time of revolution is T, then PE is proportional to

(1) $T^{1/3}$ (2) T^3 (3) $T^{-2/3}$ (4) $T^{-4/3}$

Sol. Answer (3)

According to Kepler's third law,

$T^2 \propto r^3$

r = radius of orbit

For a satellite of mass m orbiting in an orbit of radius r around planet of mass M,

$$\text{Potential energy (PE)} = \frac{-GMm}{r}$$

$$\Rightarrow\ \text{PE} \propto \frac{GMm}{T^{2/3}}$$

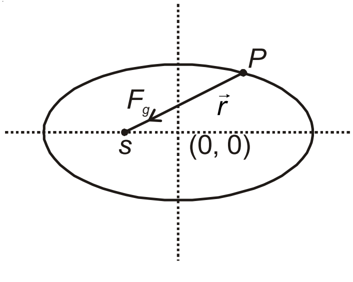
$$\Rightarrow\ \text{PE} \propto T^{-2/3}$$

5. The torque on a planet about the centre of sun is

(1) Zero (2) Negative

(3) Positive (4) Depend on mass of planet

Sol. Answer (1)



Force of gravity is acting on the planet,

Torque of force of gravity = $\vec{r} \times \overrightarrow{F_g} = rF_g\ \sin\theta$

Since θ = 180°, $\tau = 0$

6. During motion of a planet from perihelion to aphelion the work done by gravitational force of sun on it is

(1) Zero (2) Negative

(3) Positive (4) May be positive or negative

Sol. Answer (2)

According to Kepler's Law of areas, $v_A < v_P$

v_A = speed of planet at aphelion

v_P = speed of planet at perihelion

Now, work done by gravitational force of sun $= \Delta \text{K.E} = \frac{1}{2}m\left(v_A^2 - v_P^2\right)$

$\Rightarrow W_{\text{gravitation force}}$ is negative.

7. The gravitational constant depends upon

(1) Size of the bodies (2) Gravitational mass

(3) Distance between the bodies (4) None of these

Sol. Answer (4)

Gravitational constant 'G' is independent of size of bodies, gravitational mass and distance between the bodies.

8. Gravitation is the phenomenon of interaction between

(1) Point masses only (2) Any arbitrary shaped masses

(3) Planets only (4) None of these

Sol. Answer (2)

Gravitation is the phenomenon of interaction between any arbitrary shaped bodies.

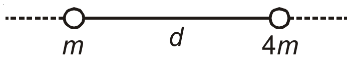
9. Force of gravitation between two masses is found to be F, in vacuum. If both the masses are dipped in water at same distance then, new force will be

(1) $> F$ (2) $< F$ (3) F (4) Cannot say

Sol. Answer (3)

Force of gravitation is independent of the medium. Force is F when masses are in vacuum. When masses are dipped in water force will be same.

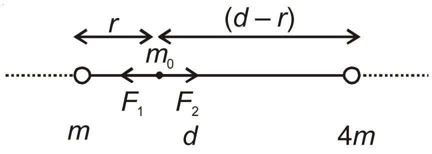
10. Two point masses m and $4m$ are separated by a distance d on a line. A third point mass m_0 is to be placed at a point on the line such that the net gravitational force on it is zero.



The distance of that point from the m mass is

(1) $\frac{d}{2}$ (2) $\frac{d}{4}$ (3) $\frac{d}{3}$ (4) $\frac{d}{5}$

Sol. Answer (3)



Force of gravitation on m_0 due to $m = \frac{Gmm_0}{r^2} = F_1$

Force of gravitation on m_0 due to $4m = \frac{G4mm_0}{(d-r)^2} = F_2$

Net force = 0

$\Rightarrow$ $F_1 = F_2$

$$\frac{Gmm_0}{r^2} = \frac{4Gmm_0}{(d-r)^2}$$

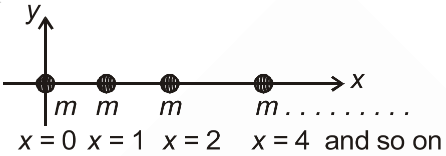
$\Rightarrow$ $(d-r)^2 = (2r)^2$

$\Rightarrow$ $d - r = 2r$

$\Rightarrow$ $d = 3r$

Thus, $r = \dfrac{d}{3}$

11. A large number of identical point masses m are placed along x-axis, at $x = 0, 1, 2, 4,$ .... The magnitude of gravitational force on mass at origin ($x = 0$), will be



(1) Gm^2 (2) $\dfrac{4}{3}Gm^2$ (3) $\dfrac{2}{3}Gm^2$ (4) $\dfrac{5}{4}Gm^2$

Sol. Answer (2)

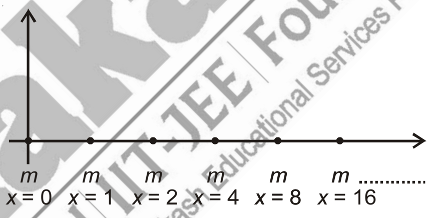
Let, F_1, F_2 , F_4, F_8 …… be the forces of gravitation due masses 'm' at $x = 1, 2, 4, 8$ … respectively.

$\Rightarrow$ $F_1 = \dfrac{Gm^2}{1^2}$

$F_2 = \dfrac{Gm^2}{2^2}$

$F_4 = \dfrac{Gm^2}{4^2}$

$F_8 = \dfrac{Gm^2}{8^2}$



$$F_1 + F_2 + F_4 + F_8 \ldots = \quad Gm^2 \underbrace{\left(\frac{1}{1} + \frac{1}{4} + \frac{1}{16} + \frac{1}{64} \ldots\right)}_{\text{infinite G.P. with common ratio } = \frac{1}{4}}$$

For an infinite G.P, sum = $\left(\dfrac{a}{1-r}\right)$

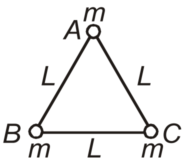
a is the first term

r is the common ratio

$\Rightarrow$ $\text{Sum} = \dfrac{1}{1-\dfrac{1}{4}} = \left(\dfrac{4}{3}\right)$

$\Rightarrow$ $F_1 + F_2 + F_4 + F_8 \ldots\ldots = \dfrac{4}{3}Gm^2$

12. Three particles *A*, *B* and *C* each of mass *m* are lying at the corners of an equilateral triangle of side *L*. If the particle *A* is released keeping the particles *B* and *C* fixed, the magnitude of instantaneous acceleration of *A* is

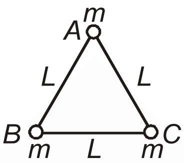


(1) $\sqrt{3}\dfrac{Gm^2}{L^2}$ (2) $\sqrt{2}\dfrac{Gm^2}{L^2}$ (3) $\sqrt{2}\dfrac{Gm}{L^2}$ (4) $\sqrt{3}\dfrac{Gm}{L^2}$

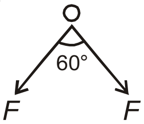
Sol. Answer (4)

At this moment,

Forces acting on particle at *A* can be shown,



where, $F = \dfrac{Gm^2}{L^2}$



$\Rightarrow$ Net force will be resultant of both,

$$F_{\text{resultant}} = \sqrt{F^2 + F^2 + 2F^2 \cos 60°} = \sqrt{3}\, F$$

$$\Rightarrow \quad F_{\text{resultant}} = \frac{\sqrt{3}\, Gm^2}{L^2}$$

$$a = \frac{F}{m} = \frac{\sqrt{3}\, Gm}{L^2}$$

13. Two planets have same density but different radii. The acceleration due to gravity would be

(1) Same on both planets
(2) Greater on the smaller planet
(3) Greater on the larger planet
(4) Dependent on the distance of planet from the sun

Sol. Answer (3)

Acceleration due to gravity at the surface of a planet, $g = \dfrac{GM}{R^2}$

where *M* is the mass of planet,

R is the radius of the planet,

Also, $M = pV$

$$\Rightarrow \quad g = \frac{G}{R^2} \times \left(\frac{4}{3}\pi GR^3\rho\right)$$

Thus, $g = \dfrac{4}{3}\pi G R \rho$

Thus $g \alpha$ Radius of the planet,

Thus, acceleration due to gravity would be greater on the larger planet.

14. If the radius of earth shrinks by 1.5% (mass remaining same), then the value of gravitational acceleration changes by

(1) 2% (2) –2% (3) 3% (4) –3%

Sol. Answer (3)

$$g = \frac{GM}{R^2}$$

$$g' = \frac{GM}{(0.985\,R)^2}$$

$$g' = (1.0306)\,\frac{GM}{R^2}$$

$\Rightarrow$ $g' = 1.0306\,g$

$\Rightarrow$ Acceleration changes by

$$\frac{\Delta g}{g} \times 100 = +3\%$$

Alternate method:

$$g' = \frac{GM}{(R + \Delta R)^2}$$

$$g' = GM(R + \Delta R)^{-2}$$

$$g' = \frac{GM}{R^2}\left(1 + \frac{\Delta R}{R}\right)^{-2}$$

for $\frac{\Delta R}{R} \ll 1$, we can use binomial and approximately,

$$g' = \frac{GM}{R^2}\left(1 - \frac{2\Delta R}{R}\right)$$

$$\Rightarrow \quad g' = g - g\,\frac{2\Delta R}{R}$$

$$\Rightarrow \quad \frac{\Delta g}{g} = \frac{-2\Delta R}{R} = -2 \times \left(\frac{-1.5}{100}\right) = \frac{+3}{100} = 3\% \qquad [g' - g = \Delta g]$$

15. If density of a planet is double that of the earth and the radius 1.5 times that of the earth, the acceleration due to gravity on the surface of the planet is

(1) $\frac{3}{4}$ times that on the surface of the earth (2) 3 times that on the surface of the earth

(3) $\frac{4}{3}$ times that on the surface of the earth (4) 6 times that on the surface of the earth

Sol. Answer (2)

Acceleration due to gravity on the surface of a planet is

given by, $g = \frac{GM}{R^2}$

$M \rightarrow$ Mass of the planet

$R \rightarrow$ Radius of the planet

Also, $M = \frac{4}{3}\pi R^3 \times \rho$

$$\Rightarrow \quad g = \frac{G}{R^2} \times \frac{4}{3}\pi R^3 \rho = \frac{4}{3}\rho G \pi R$$

$\rho \rightarrow$ Density of the planet.

$\Rightarrow$ Acceleration due to gravity α ρR

$$\Rightarrow \quad \frac{g_{\text{planet}}}{g_{\text{earth}}} = \frac{2\rho_e \times 1.5\,R_e}{\rho_e \times R_e} = 3$$

$\Rightarrow$ Acceleration due to gravity on the surface of planet is 3 times that on the surface of earth.

16. At what height above the surface of earth the value of "g" decreases by 2%? [radius of the earth is 6400 km]

(1) 32 km (2) 64 km (3) 128 km (4) 1600 km

Sol. Answer (2)

Acceleration due to gravity above the surface of earth at a height h is given $g' = g\left(1-\frac{2h}{R_e}\right)$

here, $g' = 0.98$ g

$$\Rightarrow \quad 0.98 = 1-\frac{2h}{R_e}$$

$$\Rightarrow \quad \frac{2h}{R_e} = 0.02$$

$$h = 0.01\ R_e$$

$$= 0.01 \times 6400 \text{ km}$$

$$= 64 \text{ km}$$

17. During motion of a man from equator to pole of earth, its weight will (neglect the effect of change in the radius of earth)

(1) Increase by 0.34% (2) Decrease by 0.34%

(3) Increase by 0.52% (4) Decrease by 0.52%

Sol. Answer (1)

$w_{eq} = mg - m\omega^2 R_e$

$w_p = mg$

$$\frac{w_p - w_{eq}}{w_{eq}} = \frac{m\omega^2 R}{mg - m\omega^2 R}$$

$$= \frac{\omega^2 R}{g-\omega^2 R} \qquad [\omega^2 R = 0.0337 \text{ m/s}^2]$$

$$\Rightarrow \quad \frac{\Delta w}{w_{eq}} = \frac{0.0337}{9.81-0.0337} = 0.3447\times 10^{-2}$$

$$\Rightarrow \quad \frac{\Delta w}{w_{eq}}\times 100 = 0.3447$$

$\Rightarrow$ Increases by 0.34%

18. If earth suddenly stop rotating, then the weight of an object of mass m at equator will [ω is angular speed of earth and R is its radius]

(1) Decrease by $m\omega^2 R$ (2) Increase by $m\omega^2 R$ (3) Decrease by $m\omega R^2$ (4) Increase by $m\omega R^2$

Sol. Answer (2)

At the equator,

Apparent weight, $w' = w - m\omega^2 R$

If Earth stops rotating, w' will be equal to ω.

Thus, the weight of an object of mass m at equator will increase by $m\omega^2 R$.

19. If R is the radius of earth and g is the acceleration due to gravity on the earth's surface. Then mean density of earth is

(1) $\frac{4\pi G}{3gR}$ (2) $\frac{3\pi R}{4gG}$ (3) $\frac{3g}{4\pi RG}$ (4) $\frac{\pi Rg}{12G}$

Sol. Answer (3)

Acceleration due to gravity at earth's surface is given by,

$$g = \frac{GM}{R^2}$$

$$M = \frac{4}{3}\pi R^3\rho$$

$M \rightarrow$ Mass of earth

$\rho \rightarrow$ Density of earth

$R \rightarrow$ Radius of earth

$$\Rightarrow \quad g = \frac{G}{R^2} \times \frac{4}{3}\pi R^3\rho$$

$$\Rightarrow \quad \rho = \frac{3g}{4\,\pi GR}$$

20. The value of g at the surface of earth is 9.8 m/s^2. Then the value of 'g' at a place 480 km above the surface of the earth will be nearly (radius of the earth is 6400 km)

(1) 9.8 m/s^2 (2) 7.2 m/s^2 (3) 8.5 m/s^2 (4) 4.2 m/s^2

Sol. Answer (3)

$$g_h = g\left[\frac{R}{R+h}\right]^2$$

$$\Rightarrow \quad g_h = 9.8\left[\frac{6400}{6400+480}\right] = 8.48 \text{ m/s}^2$$

21. If the change in the value of 'g' at a height 'h' above the surface of the earth is same as at a depth x below it, then (x and h being much smaller than the radius of the earth)

(1) $x = h$ (2) $x = 2h$ (3) $x = \frac{h}{2}$ (4) $x = h^2$

Sol. Answer (2)

$$g_h = g\left(1 - \frac{2h}{R_e}\right)$$

$$g_x = g\left(1 - \frac{x}{R_e}\right)$$

According to the question,

$$g_h - g = g_x - g$$

$$\Rightarrow \quad g\left(-\frac{2h}{R_e}\right) = g\left(\frac{-x}{R_e}\right)$$

$$\Rightarrow \quad x = 2h$$

22. As we go from the equator to the poles, value of 'g'

(1) Remains the same (2) Decreases

(3) Increases (4) First increase and then decrease

Sol. Answer (3)

At Latitude λ,

$$g' = g_0 - \omega^2 R \cos^2 \lambda$$

at equator, $\lambda = 0$

$$g' = g_0 - \omega^2 R$$

at poles, $\lambda = 90°$

$$g' = g_0$$

$\Rightarrow$ As we g_0 from equator to the poles, value of g' increase.

23. What should be the angular speed with which the earth have to rotate on its axis so that a person on the equator would weigh $\frac{3}{5}$th as much as present?

(1) $\sqrt{\frac{2g}{5R}}$ (2) $\sqrt{\frac{2R}{5g}}$ (3) $\frac{2\sqrt{R}}{\sqrt{5g}}$ (4) $\frac{2g}{5R}$

Sol. Answer (1)

$$w' = w - m\omega^2 R$$

$$\Rightarrow \quad mg_e = mg - m\omega^2 R$$

$$mg_e = \frac{3}{5} mg$$

$$\Rightarrow \quad m\omega^2 R = \frac{2}{5} mg$$

$$\Rightarrow \quad \omega = \sqrt{\frac{2g}{5R}}$$

24. The acceleration due to gravity on a planet is 1.96 m/s^2. If it is safe to jump from a height of 3 m on the earth, the corresponding height on the planet will be

(1) 3 m (2) 6 m (3) 9 m (4) 15 m

Sol. Answer (4)

It is safer to jump from a height of 3 m on earth,

$\Rightarrow$ Corresponding velocity attained = $\sqrt{2g_1h_1}$

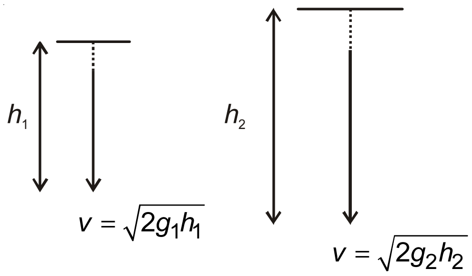
It will be safer to jump from a height on other planet

If the velocity attained is same = $\sqrt{2g_2h_2}$

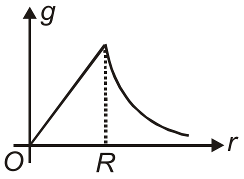
$$\Rightarrow \quad \sqrt{2g_1h_1} = \sqrt{2g_2h_2}$$

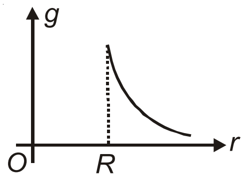
$$9.8 \times 3 = 1.96 \times h_2$$

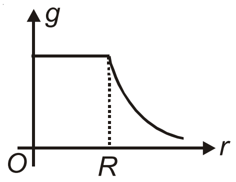
$$\Rightarrow \quad h_2 = 5 \times 3 = 15 \text{ m}$$

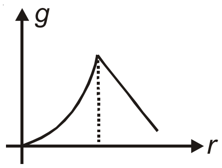


25. Which of the following graph represents the variations of acceleration due to gravity(g) with distance r from the centre of earth?

(1) 

(2) 

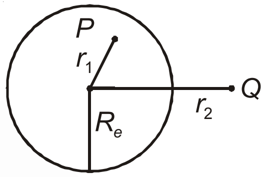
(3) 

(4) 

Sol. Answer (1)

$M_e \rightarrow$ Mass of earth

$R_e \rightarrow$ Radius of earth

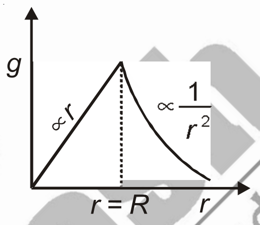


The acceleration due to gravity at a distance r_1 from the centre of earth such that $r_1 < R$,

is given by $gr_1 = \frac{GM}{R^3} r_1$

$\Rightarrow \quad g \propto r$

The acceleration due to gravity at a distance r_2 from the centre of earth such that $r_2 > R$,



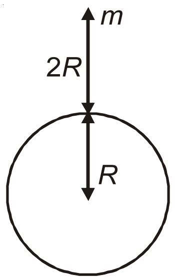
is given by $gr_2 = \frac{GM}{r_2^2}$

$\Rightarrow \quad g \propto \frac{1}{r^2}$

26. An object is taken to height $2R$ above the surface of earth, the increase in potential energy is [R is radius of earth]

(1) $\frac{mgR}{2}$ (2) $\frac{mgR}{3}$ (3) $\frac{2mgR}{3}$ (4) $2\,mgR$

Sol. Answer (3)



Potential energy at surface $= -\frac{GMm}{R}$

Potential energy at height, $2R = -\frac{GMm}{3R}$

Change in potential energy $= -\frac{GMm}{3R} + \frac{GMm}{R}$

$$= \frac{GMm}{R}\left(\frac{-1+3}{3}\right)$$

$$= \frac{2}{3}\frac{GMm}{R}$$

$$= \frac{2}{3}\left(\frac{GM}{R^2}\right)mR$$

$$= \frac{2}{3}mgR$$

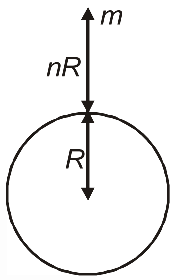
27. The change in potential energy when a body of mass m is raised to height nR from the earth's surface is (R is radius of earth)

(1) $mgR\left(\frac{n}{n-1}\right)$ (2) $nmgR$ (3) $mgR\left(\frac{n}{n+1}\right)$ (4) $mgR\left(\frac{n^2}{n^2+1}\right)$

Sol. Answer (3)

Potential energy at the surface $= -\frac{GMm}{R}$

Potential energy at height, $nR = -\frac{GMm}{(n+1)R}$



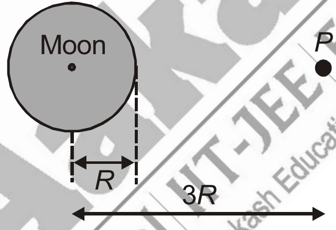
Change in potential energy $= -\frac{GMm}{(n+1)R} + \frac{GMm}{R}$

$$= \frac{GMm}{R}\left(\frac{-1+n+1}{n+1}\right)$$

$$= \left(\frac{n}{n+1}\right)\left(\frac{GM}{R^2}\right) m \times R$$

$$= mgR\left(\frac{n}{n+1}\right)$$

28. A stationary object is released from a point P at a distance $3R$ from the centre of the moon which has radius R and mass M. Which of the following gives the speed of the object on hitting the moon?



(1) $\left(\frac{2GM}{3R}\right)^{1/2}$ (2) $\left(\frac{4GM}{3R}\right)^{1/2}$ (3) $\left(\frac{GM}{3R}\right)^{1/2}$ (4) $\left(\frac{GM}{R}\right)^{1/2}$

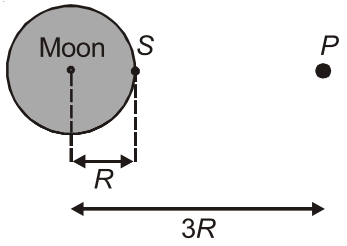
Sol. Answer (2)

Conserving mechanical energy between points P and S,

$$-\frac{GMm}{3R} = \frac{1}{2}mv^2 - \frac{GMm}{R}$$

$$\Rightarrow \frac{1}{2}mv^2 = -\frac{GMm}{3R} + \frac{GMm}{R}$$

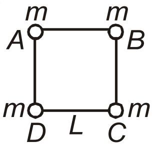
$$= \frac{GMm}{R}\left(\frac{-1}{3}+1\right)$$



$$\frac{1}{2}\cancel{m}v^2 = \frac{2GM\cancel{m}}{3R}$$

$$\Rightarrow v = \sqrt{\frac{4GM}{3R}}$$

29. Four particles A, B, C and D each of mass m are kept at the corners of a square of side L. Now the particle D is taken to infinity by an external agent keeping the other particles fixed at their respective positions. The work done by the gravitational force acting on the particle D during its movement is



(1) $2\frac{Gm^2}{L}$ (2) $-2\frac{Gm^2}{L}$ (3) $\frac{Gm^2}{L}\left(\frac{2\sqrt{2}+1}{\sqrt{2}}\right)$ (4) $-\frac{Gm^2}{L}\left(\frac{2\sqrt{2}+1}{\sqrt{2}}\right)$

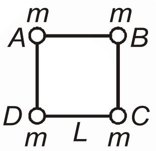
Sol. Answer (4)

Work done by the gravitational force acting on the particle D during its movement

$= -\Delta U$

$= -(U_{\text{final}} - U_{\text{initial}})$

$= U_{\text{initial}} - U_{\text{final}}$



Now, when the particle is at infinity, $U = 0$

$\Rightarrow$ $U_{\text{final}} = 0$

$\Rightarrow$ Work done = U_{initial}

$$U_{\text{initial}} = -\frac{Gm^2}{L} - \frac{Gm^2}{L} - \frac{Gm^2}{\sqrt{2}L}$$

$$= -\frac{Gm^2}{L}\left(2 + \frac{1}{\sqrt{2}}\right)$$

$$= -\frac{Gm^2}{L}\left(\frac{2\sqrt{2}+1}{\sqrt{2}}\right)$$

30. If an object is projected vertically upwards with speed, half the escape speed of earth, then the maximum height attained by it is [R is radius of earth]

(1) R (2) $\frac{R}{2}$ (3) $2R$ (4) $\frac{R}{3}$

Sol. Answer (4)

$$V_e = \sqrt{\frac{2GM}{R}}$$

$M \rightarrow$ mass of earth

$R \rightarrow$ Radius of earth

Now, conserving potential energy at the surface of earth and highest point,

$$-\frac{GMm}{R} + \frac{1}{2}m\left(\frac{1}{2}\sqrt{\frac{2GM}{R}}\right)^2 = -\frac{GMm}{r}$$

$$-\frac{GMm}{R} + \frac{GMm}{4R} = -\frac{GMm}{r}$$

$$-\frac{3GMm}{4R} = -\frac{GMm}{r}$$

$$\Rightarrow \quad r = \frac{4R}{3}$$

$$\Rightarrow \quad R + h = \frac{4R}{3}$$

$$\Rightarrow \quad h = \left(\frac{R}{3}\right)$$

31. The total mechanical energy of an object of mass *m* projected from surface of earth with escape speed is

(1) Zero (2) Infinite (3) $-\frac{GMm}{2R}$ (4) $-\frac{GMm}{3R}$

Sol. Answer (1)

Total mechanical energy = K.E + P.E

$$V_{\text{escape}} = \sqrt{\frac{2GM}{R}}$$

$$\Rightarrow \text{ Total mechanical energy } = \frac{1}{2}m \times \frac{2GM}{R} - \frac{GMm}{R}$$

$$= 0$$

32. A body is thrown with a velocity equal to *n* times the escape velocity (v_e). Velocity of the body at a large distance away will be

(1) $v_e\sqrt{n^2-1}$ (2) $v_e\sqrt{n^2+1}$ (3) $v_e\sqrt{1-n^2}$ (4) None of these

Sol. Answer (1)

At large distance potential energy = 0

Conserving mechanical energy at surface of earth and large distance from earth,

$$\frac{1}{2}m(nv_e)^2 - \frac{GMm}{R} = \frac{1}{2}mv^2$$

Also, $v_e = \sqrt{\frac{2GM}{R}}$

$$\Rightarrow \quad \frac{2GMm}{R}(n^2-1) = mv^2$$

$$\Rightarrow \quad v = \sqrt{\frac{2GM}{R}}(n^2-1)^{1/2}$$

$$\Rightarrow \quad v = v_e\sqrt{n^2-1}$$

33. The escape velocity of a body from earth is about 11.2 km/s. Assuming the mass and radius of the earth to be about 81 and 4 times the mass and radius of the moon, the escape velocity in km/s from the surface of the moon will be

(1) 0.54 (2) 2.48 (3) 11 (4) 49.5

Sol. Answer (2)

$$V_{\text{escape}} = \sqrt{\frac{GM}{R}}$$

$$\frac{V_{\text{escape Earth}}}{V_{\text{escape moon}}} = \sqrt{\frac{M_e}{R_e} \times \frac{R_m}{M_m}} = \sqrt{\frac{81}{4}} = \left(\frac{9}{2}\right)$$

$$\Rightarrow \quad V_{\text{moon}} = \frac{2}{9} \times 11.2 = 2.48 \text{ km/s}$$

34. If M is mass of a planet and R is its radius then in order to become black hole [c is speed of light]

(1) $\sqrt{\frac{GM}{R}} \le c$ (2) $\sqrt{\frac{GM}{2R}} \ge c$ (3) $\sqrt{\frac{2GM}{R}} \ge c$ (4) $\sqrt{\frac{2GM}{R}} \le c$

Sol. Answer (3)

A planet can become a black hole if its mass and radius are such that it has an immense force of gravity on its surface. The force of attractum has to be so large that even light cannot escape from its surface.

Speed of light = c

$$v_e = \sqrt{\frac{2GM}{R}}$$

If $v_e \ge c$

$\Rightarrow$ Even light can't escape from the surface of such planet making it appear black.

35. The atmosphere on a planet is possible only if [where v_{rms} is root mean square speed of gas molecules on planet and v_e is escape speed on its surface]

(1) $v_{\text{rms}} = v_e$ (2) $v_{\text{rms}} > v_e$ (3) $v_{\text{rms}} \le v_e$ (4) $v_{\text{rms}} < v_e$

Sol. Answer (4)

The atmosphere on a planet is possible only if $v_{\text{rms}} < v_e$

If $v_{\text{rms}} \ge v_{\text{escape}}$ the gas molecules will leave the surroundings of the planet, i.e., will be free from gravitational pull of the planet.

36. A small satellite is revolving near earth's surface. Its orbital velocity will be nearly

(1) 8 km/s (2) 11.2 km/s (3) 4 km/s (4) 6 km/s

Sol. Answer (1)

For a satellite revolving near earth's surface,

$$v_0 = \sqrt{\frac{GM_e}{R_e}} = \sqrt{gR_e}$$

Taking $g = 9.81 \text{ m/s}^2$ and $R_e = 6400$ km

$$v_0 = \sqrt{\frac{9.8}{1000} \times 6400} = 7.92 \text{ km/s} \simeq 8 \text{ km/s}$$

37. The time period of a satellite in a circular orbit of radius R is T. The period of another satellite in a circular orbit of radius $4R$ is

(1) $4T$ (2) $\frac{T}{4}$ (3) $8T$ (4) $\frac{T}{8}$

Sol. Answer (3)

Using Kepler's third law,

$$T^2 \propto R^3$$

$$\Rightarrow \frac{T_2}{T} = \left(\frac{4R}{R}\right)^{3/2}$$

$$\Rightarrow T_2 = T \times 2^3$$

$$= 8T$$

38. When speed of a satellite is increased by x percentage, it will escape from its orbit, where the value of x is

(1) 11.2% (2) 41.4% (3) 27.5% (4) 34.4%

Sol. Answer (2)

For a satellite near Earth's surface,

$$v_0 = \sqrt{\frac{GM_e}{R_e}}, \; v_e = \sqrt{\frac{2GM_e}{R_e}}$$

$$v_e = \sqrt{2}\, v_0$$

$$\Rightarrow \text{ \% increase, } x = \left(\frac{\sqrt{2}-1}{1}\right) \times 100 = 41.4\%$$

39. If potential energy of a satellite is –2MJ, then the binding energy of satellite is

(1) 1 MJ (2) 2 MJ (3) 8 MJ (4) 4 MJ

Sol. Answer (1)

For a satellite of mass m revolving around a planet of mass in a circular orbit of radius r,

$$\text{P.E} = -\frac{GMm}{r}$$

$$\text{K.E} = \frac{1}{2} m \frac{GM}{r} = \frac{GMm}{2r}$$

$$\text{T.E} = -\frac{GMm}{2r}$$

$$\text{Binding energy } = |\text{T.E}| = \frac{GMm}{2r}$$

$$= \frac{|\text{P.E}|}{2} = 1\,\text{MJ}$$

Alternate method,

$$\text{Binding energy } = -\text{ T.E}$$

$$= -\frac{\text{P.E}}{2}$$

$$= 1 \text{ MJ}$$

40. The time period of polar satellites is about

(1) 24 hr (2) 100 min (3) 84.6 min (4) 6 hr

Sol. Answer (2)

Time period of polar satellites is about 100 minutes polar satellites are low altitude satellites. ($h \simeq 500 - 800$ km)

41. If a satellite of mass 400 kg revolves around the earth in an orbit with speed 200 m/s then its potential energy is

(1) –1.2 MJ (2) –8.0 MJ (3) –16 MJ (4) –2.4 MJ

Sol. Answer (3)

For a satellite,

$$\text{P.E} = -\frac{GMm}{r}$$

m = mass of satellite

r = radius of orbit

$$\text{K.E} = \frac{1}{2}mv^2 = \frac{GMm}{2r} = -\frac{\text{P.E}}{2}$$

$$\Rightarrow \text{P.E} = -mv^2$$

$$= -400 \times 4 \times 10^4$$

$$= -16 \text{ MJ}$$

42. An artificial satellite revolves around a planet for which gravitational force(F) varies with distance r from its centre as $F \propto r^2$. If v_0 its orbital speed, then

(1) $v_0 \propto r^{-1/2}$ (2) $v_0 \propto r^{3/2}$ (3) $v_0 \propto r^{-3/2}$ (4) $v_0 \propto r$

Sol. Answer (2)

Gravitational force (F) provides the necessary centripetal force to keep the satellite in orbit,

$$\Rightarrow \frac{mv_0^2}{r} \propto F$$

$$\frac{mv_0^2}{r} \propto r^2$$

$v_0 \rightarrow$ Orbital speed

$r \rightarrow$ Radius of orbit

$$\Rightarrow v_0 \propto r^{3/2}$$

43. The mean radius of earth is R, and its angular speed on its axis is ω. What will be the radius of orbit of a geostationary satellite?

(1) $\left(\frac{Rg}{\omega^2}\right)^{1/3}$ (2) $\left(\frac{R^2g}{\omega^2}\right)^{1/3}$ (3) $\left(\frac{R^2g}{\omega}\right)^{1/3}$ (4) $\left(\frac{R^2\omega^2}{g}\right)^{1/3}$

Sol. Answer (2)

Time period of rotation of earth $= \frac{2\pi}{\omega}$

(Duration of one day)

Geostationary satellite has same time period, $T = \frac{2\pi}{\omega}$. Let r be the radius of orbit of satellite

$\Rightarrow$ Time period of satellite $= \frac{2\pi r^{3/2}}{\sqrt{GM_e}}$

Also, $g = \frac{GM_e}{R_e^2}$

$$\Rightarrow \quad T = \frac{2\pi\, r^{3/2}}{\sqrt{g}(R_e)} = \frac{2\pi\, r^{3/2}}{R_e\sqrt{g}} = \frac{2\pi}{\omega}$$

$$\Rightarrow \quad r^{3/2} = \frac{R_e}{\omega}\sqrt{g}$$

$$\Rightarrow \quad r = \left(\frac{R_e^2}{\omega^2}g\right)^{1/2}$$

44. A satellite of the earth is revolving in a circular orbit with a uniform speed v. If the gravitational force suddenly disappears, the satellite will

(1) Continue to move with velocity v along the original orbit

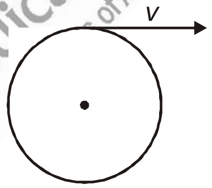
(2) Move with a velocity v, tangentially to the original orbit

(3) Fall down with increasing velocity

(4) Ultimately come to rest somewhere on the original orbit

Sol. Answer (2)

For a satellite revolving in a circular orbit, gravitational force provides the necessary centripetal force. If the gravitational force suddenly disappears, the satellite will move with a velocity v, tangentally to the original orbit.



45. The relay satellite transmits the television signals continuously from one part of the world to another because its

(1) Period is greater than the period of rotation of the earth

(2) Period is less than the period of rotation of the earth

(3) Period has no relation with the period of the earth about its axis

(4) Period is equal to the period of rotation of the earth about its axis

Sol. Answer (4)

A relay satellite transmits the television signals continuously from one part of the world to another bacause its period is equal to the period of rotation of the earth about its axis.

46. If height of a satellite from the surface of earth is increased, then its

(1) Potential energy will increase (2) Kinetic energy will decrease

(3) Total energy will increase (4) All of these

Sol. Answer (4)

For a satellite orbiting at height *h* from earth,

$$\text{P.E} = -\frac{GM_e m_s}{(R_e + h)}$$

$$\text{K.E} = \frac{GM_e m_s}{2(R_e + h)}$$

$$\text{T.E} = -\frac{GM_e m_s}{2(R_e + h)}$$

If *h* is increased, P.E increases (becomes less negative)

K.E decreases

T.E increases (becomes less negative)

47. The gravitational force on a body of mass 1.5 kg situated at a point is 45 N. The gravitational field intensity at that point is

(1) 30 N/kg (2) 67.5 N/kg (3) 46.5 N/kg (4) 43.5 N/kg

Sol. Answer (1)

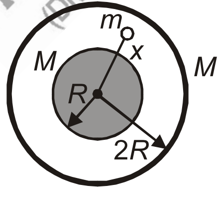
Gravitation force = *mg*

g = gravitation field intensity.

$\Rightarrow$ $45 = 1.5 \times g$

$\Rightarrow$ $g = \frac{45}{1.5} = 30$ N/kg

48. A uniform sphere of mass *M* and radius *R* is surrounded by a concentric spherical shell of same mass but radius 2*R*. A point mass *m* is kept at a distance *x* (>*R*) in the region bounded by spheres as shown in the figure. The net gravitational force on the particle is



(1) $\frac{GMm}{x^2}$ (2) $\frac{GMmx}{R^3}$ (3) $\frac{G(M+m)}{x^2}$ (4) Zero

Sol. Answer (1)

The gravitational force on the point mass *m* due to uniform sphere $= \frac{GMm}{x^2}$.

The gravitational force on the point mass due to the outer spherical shell is zero because gravitational force of attraction on a point mass due to various rejoins of the spherical shell cancels each other completely as their vector sum is zero.

49. If the gravitational potential on the surface of earth is V_0, then potential at a point at height half of the radius of earth is

(1) $\dfrac{V_0}{2}$ (2) $\dfrac{2}{3}V_0$ (3) $\dfrac{V_0}{3}$ (4) $\dfrac{3V_0}{2}$

Sol. Answer (2)

Gravitational potential on the surface,

$$V_0 = -\frac{GM_e}{R_e}$$

Gravitational potential at height h,

$$V_n = -\frac{GM_e}{\left(R_e + \dfrac{R_e}{2}\right)}$$

$$= -\frac{2}{3}\frac{GM_e}{R_e}$$

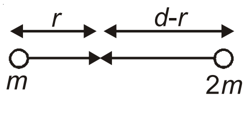
$$= \frac{2}{3}V_0$$

50. Two point masses having mass m and $2m$ are placed at distance d. The point on the line joining point masses, where gravitational field intensity is zero will be at distance

(1) $\dfrac{2d}{\sqrt{3}+1}$ from point mass "2m" (2) $\dfrac{2d}{\sqrt{3}-1}$ from point mass "2m"

(3) $\dfrac{d}{1+\sqrt{2}}$ from point mass "m" (4) $\dfrac{d}{1-\sqrt{2}}$ from point mass "m"

Sol. Answer (3)



Gravitational field intensity will be zero,

$$\Rightarrow \frac{Gm}{r^2} = \frac{2Gm}{(d-r)^2}$$

$$\Rightarrow \frac{1}{r} = \frac{\sqrt{2}}{d-r}$$

$$\Rightarrow d - r = \sqrt{2}r$$

$$\Rightarrow r\left(1+\sqrt{2}\right) = d$$

$$\Rightarrow r = \frac{d}{\left(1+\sqrt{2}\right)}$$

SECTION - B

Objective Type Questions

1. The ratio of kinetic energy of a planet at perigee and apogee during its motion around the sun in elliptical orbit of eccentricity e is

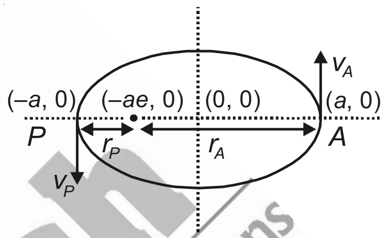
(1) $1 : e$ (2) $\frac{1+e}{1-e}$ (3) $\left(\frac{1+e}{1-e}\right)^2$ (4) $\left(\frac{1-e}{1+e}\right)^2$

Sol. Answer (3)

$$\text{K.E of a planet} = \frac{1}{2}mv^2$$

$$\text{K.E at perigee} = \frac{1}{2}mv_P^2$$

$$\text{K.E at apogee} = \frac{1}{2}mv_A^2$$



Using conservation of angular momentum at P and A

$$\Rightarrow mv_Pr_P = mv_Ar_A$$

$$\Rightarrow \frac{v_P}{v_A} = \frac{r_A}{r_P} = \frac{a(1+e)}{a(1-e)}$$

$$\Rightarrow \frac{\text{K.E}_P}{\text{K.E}_A} = \frac{v_P^2}{v_A^2} = \left(\frac{1+e}{1-e}\right)^2$$

2. An earth satellite X is revolving around earth in an orbit whose radius is one-fourth of the radius of orbit of a communication satellite. Time period of revolution of X is

(1) 3 hrs (2) 6 hrs (3) 4 days (4) 72 days

Sol. Answer (1)

Time period of a communication satellite = 24 hours.

Using kepler's third law,

$$T^2 \propto r^3$$

$$\Rightarrow \frac{T_c}{T_x} = \left(\frac{r_c}{r_x}\right)^{3/2}$$

$$\Rightarrow \frac{24}{T_x} = (4)^{3/2}$$

$$\Rightarrow T_x = \frac{24}{8} = 3\text{ hrs}$$

3. Two satellites of equal mass are revolving around earth in elliptical orbits of different semi-major axis. If their angular momenta about earth centre are in the ratio 3 : 4 then ratio of their areal velocity is

(1) $\frac{3}{4}$ (2) $\frac{2}{3}$ (3) $\frac{1}{3}$ (4) $\frac{4}{3}$

Sol. Answer (1)

Areal velocity, $\frac{\Delta A}{\Delta t} = \frac{|\vec{L}|}{2m} = v_A$

$\vec{L}$ is the angular momentum of satellite, m is the mass of satellite,

$$\Rightarrow \frac{v_{A1}}{v_{A2}} = \frac{|\vec{L}_1|}{|\vec{L}_2|} = \left(\frac{3}{4}\right)$$

4. When a satellite moves around the earth in a certain orbit, the quantity which remains constant is

(1) Angular velocity (2) Kinetic energy (3) Areal velocity (4) Potential energy

Sol. Answer (3)

The path of a satellite moving around sun in a certain orbit is not exactly circular but elliptical with low value of eccentricity, e. Thus only areal velocity is constant.

5. Consider a planet moving around a star in an elliptical orbit with period T. The area of the elliptical orbit is proportional to

(1) $T^{\frac{4}{3}}$ (2) T (3) $T^{\frac{2}{3}}$ (4) $T^{\frac{1}{2}}$

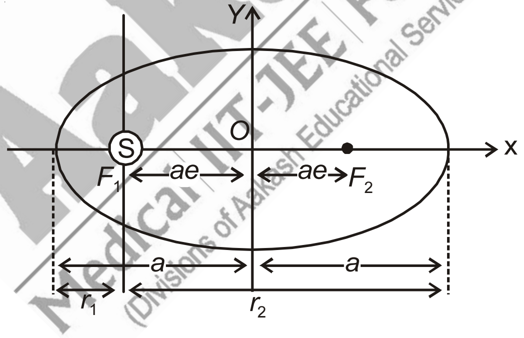
Sol. Answer (1)

Area of ellipse

$A = \pi r_1 r_2$

$\because\ r_1 = a - ae = a(1 - e)$

and $r_2 = a + ae = a(1 + e)$



$A = \pi\{a(1 - e)\}\ \{a(1 + e)\}$

$= \pi a^2\ (1 - e)\ (1 + e)$

$= \pi a^2(1^2 - e^2)$

$\because\ e^2 << a^2$ then

$A = \pi a^2$

So, $a \propto A^{1/2}$ (1)

According to Keplar's III law

$T^2 \propto a^3$

$T^2 \propto \left[(A)^{1/2}\right]^3$

$T^2 \propto A^{3/2}$

$A \propto (T^2)^{2/3}$

$A \propto T^{4/3}$

6. A body weighs 72 N on surface of the earth. When it is taken to a height of $h = 2R$, where R is radius of earth, it would weigh

(1) 36 N (2) 18 N (3) 9 N (4) 8 N

Sol. Answer (4)

Weight on earth = mg

$$= m \times \frac{GM}{R^2} = 72 \text{ N}$$

Weight at height, $h = 2R$ will be $mg' = m\left(\frac{GM}{r^2}\right)$

$$= m \times \frac{GM}{(R+2R)^2}$$

$$= \frac{GMm}{9R^2} = \frac{72}{9} = 8 \text{ N}$$

7. If all objects on the equator of earth feel weightless then the duration of the day will nearly become

(1) 6.2 hr (2) 4.4 hr (3) 2.2 hr (4) 1.41 hr

Sol. Answer (4)

$W_{eq} = mg - m\omega^2 R$

$\Rightarrow$ $mg - m\omega^2 R = 0$

$\Rightarrow$ $\omega^2 R = g$

$$\omega = \sqrt{\frac{g}{R}}$$

$\Rightarrow$ Time period of rotation, *i.e.,* duration of the day,

$$= \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{R}{g}} = 1.41 \text{ hr}$$

8. A body is projected vertically upwards with a speed of $\sqrt{\frac{GM}{R}}$ (M is mass and R is radius of earth). The body will attain a height of

(1) $\frac{R}{2}$ (2) R (3) $\frac{5}{4}R$ (4) $\frac{3R}{2}$

Sol. Answer (2)

Conserving mechanical energy at earth surface and at the maximum height attained by the body,

$\text{P.E}_i + \text{K.E}_i = \text{P.E}_j + \text{K.E}_j$

$$-\frac{GMm}{R} + \frac{1}{2}m\left(\frac{GM}{R}\right) = -\frac{GMm}{r} + 0$$

$\Rightarrow$ $-\frac{GMm}{2R} = -\frac{GMm}{r}$

$\Rightarrow$ $r = 2R$

$\Rightarrow$ $R + h = 2R$

$h = R$

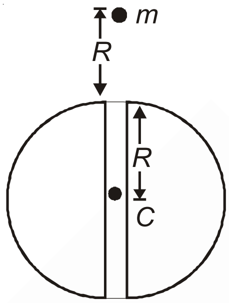
9. If the gravitational potential energy of two point masses infinitely away is taken to be zero then gravitational potential energy of a galaxy is

(1) Zero (2) Positive (3) Negative (4) Can have any value

Sol. Answer (3)

A galaxy is a bounded system, for a bounded system or closed system like planet-sun, satellite Earth, electron-nucleus etc. total energy and the potential energy both are negative.

10. A particle of mass *m* is dropped from a height *R* equal to the radius of the earth above the tunnel dug through the earth as shown in the figure. Hence the correct statement is



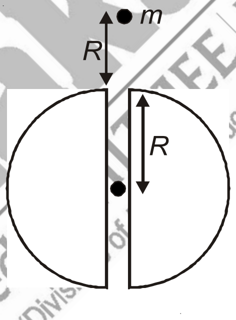
(1) Particle will oscillate through the earth to a height *h* = *R* on both sides

(2) Motion of the particle is periodic

(3) Motion of the particle is simple harmonic

(4) Both (1) & (2)

Sol. Answer (4)



When the particle is outside the tunnel force acting on it is $\propto \frac{1}{r^2}$ where, *r* is the distance from the centre of the earth.

When the particle is inside the tunnel force acting on it is $\propto \frac{1}{r}$ where, *r* is the distance from the centre of the earth.

In both cases, force is always directed towards the centre of the earth.

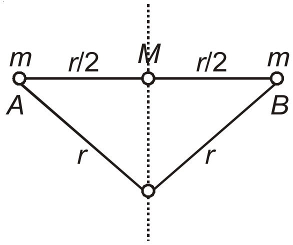
Thus motion is oscillatory and also periodic but not SHM.

11. The particles *A* and *B* of mass *m* each are separated by a distance *r*. Another particle *C* of mass *M* is placed at the midpoint of *A* and *B*. Find the work done in taking *C* to a point equidistant *r* from *A* and *B* without acceleration (*G* = Gravitational constant and only gravitational interaction between *A*, *B* and *C* is considered)

(1) $\frac{GMm}{r}$ (2) $\frac{2GMm}{r}$ (3) $\frac{3GMm}{r}$ (4) $\frac{4GMm}{r}$

Sol. Answer (2)

Since particle *C* is moved without any acceleration,



$\Rightarrow$ ΔK.E = 0

$\Rightarrow$ Work done by external agent + $W_{\text{gravitation}} = 0$

$\Rightarrow$ Work done by external agent = $-\,Wg$

$= -(-\Delta U)$

$= \Delta U$

$= U_f - U_{\text{in}}$

$$U_f = -\frac{GMm}{r} - \frac{GMm}{r} = -\frac{2GMm}{r}$$

$$U_i = -\frac{GMm}{r/2} - \frac{GMm}{r/2} = -\frac{4GMm}{r}$$

$\Rightarrow$ Work done $= \dfrac{2GMm}{r}$

12. The magnitude of potential energy per unit mass of an object at the surface of earth is *E*, then the escape velocity of the object is

(1) $\sqrt{2E}$ (2) $4E^2$ (3) $\sqrt{E}$ (4) $2E$

Sol. Answer (1)

P.E of an object on earth surface $= -\dfrac{GMm}{R}$

Magnitude of potential energy per unit mass $= \left(\dfrac{GM}{R}\right) = E$

$$V_{\text{escape}} = \sqrt{\frac{2GM}{R}}$$

$$= \sqrt{2E}$$

13. The orbital speed of a satellite revolving around a planet in a circular orbit is v_0. If its speed is increased by 10%, then

(1) It will escape from its orbit

(2) It will start rotating in an elliptical orbit

(3) It will continue to move in the same orbit

(4) It will move in a circular orbit of radius 20% more then radius of initial orbit

Sol. Answer (2)

When the orbital speed of a satellite revolving around a planet is increased by 10%, it corresponds to the case when $v_0 < v < v_e$.

14. If *L* is the angular momentum of a satellite revolving around earth in a circular orbit of radius *r* with speed *v*, then

(1) $L \propto v$ (2) $L \propto r$ (3) $L \propto \sqrt{r}$ (4) $L \propto \sqrt{v}$

Sol. Answer (3)

Angular momentum of a satellite revolving around earth in a circular orbit, $L = mvr$

$m \rightarrow$ mass of satellite

$v \rightarrow$ speed of satellite

$r \rightarrow$ radius of orbit

$\Rightarrow L = mvr$

Also, $v = \sqrt{\frac{GM}{r}}$

$$\Rightarrow \quad L = m\sqrt{\frac{GM}{r}}\,r$$

Thus, $L \propto \sqrt{r}$

15. Two satellites of mass m and 2 m are revolving in two circular orbits of radii r and $2r$ around an imaginary planet, on the surface of which gravitational force is inversely proportional to distance from its centre. The ratio of orbital speed of satellites is

(1) 1 : 1 (2) 1 : 2 (3) 2 : 1 (4) $1:\sqrt{2}$

Sol. Answer (1)

Force of gravitation provides the necessary centripetal force,

$$\Rightarrow \frac{mv^2}{r} = \frac{GMm}{r}$$

$$v = \sqrt{GM}$$

Independent of mass of satellite and radius of orbit.

$$\Rightarrow \frac{v_1}{v_2} = \frac{1}{1}$$

16. A satellite of mass m is revolving close to surface of a planet of density d with time period T. The value of universal gravitational constant on planet is given by

(1) $2d^2T\pi$ (2) $dT^2\pi$ (3) $\frac{1}{d^2T\pi}$ (4) $\frac{3\pi}{dT^2}$

Sol. Answer (4)

Time period of a satellite revolving close to surface,

$$T = \frac{2\pi R}{v} = \frac{2\pi R^{3/2}}{\sqrt{GM}}$$

$$T^2 = \frac{4\pi^2R^3}{GM}$$

$$M = \frac{4}{3}\pi R^3 \times d$$

$$T^2 = \frac{4\pi^2R^3}{G\frac{4}{3}\pi R^3 d}$$

$$G = \frac{3\pi}{dT^2}$$

17. When energy of a satellite-planet system is positive then satellite will

(1) Move around planet in circular orbit

(2) Move around planet in elliptical orbit

(3) Escape out with minimum speed

(4) Escape out with speed greater than escape velocity

Sol. Answer (4)

When the energy of a satellite-planet system is positive, satellite escapes away from the gravitational field of the planet with speed greater than the escape speed.

18. If radius of an orbiting satellite is decreased, then its kinetic energy

(1) And potential energy decrease

(2) And potential energy increase

(3) Decreases and potential energy increases

(4) Increases and potential energy decreases

Sol. Answer (4)

$$\text{K.E} = \frac{GMm}{2r}$$

$$\text{P.E} = -\frac{GMm}{r}$$

$M \rightarrow$ mass of planet

$m \rightarrow$ mass of satellite

$r \rightarrow$ radius of orbit

When r is decreased,

Kinetic energy increases,

Potential energy decreases (becomes more negative).

19. Two point masses having m and $4m$ are placed at distance at r. The gravitational potential at a point, where gravitational field intensity zero is

(1) $\frac{-9GM}{r}$

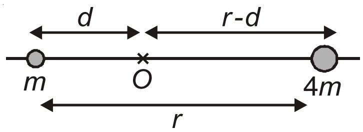
(2) $\frac{-2GM}{3r}$

(3) $\frac{-3GM}{r}$

(4) $\frac{-6GM}{5r}$

Sol. Answer (1)

Gravitational field intensity at O is zero,



$$\Rightarrow \frac{Gm}{d^2} = \frac{4Gm}{(r-d)^2}$$

$$\Rightarrow \frac{(r-d)^2}{d^2} = 4$$

$$\frac{r-d}{d} = \pm 2$$

$$r - d = \pm 2d$$

$$\Rightarrow d = \frac{r}{3}, -r \qquad (d = -r, \text{ not possible})$$

Taking the +ve value of d,

Calculating gravitational potential at *O*,

$$V = \frac{-Gm}{r/3} - \frac{4Gm}{2r/3}$$

$$= \frac{-3Gm}{r} - \frac{6Gm}{r}$$

$$= \frac{-9Gm}{r}$$

20. If gravitational field intensity is *E* at distance *R*/2 outside from then surface of a thin shell of radius *R*, the gravitational field intensity at distance *R*/2 from its centre is

(1) Zero (2) 2 *E* (3) $\frac{2E}{3}$ (4) $\frac{3E}{2}$

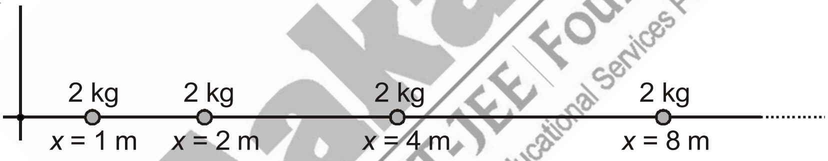
Sol. Answer (1)

Gravitational field intensity at every point inside a hollow spherical shell of uniform density is zero, because gravitational field due to various regions of the spherical shell cancels each other completely as their vector sum is zero.

21. Infinite number of bodies, each of mass 2 kg are situated on x-axis at distance 1 m, 2 m, 4 m, 8 m, ... respectively, from the origin. The resulting gravitational potential due to this system at the origin will be

(1) $-\frac{8}{3}G$ (2) $-\frac{4}{3}G$ (3) –4*G* (4) –*G*

Sol. Answer (3)



Gravitational potential at origin $= -\frac{G\times 2}{1} - \frac{G\times 2}{2} - \frac{G\times 2}{4} - \frac{G\times 2}{8} \ldots\ldots\ldots$

$$= -G\times 2\underbrace{\left(1+\frac{1}{2}+\frac{1}{4}+\frac{1}{8}\ldots \text{ and so on}\right)}_{\text{Infinite G.P}}$$

For an infinite G.P,

$$\text{Sum} = \frac{a}{1-r}$$

$a \rightarrow$ First term = 1

$r \rightarrow$ Common ratio $= \frac{1}{2}$

$\Rightarrow$ $\text{Sum} = \frac{1}{1-\frac{1}{2}} = 2$

$\Rightarrow$ $V_{\text{origin}} = -4G$

22. If potential at the surface of earth is assigned zero value, then potential at centre of earth will be (Mass = M, Radius = R)

(1) 0 (2) $-\dfrac{GM}{2R}$ (3) $-\dfrac{3GM}{2R}$ (4) $\dfrac{3GM}{2R}$

Sol. Answer (2)

The concept involved here is that,

Gravitational potential difference between any two points in a gravitational field is independent of the choice of reference. When potential at the infinity is assigned zero value,

Potential at the surface $= -\dfrac{GM}{R} = V_s$

Potential at the centre $= -\dfrac{3GM}{2R} = V_c$

$$V_s - V_c = -\frac{GM}{R} + \frac{3GM}{2R} = \frac{GM}{2R}$$

Now, when potential at the surface is assigned zero value,

$$V_s - V_c = V_s' - V_c'$$

$$\Rightarrow \frac{GM}{2R} = 0 - V_c' \quad \Rightarrow \quad V_c' = -\frac{GM}{2R}$$

Here, V_s' and V_c' are the new values of potential at the sum and centre respectively.

23. An object is projected horizontally with speed $\dfrac{1}{2}\sqrt{\dfrac{GM}{R}}$, from a point at height 3 R [where R is radius and M is mass of earth, then object will]

(1) Fall back on surface of earth by following parabolic path

(2) Fall back on surface of earth by following hyperbolic path

(3) Start rotating around earth in a circular orbit

(4) Escape from gravitational field of earth

Sol. Answer (3)

At height 3 R, i.e at distance 4 R from the centre of the earth,

$$V_{\text{orbital}} = \sqrt{\frac{GM}{r}}$$

Here, $r = 4R \quad \Rightarrow \quad V_0 = \sqrt{\dfrac{GM}{4R}} = \dfrac{1}{2}\sqrt{\dfrac{GM}{R}}$,

Thus, an object taken to a height 3 R if projected horizontally with speed $\dfrac{1}{2}\sqrt{\dfrac{GM}{R}}$, will start rotating around earth in a circular orbit.

24. If acceleration due to gravity at distance $d[< R]$ from the centre of earth is β, then its value at distance d above the surface of earth will be [where R is radius of earth]

(1) $\frac{\beta R^2}{(R+d)^3}$ (2) $\frac{\beta R}{2d}$ (3) $\frac{\beta d}{(R+d)^2}$ (4) $\frac{\beta R^3}{d(R+d)^2}$

Sol. Answer (4)

Here, $g_d = \frac{GM}{R^3} d = \beta, \quad d < R$ ...(1)

$g'_d = \frac{GM}{(R+d)^2}, \; d > R$ ...(2)

Using (1), $GM = \frac{\beta R^3}{d}$

$$g'_d = \frac{\beta R^3}{d(R+d)^2}$$

25. If potential energy of a body of mass m on the surface of earth is taken as zero then its potential energy at height h above the surface of earth is [R is radius of earth and M is mass of earth]

(1) $\frac{-GMm}{R+h}$ (2) $\frac{-GMm}{h}$ (3) $\frac{GMmh}{R(R+h)}$ (4) $\frac{GMmh}{h+2R}$

Sol. Answer (3)

The concept involved here is that,

Gravitational potential energy difference between any two points in a gravitational field is independent of the choice of reference.

When potential at infinity is assigned zero value,

Potential energy of a body of mass m on the surface of earth $= \frac{-GMm}{R} = U_s$

Potential energy at height, $h = \frac{-GMm}{R+h} = U_h$

$$U_s - U_h = +GMm\left(-\frac{1}{R} + \frac{1}{R+h}\right)$$

$$= GMm\left(\frac{-R-h+R}{R(R+h)}\right)$$

$$= \frac{-GMmh}{R(R+h)}$$

Now, when potential at the surface is taken zero, Let U_s', U_h' be the new values of potential energy at the surface and height h respectively,

And, $U_s - U_h = U_s' - U_h'$

$$\Rightarrow \frac{-GMmh}{R(R+h)} = 0 - U'_h$$

$$\Rightarrow U'_h = \frac{GMmh}{R(R+h)}$$

26. Gravitational potential in a region is given by $V = -(x + y + z)$ J/kg. Find the gravitational intensity at (2, 2, 2)

(1) $(\hat{i}+\hat{j}+\hat{k})$ N/kg (2) $2(\hat{i}+\hat{j}+\hat{k})$ N/kg (3) $3(\hat{i}+\hat{j}+\hat{k})$ N/kg (4) $4(\hat{i}+\hat{j}+\hat{k})$ N/kg

Sol. Answer (1)

Let I denote the gravitation intensity at any point,

As we know, $\vec{I} = -\left[\frac{\partial v}{\partial x}\hat{i} + \frac{\partial v}{\partial y}\hat{j} + \frac{\partial v}{\partial z}\hat{k}\right]$

$\Rightarrow \vec{I}_{(2,2,2)} = -\left[-\hat{i} - \hat{j} - \hat{k}\right] = \hat{i} + \hat{j} + \hat{k}$ N/kg

27. A particle is projected vertically up with velocity $v = \sqrt{\frac{4gR_e}{3}}$ from earth surface. The velocity of particle at height equal to half of the maximum height reached by it

(1) $\sqrt{\frac{gR_e}{2}}$ (2) $\sqrt{\frac{gR_e}{3}}$ (3) $\sqrt{gR_e}$ (4) $\sqrt{\frac{2gR_e}{3}}$

Sol. Answer (2)

Conserving mechanical energy at the surface of earth and the maximum height attained,

$$\frac{-GMm}{R_e} + \frac{1}{2}m\frac{4GM}{3R_e^2}R_e = \frac{-GMm}{r} + 0$$

$$\text{P.E}_i \quad + \quad \text{K.E}_i \quad = \text{P.E}_f \quad + \text{K.E}_f$$

$$\Rightarrow \frac{-GMm}{R_e} + \frac{2GMm}{3R^e} = \frac{-GMm}{r}$$

$$-\frac{1}{3}\frac{GMm}{R_e} = \frac{-GMm}{r}$$

$\Rightarrow r = 3R_e$

$\Rightarrow R_e + h = 3R_e$

$h = 2R_e$

Now, let us calculate the velocity of the particle at height equal to half of the maximum height *i.e* at $h = R_e$

Again using mechanical conservation of energy,

$$\text{P.E}_i + \text{K.E}_i = \text{P.E}_j + \text{K.E}_j$$

$$\frac{-GMm}{R_e} + \frac{1}{2}m\frac{4}{3}\frac{GM}{R_e^2} \times R_e = \frac{-GMm}{2R} + \frac{1}{2}mv^2$$

$$\Rightarrow -\frac{1}{3}\frac{GMm}{R_e} + \frac{GMm}{2R_e} = \frac{1}{2}mv^2$$

$$\Rightarrow \frac{GMm}{6R_e} = \frac{1}{2}mv^2$$

$$\Rightarrow v = \sqrt{\frac{GM}{3R_e}} = \sqrt{\frac{GM}{R_e^2} \times \frac{R_e}{3}} = \sqrt{\frac{gR_e}{3}}$$

SECTION - C

Previous Years Questions

1. A body of mass 'm' taken from the earth's surface to the height equal to twice the radius (R) of the earth. The change in potential energy of body will be

(1) $\frac{2}{3}mgR$ (2) $3mgR$ (3) $\frac{1}{3}mgR$ (4) $mg2R$

Sol. Answer (1)

P.E at surface of earth $= \frac{-GMm}{R}$

$$= \frac{-GM}{R^2} \times mR$$

$$U_{\text{in}} = -mgR \qquad \left[g = \frac{GM}{R^2}\right]$$

P.E at height, $h = 2R$ $= \frac{-GMm}{3R}$

$$= \frac{-GM}{3R^2} \times mR$$

$$U_f = \frac{-mgR}{3}$$

$U_f - U_{\text{in}}$ = Change in P.E $= \frac{-mgR}{3} + mgR$

$$= \frac{2mgR}{3}$$

2. A spherical planet has a mass M_p and diameter D_p. A particle of mass m falling freely near the surface of this planet will experience an acceleration due to gravity, equal to

(1) GM_p / D_p^2 (2) $4\,GM_p m / D_p^2$ (3) $4\,GM_p / D_p^2$ (4) $GM_p m / D_p^2$

Sol. Answer (3)

Acceleration due to gravity, near surface $= \frac{GM_p}{R_p^2} = g_p$

Here, $D_p = 2R_p$

$$\Rightarrow \quad g_p = \frac{4GM_p}{D_p^2}$$

3. A geostationary satellite is orbiting the earth at a height of $5R$ above that surface of the earth, R being the radius of the earth. The time period of another satellite in hours at a height of $2R$ from the surface of the earth is

(1) $6\sqrt{2}$ (2) $\frac{6}{\sqrt{2}}$ (3) 5 (4) 10

Sol. Answer (1)

Time period of a geostationary satellite = 24 hours.

Using Keplers third law,

$T^2 \propto r^3$

T_1, time period of geostationary satellite $\propto (6R)^{3/2}$ thus $T_2 \propto (3R)^{3/2}$

$$\Rightarrow \frac{T_2}{T_1} = \left(\frac{3R}{6R}\right)^{3/2}$$

$$\Rightarrow T_2 = 24 \times \frac{1}{2^{3/2}}$$

$$= \frac{24}{2\sqrt{2}} = 6\sqrt{2} \text{ hours.}$$

4. The height at which the weight of a body becomes $\frac{1}{16}^{\text{th}}$, its weight on the surface of earth (radius R), is

(1) 3 R (2) 4 R (3) 5 R (4) 15 R

Sol. Answer (1)

Weight on surface of earth, $W = mg$

$$= m\left(\frac{GM}{R_e^2}\right)$$

Weight at height h from surface, $W' = m\frac{GM}{(R_e + h)^2}$

$$\frac{W'}{W} = \frac{1}{16} = \frac{R_e^2}{(R_e + h)^2}$$

$\Rightarrow R_e + h = 4R_e$

$\Rightarrow h = 3R_e$

5. The radius of a planet is twice the radius of earth. Both have almost equal average mass-densities. If V_P and V_E are escape velocities of the planet and the earth, respectively, then

(1) $V_E = 1.5V_P$ (2) $V_P = 1.5V_E$ (3) $V_P = 2V_E$ (4) $V_E = 3V_P$

Sol. Answer (3)

$$V_{\text{escape}} = R\left(\sqrt{\frac{8\pi GP}{3}}\right)$$

$$\Rightarrow \frac{V_P}{V_E} = 2$$

$V_P = 2V_E$

6. A particle of mass '*m*' is kept at rest at a height 3*R* from the surface of earth, where '*R*' is radius of earth and '*M*' is mass of earth. The minimum speed with which it should be projected, so that it does not return back, is (*g* is acceleration due to gravity on the surface of earth)

(1) $\left(\frac{GM}{R}\right)^{1/2}$ (2) $\left(\frac{GM}{2R}\right)^{1/2}$ (3) $\left(\frac{gR}{4}\right)^{1/2}$ (4) $\left(\frac{2g}{R}\right)^{1/2}$

Sol. Answer (2)

The particle won't return back if it is provided speed such that its total mechanical energy is zero or positive for minimum speed, we take total energy zero,

$$\Rightarrow \frac{-GMm}{4R}+\frac{1}{2}mv^2=0$$

$$\Rightarrow v=\sqrt{\frac{GM}{2R}}$$

7. If v_e is escape velocity and v_o is orbital velocity of a satellite for orbit close to the earth's surface, then these are related by

(1) $v_o=\sqrt{2}v_e$ (2) $v_o = v_e$ (3) $v_e=\sqrt{2}v_o$ (4) $v_e=\sqrt{2}v_o$

Sol. Answer (4)

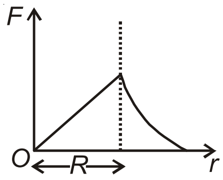
$$v_e=\sqrt{\frac{2GM}{R}}$$

$$v_o=\sqrt{\frac{GM}{R}}$$

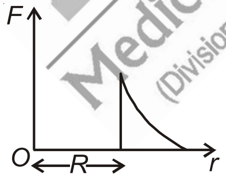
$$\Rightarrow v_e=\sqrt{2}v_o$$

8. Which one of the following plots represents the variation of gravitational field on a particle with distance *r* due to a thin spherical shell of radius *R*? (*r* is measured from the centre of the spherical shell)

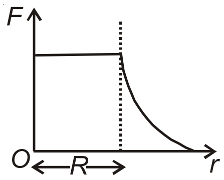
(1)



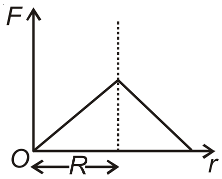
(2)



(3)



(4)

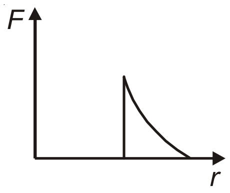


Sol. Answer (2)

For a thin spherical shell gravitational field for *r* < *R* is zero.

For a thin spherical shell gravitational field for *r* > *R* is given by $F=\frac{GM}{r^2}$

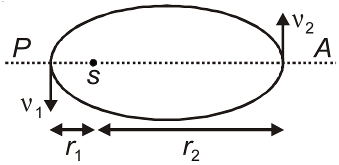
Thus, most suitable plot is



9. A planet moving along an elliptical orbit is closest to the sun at a distance r_1 and farthest away at a distance of r_2. If ν_1 and ν_2 are the linear velocities at these points respectively. Then the ratio $\frac{\nu_1}{\nu_2}$ is

(1) $\frac{r_1}{r_2}$ (2) $\left(\frac{r_1}{r_2}\right)^2$ (3) $\frac{r_2}{r_1}$ (4) $\left(\frac{r_2}{r_1}\right)^2$

Sol. Answer (3)



Using conservation of angular momentum at *P* and *A*,

$\Rightarrow$ $m\nu_1 r_1 = m\nu_2 r_2$

$$\frac{\nu_1}{\nu_2} = \frac{r_2}{r_1}$$

10. A particle of mass *m* is thrown upwards from the surface of the earth, with a velocity *u*. The mass and the radius of the earth are, respectively, *M* and *R*.*G* is gravitational constant and *g* is acceleration due to gravity on the surface of the earth. The minimum value of *u* so that the particle does not return back to earth, is

(1) $\sqrt{2gR^2}$ (2) $\sqrt{\frac{2GM}{R^2}}$ (3) $\sqrt{\frac{2GM}{R}}$ (4) $\sqrt{\frac{2gM}{R^2}}$

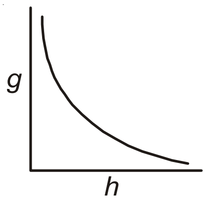
Sol. Answer (3)

Particle will not return back if it is thrown upwards with escape velocity,

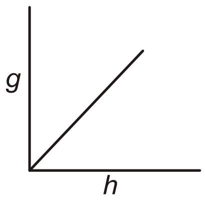
$$\frac{-GMm}{R} + \frac{1}{2}mv_e^2 = 0$$

$$\Rightarrow v_e = \sqrt{\frac{2GM}{R}}$$

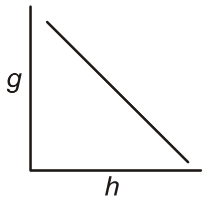
11. Which of the following graphs shows the variation of acceleration due to gravity *g* with depth *h* from the surface of the earth?



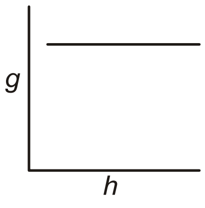
(a)



(b)



(c)



(d)

(1) (a) (2) (b) (3) (c) (4) (d)

Sol. Answer (3)

Acceleration due to gravity at depth h from surface of earth, $g_h = g_0\left(1 - \frac{h}{R}\right)$

$$g = g_0 - g_0\frac{h}{R}$$

$$g = -g_0\frac{h}{R} + g_0$$

$$g = \left(\frac{-g_0}{R}\right)^h + g_0$$

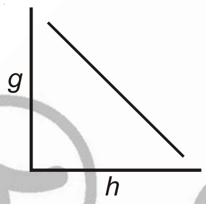
Comparing with equation of straight line,

$y = mx + c$

Slope, m is –ve

Intercept c is +ve,

Thus, most appropriate graph is



12. At what altitude (h) above the earth's surface would the acceleration due to gravity be one fourth of its value at the earth's surface?

(1) $h = R$ (2) $h = 4R$ (3) $h = 2R$ (4) $h = 16R$

Sol. Answer (1)

At altitude (h) above the earth's surface, $g_h = \frac{GM}{(R+h)^2}$

$$\Rightarrow \quad g_h = \frac{GM}{R^2} \times \frac{R^2}{(R+h)^2}$$

$$\Rightarrow \quad g_h = g \times \frac{R^2}{(R+h)^2}$$

$$\Rightarrow \quad \frac{1}{4} = \frac{R^2}{(R+h)^2}, \pm\frac{1}{2} = \frac{R}{(R+h)}$$

Using the +ve value,

$R + h = 2R$

$h = R$

13. If the gravitational force between two objects were proportional to $1/R$ (and not as $1/R^2$), where R is the distance between them, then a particle in a circular path (under such a force) would have its orbital speed v, proportional to

(1) R (2) R^0 (independent of R)

(3) $\frac{1}{R^2}$ (4) $\frac{1}{R}$

Sol. Answer (2)

Gravitational force provides the necessary centripetal force for a particle to move in the circular path.

$$\Rightarrow \quad \frac{mv^2}{R} = \frac{K}{R} \qquad \left[\text{not } \frac{K}{R^2}\right]$$

$$v = \sqrt{\frac{K}{m}}$$

Thus independent of *R*.

14. The distance of two planets from the sun are 10^{13} m and 10^{12} m respectively. The ratio of time periods of the planets is

(1) $\sqrt{10} : 1$ (2) $10\sqrt{10} : 1$ (3) 10 : 1 (4) 1 : 1

Sol. Answer (2)

Using Kepler's third law,

$$T^2 \propto r^3$$

$$\frac{T_1}{T_2} = \left(\frac{r_1}{r_2}\right)^{3/2}$$

$$\Rightarrow \quad \frac{T_1}{T_2} = 10^{3/2} = 10\sqrt{10}$$

15. The radius of earth is about 6400 km and that of Mars is 3200 km. The mass of the earth is about 10 times the mass of Mars. An object weighs 200 N on the surface of Earth. Its weight on the surface of mars will be

(1) 20 N (2) 8 N (3) 80 N (4) 40 N

Sol. Answer (3)

R_e = 6400 km

R_M = 3200 km

$$\frac{M_e}{M_M} = 10$$

$$W_e = m \times \frac{GM_e}{R_e^2} = mg_e$$

$$W_M = m \times \frac{GM_M}{R_M^2} = mg_M$$

$$\frac{W_e}{W_M} = \left(\frac{M_e}{M_M}\right)\left(\frac{R_M}{R_e}\right)^2$$

$$\frac{200}{W_M} = 10 \times \left(\frac{1}{2}\right)^2 \qquad \Rightarrow \quad W_M = \frac{200 \times 4}{10} = 80 \text{ N}$$

16. The earth (mass = 6×10^{24} kg) revolves around the sun with an angular velocity of 2×10^{-7} rad/s in a circular orbit of radius 1.5×10^{8} km. The force exerted by the sun on the earth, in newtons, is

(1) 36×10^{21} (2) 27×10^{39} (3) Zero (4) 18×10^{25}

Sol. Answer (1)

The force of gravitation exerted by sun provides the necessary centripetal force = $m\omega^2 r$

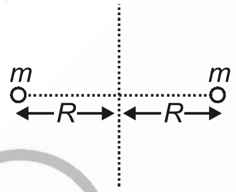
$$\Rightarrow F_g = 6 \times 10^{24} \times 4 \times 10^{-14} \times 1.5 \times 10^{11}$$

$$= 36 \times 10^{21} \text{ N}$$

17. Two particles of equal mass m go around a circle of radius R under the action of their mutual gravitational attraction. The speed v of each particle is

(1) $\frac{1}{2}\sqrt{\frac{Gm}{R}}$ (2) $\sqrt{\frac{4Gm}{R}}$ (3) $\frac{1}{2R}\sqrt{\frac{1}{Gm}}$ (4) $\sqrt{\frac{Gm}{2R}}$

Sol. Answer (1)



Gravitation force provides the necessary centripetal force,

$$\frac{Gm^2}{(2R)^2} = \frac{mv^2}{r}$$

Where, r is the radius of circular path i.e R

$$\Rightarrow v = \sqrt{\frac{Gm}{4R}} = \frac{1}{2}\sqrt{\frac{Gm}{R}}$$

18. The acceleration due to gravity g and mean density of the earth ρ are related by which of the following relations? (where G is the gravitational constant and R is the radius of the earth.)

(1) $\rho = \frac{3g}{4\pi GR}$ (2) $\rho = \frac{3g}{4\pi GR^3}$ (3) $\rho = \frac{4\pi gR^2}{3G}$ (4) $\rho = \frac{4\pi gR^3}{3G}$

Sol. Answer (1)

$$g = \frac{GM}{R^2}$$

$$M = \frac{4}{3}\pi R^3 \rho \quad \Rightarrow \quad g = \frac{G}{R^2} \times \frac{4}{3}\pi R^3 \rho$$

Thus, $\rho = \frac{3g}{4\pi GR}$

19. What will be the formula of mass of the earth in terms of g, R and G?

(1) $G\frac{R^2}{g}$ (2) $g\frac{R^2}{G}$ (3) $g^2\frac{R}{G}$ (4) $G\frac{R}{g}$

Sol. Answer (2)

$$g = \frac{GM}{R^2}$$

$$\Rightarrow \text{ Mass of earth } = g\frac{R^2}{G}$$

20. The period of revolution of planet *A* around the sun is 8 times that of *B.* The distance of *A* from the sun is how many times greater than that of *B* from the sun?

(1) 4 (2) 5 (3) 2 (4) 3

Sol. Answer (1)

Using kepler's third law,

$$T^2 \propto r^3$$

$$\frac{T_A}{T_B} = \left(\frac{r_A}{r_B}\right)^{3/2}$$

$$\Rightarrow (8)^{2/3} = \left(\frac{r_A}{r_B}\right)$$

$$\Rightarrow r_A = 4r_B$$

21. The escape velocity of a body on the surface of the earth is 11.2 km/s. If the earth's mass increases to twice its present value and radius of the earth becomes half, the escape velocity becomes

(1) 22.4 km/s (2) 44.8 km/s (3) 5.6 km/s (4) 11.2 km/s

Sol. Answer (1)

$$V_e = \sqrt{\frac{2GM}{R}}$$

$$V_e' = \sqrt{\frac{2G(2M)}{R/2}} = 2\sqrt{\frac{2GM}{R}} = 22.4 \text{ km/s}$$

22. The escape velocity of a sphere of mass *m* from the surface of earth is given by (*G* = Universal gravitational constant; *M* = Mass of the earth and R_e = Radius of the earth)

(1) $\sqrt{\frac{2GMm}{R_e}}$ (2) $\sqrt{\frac{2GM}{R_e}}$ (3) $\sqrt{\frac{GM}{R_e}}$ (4) $\sqrt{\frac{2GM+R_e}{R_e}}$

Sol. Answer (2)

$$v_e = \sqrt{\frac{2GM}{R_e}}$$

$$\frac{-GMm}{R_e} + \frac{1}{2}mv_e^2 = 0$$

$$\Rightarrow v_e = \sqrt{\frac{2GM}{R_e}}, \text{ independent of the mass of sphere.}$$

23. A body of weight 72 N moves from the surface of earth at a height half of the radius of earth, then gravitational force exerted on it will be

(1) 36 N (2) 32 N (3) 144 N (4) 50 N

Sol. Answer (2)

Gravitational force on body $= mg_s = \dfrac{mGM}{R^2} = 72\text{ N}$

(On the surface of earth)

Gravitational force at height, $h = \dfrac{R}{2} = mg' = \dfrac{mGM}{\left(\dfrac{3R}{2}\right)^2}$

$$= \frac{mGM}{R^2} \times \frac{4}{9} = \frac{4}{9} \times 72 = 32\text{ N}$$

24. A planet has mass equal to mass of the earth but radius one fourth of radius of the earth. Then escape velocity at the surface of this planet will be

(1) 11.2 km/s (2) 22.4 km/s (3) 5.6 km/s (4) 44.8 km/s

Sol. Answer (2)

$$V_e = \sqrt{\frac{GM}{R}} = 11.2\text{ km/s}$$

$$V_p = \sqrt{\frac{GM}{R/4}} = 2\sqrt{\frac{GM}{R}} = 22.4\text{ km/s}$$

25. With what velocity should a particle be projected so that it attains a height equal to radius of earth?

(1) $\left(\dfrac{GM}{R}\right)^{1/2}$ (2) $\left(\dfrac{8GM}{R}\right)^{1/2}$ (3) $\left(\dfrac{2GM}{R}\right)^{1/2}$ (4) $\left(\dfrac{4GM}{R}\right)^{1/2}$

Sol. Answer (1)

Using conservation of mechanical energy at the surface of earth and at the height, $h = R$

$$\text{P.E}_i + \text{K.E}_i = \text{P.E}_j + \text{K.E}_j$$

$$\frac{-GMm}{R} + \frac{1}{2}mv^2 = \frac{-GMm}{2R}$$

$$\Rightarrow \quad \frac{1}{2}mv^2 = \frac{GMm}{R}\left(-\frac{1}{2} + 1\right)$$

$$\frac{1}{2}mv^2 = \frac{GMm}{2R}$$

$$v = \sqrt{\frac{GM}{R}}$$

26. A body of mass m is placed on earth surface which is taken from earth surface to a height of $h = 3R$, then change in gravitational potential energy is

(1) $\frac{mgR}{4}$ (2) $\frac{2}{3}mgR$ (3) $\frac{3}{4}mgR$ (4) $\frac{mgR}{2}$

Sol. Answer (3)

Potential energy of the body at earth surface $= \frac{-GMm}{R}$

$$= \frac{-GM}{R^2} \times R \times m$$

$$U_i = -mgR$$

Potential energy of the body at height, $h = 3R$ $= \frac{-GMm}{4R}$

$$U_f = \frac{-mgR}{4}$$

Change in P.E $= U_f - U_i = \frac{-mgR}{4} + mgR$

$$= \frac{3}{4}mgR$$

27. The acceleration due to gravity on a planet A is 9 times the acceleration due to gravity on planet B. A man jumps to a height of 2 m on the surface of A. What is the height of jump by the same person on the planet B?

(1) 2/9 m (2) 18 m (3) 6 m (4) 2/3 m

Sol. Answer (2)

Maximum height to which man jumps on A,

$$h_A = \frac{v^2}{2g_A}$$

Height to which man jumps on B,

$$h_B = \frac{v^2}{2g_B}$$

$$\frac{h_A}{h_B} = \frac{g_B}{g_A} \Rightarrow \frac{2}{h_B} = \frac{1}{9}$$

$\Rightarrow h_B = 18$ m

28. Two spheres of masses m and M are situated in air and the gravitational force between them is F. The space around the masses is now filled with a liquid of specific gravity 3. The gravitational force will now be

(1) $3F$ (2) F (3) $F / 3$ (4) $F / 9$

Sol. Answer (2)

Gravitational force is independent of the medium between the particles, thus force will remain unchanged.

29. The density of a newly discovered planet is twice that of earth. The acceleration due to gravity at the surface of the planet is equal to that at the surface of the earth. If the radius of the earth is R, then the radius of the planet would be

(1) $2R$ (2) $4R$ (3) $\frac{1}{4}R$ (4) $\frac{1}{2}R$

Sol. Answer (4)

Acceleration due to gravity on the surface of a planet,

$$g = \frac{GM}{R^2} = \frac{G}{R^2} \times \frac{4}{3}\pi R^3 \rho$$

$$= \frac{4\pi G R\rho}{3}$$

$\Rightarrow$ $R_e\rho_e = R_p\rho_p$

$R \times \rho_e = R_p \times 2\rho_e$

$$R_p = \frac{R}{2}$$

30. For a satellite moving in an orbit around the earth, the ratio of kinetic energy to potential energy is

(1) $\frac{1}{2}$ (2) $\frac{1}{\sqrt{2}}$ (3) 2 (4) $\sqrt{2}$

Sol. Answer (1)

$$\text{P.E} = \frac{-GMm}{R}$$

$$\text{K.E} = \frac{GMm}{2R}$$

$$\Rightarrow \left|\frac{\text{K.E}}{\text{P.E}}\right| = \frac{1}{2}$$

31. Imagine a new planet having the same density as that of earth but it is 3 times bigger than the earth in size. If the acceleration due to gravity on the surface of earth is g and that on the surface of the new planet is g', then

(1) $g' = g/9$ (2) $g' = 27g$ (3) $g' = 9g$ (4) $g' = 3g$

Sol. Answer (4)

$$g = \frac{4\pi G R\rho}{3}$$

$$g' = \frac{4\pi G(3R)\rho}{3}$$

$$= 3 \times \left(\frac{4\pi G R\rho}{3}\right) = 3g$$

32. The Earth is assumed to be a sphere of radius R. A platform is arranged at a height R from the surface of the Earth. The escape velocity of a body from this platform is fv, where v is its escape velocity from the surface of the Earth. The value of f is

(1) $\frac{1}{2}$ (2) $\sqrt{2}$ (3) $\frac{1}{\sqrt{2}}$ (4) $\frac{1}{3}$

Sol. Answer (3)

Escape velocity from height, $h = R$ from earth can be evaluated using conservation of mechanical energy,

$$\frac{-GMm}{2R}+\frac{1}{2}m(v_e')^2 = 0$$

$$\Rightarrow \quad v_e' = \sqrt{\frac{GM}{R}}$$

From surface of earth, $v_e = \sqrt{\frac{2GM}{R}}$

$$\Rightarrow \quad v_e' = \frac{1}{\sqrt{2}}v_e = fv$$

Thus, $f = \frac{1}{\sqrt{2}}$

33. Two satellites of earth S_1 and S_2 are moving in the same orbit. The mass of S_1 is four times the mass of S_2. Which one of the following statements is true?

(1) The potential energies of earth and satellite in the two cases are equal

(2) S_1 and S_2 are moving with the same speed

(3) The kinetic energies of the two satellites are equal

(4) The time period of S_1 is four times that of S_2

Sol. Answer (2)

$v_0 = \sqrt{\frac{GM_e}{r}}$, r is the radius of the orbit.

Radius of orbit is same for both S_1 and S_2,

Thus, $v_{01} = v_{02}$

S_1 and S_2 are moving with the same speed.

34. A ball is dropped from a spacecraft revolving around the earth at a height of 120 km. What will happen to the ball?

(1) It will fall down to the earth gradually

(2) It will go very far in the space

(3) It will continue to move with the same speed along the original orbit of spacecraft

(4) It will move with the same speed, tangentially to the spacecraft

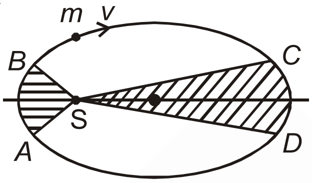
Sol. Answer (3)

A ball dropped from a spacecraft revolving around the earth will have zero relative velocity with respect to the aircraft.

But with respect to the centre of the earth its speed will be equal to the speed of the aircraft i.e the orbital speed.

Thus, it will continue to move with same speed along the original orbit and force of gravitation of earth will provide it the necessary centripetal force.

35. The figure shows elliptical orbit of a planet m about the sun S. The shaded area SCD is twice the shaded area SAB. If t_1 is the time for the planet to move from C to D and t_2 is the time to move from A to B then



(1) $t_1 = t_2$ (2) $t_1 > t_2$ (3) $t_1 = 4t_2$ (4) $t_1 = 2t_2$

Sol. Answer (4)

According to Kepler's law of Areas : The line that joins any planet to the sun sweeps out equal areas in equal intervals of time

i.e $\frac{\Delta A}{\Delta t}$ is constant.

Area $SCD = 2 \times$ Area SAB

Using, $\frac{\Delta A_{SCD}}{\Delta A_{SAB}} = \frac{\Delta t_{SCD}}{\Delta t_{SAB}} = \left(\frac{t_1}{t_2}\right)$

$\Rightarrow$ $t_1 = 2t_2$

36. The radii of circular orbits of two satellites A and B of the earth, are $4R$ and R, respectively. If the speed of satellite A is $3\ V$, then the speed of satellite B will be

(1) $\frac{3\,V}{2}$ (2) $\frac{3\,V}{4}$ (3) $6\ V$ (4) $12\ V$

Sol. Answer (3)

$$V_0 = \sqrt{\frac{GM_e}{r}}$$

$r \rightarrow$ radius of orbit

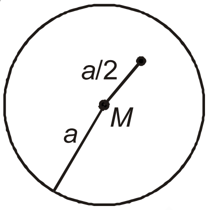
$$\frac{V_A}{V_B} = \sqrt{\frac{r_B}{r_A}}$$

$$\Rightarrow \frac{3V}{V_B} = \sqrt{\frac{1}{4}} \Rightarrow V_B = 6\ V$$

37. A particle of mass M is situated at the centre of a spherical shell of same mass and radius a. The gravitational potential at a point situated at $\frac{a}{2}$ distance from the centre, will be

(1) $-\frac{4\,GM}{a}$ (2) $-\frac{3\,GM}{a}$ (3) $-\frac{2\,GM}{a}$ (4) $-\frac{GM}{a}$

Sol. Answer (2)



Gravitational potential at a point situated at $\frac{a}{2}$ distance from the centre will be sum of potential due to spherical shell and due to mass M at the centre,

Thus, $V = V_1 + V_2$

$$V_{\text{spherical shell}} = \frac{-GM}{a} = V_1$$

$$V_{\text{mass } M} = \frac{-GM}{a/2} = \frac{-2GM}{a} = V_2$$

$$\Rightarrow \quad V_{\text{total}} = -\frac{3GM}{a}$$

38. The additional kinetic energy to be provided to a satellite of mass m revolving around a planet of mass M, to transfer it from a circular orbit of radius R_1 to another of radius R_2 ($R_2 > R_1$) is

(1) $GmM\left(\frac{1}{R_1^2}-\frac{1}{R_2^2}\right)$ (2) $GmM\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$

(3) $2GmM\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$ (4) $\frac{1}{2}GmM\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$

Sol. Answer (4)

To find out the additional kinetic energy to be provided to a satellite of mass m,

We can use conservation of mechanical energy,

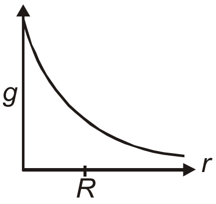
$$\text{K.E}_i + \text{P.E}_i + \text{K.E}_{\text{additional}} = \text{K.E}_f + \text{P.E}_f$$

$$\frac{1}{2}\frac{GMm}{R_1} - \frac{GMm}{R_1} + \text{K.E}_{\text{additional}} = \frac{1}{2}\frac{GMm}{R_2} - \frac{GMm}{R_2}$$

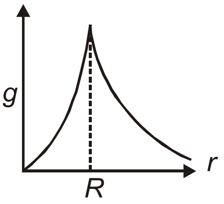
$$\Rightarrow \quad \text{K.E}_{\text{additional}} = \frac{GMm}{2}\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

39. The dependence of acceleration due to gravity g on the distance r from the centre of the earth, assumed to be a sphere of radius R of uniform density is as shown in figures below

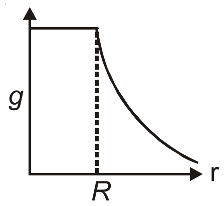
(a)



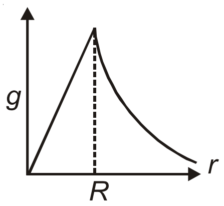
(b)



(c)



(d)



The correct figure is

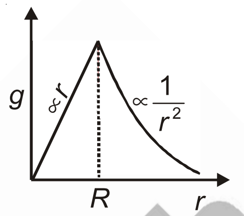
(1) (d) (2) (a) (3) (b) (4) (c)

Sol. Answer (1)

$$g_{\text{inside}} = \frac{GM}{R^3} r \text{ i.e for } r < R$$

$$g_{\text{outside}} = \frac{GM}{r^2} \text{ i.e for } r > R$$

The suitable graph is,



SECTION - D

Assertion - Reason Type Questions

1. A : The gravitational force does not depend on the intervening medium.

R : The value of G has same value anywhere in the space.

Sol. Answer (1)

Property of gravitational force:

It is independent of the medium between the particles.

2. A : The acceleration due to gravity for an object is independent from its mass.

R : The value of 'g' depends on the mass of planet.

Sol. Answer (2)

$g = \frac{GM}{R^2}$, independent of mass of object.

$M \rightarrow$ Mass of planet.

3. A : If angular speed of the earth increases, the effective value of g will decrease at all places on earth.

R : The value of 'g' at latitude λ is given by $g' = g - m\omega R^2 \cos\lambda$.

Sol. Answer (4)

$g' = g - m\omega R^2 \cos\lambda$ is incorrect.

$g' = g - \omega^2 R \cos^2\lambda$ is correct.

At poles $\lambda = 90°$

Thus, $g' = g$, no effect of earth's rotation.

4. A : The gravitational field intensity is zero everywhere inside a uniform spherical shell.

   R : The net force on a point mass inside a uniform spherical shell is zero everywhere.

Sol. Answer (1)

Gravitational force of attraction on a point mass due to various regions of the spherical shell cancels each other completely as their vector sum is zero.

5. A : The value of potential energy depends on the reference taken for zero potential energy.

   R : The value of change in potential energy is independent from reference level.

Sol. Answer (2)

Potential at a point depends on the choice of reference. Potential difference is independent of the choice of reference.

Potential energy is mass times the potential at the point.

6. A : When a satellite is orbiting then no energy is required to keep moving in its orbit.

   R : The total mechanical energy of a satellite is conserved.

Sol. Answer (1)

Total mechanical energy of the system is conserved, since the dissipative forces are absent or negligible.

7. A : An astronaut in a satellite may float in the free space outside and inside the satellite.

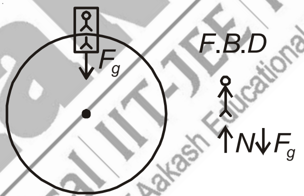
   R : An astronaut in a satellite is in weightless state.

Sol. Answer (1)

The force of gravitation provides the necessary centripetal force, for an astronant in a satellite, the *F.B.D* can be drawn,

$$F_g - N = \frac{mv_0^2}{r}$$

$$v_0 = \text{orbital speed} = \sqrt{\frac{GM}{r}}$$



$$\Rightarrow \frac{GMm}{r^2} - N = \left(\frac{m}{r}\right)\frac{GM}{r}$$

$$\Rightarrow \frac{GMm}{r^2} - N = \frac{GMm}{r^2}$$

Thus, $N = 0$, making the astronaut feel weightless.

8. A : The speed of a planet is maximum at perihelion.

   R : The angular momentum of a planet about centre of sun is conserved.

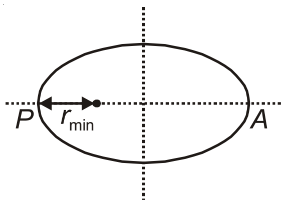
Sol. Answer (1)

Angular momentum of a planet about centre of sun is conserved,

Thus, $m\vec{r} \times \vec{v} =$ constant

At perihelion r is minimum,

Thus speed of planet is maximum.



9. A : Kepler's third law of planetary motion is valid only for inverse square forces.

   R : Only inverse square forces are always central.

Sol. Answer (3)

$$T^2 \propto r^3$$

Is valid only for inverse square forces, for a planet going in a circular orbit,

$$T = \frac{2\pi r}{v}$$

v is the orbital speed $= \sqrt{\dfrac{GM}{r}}$

$$\Rightarrow \quad T = \frac{2\pi r}{\sqrt{\dfrac{GM}{r}}} = \frac{2\pi}{\sqrt{GM}} r^{3/2}$$

Also, it is not true that,

Only inverse square forces are always central.

10. A : Kepler's law cannot be used for asteroids and comets.

    R : Asteroids and comets do not revolve around sun under its gravitational force.

Sol. Answer (4)

Kepler's laws can be used for asteroids and comets. All the 3 laws can be proved from the Newton's universal law of gravitation.

Asteroids and comets do revolve around sun.

11. A : During orbital motion of planet around the sun work done by the centripetal force is not zero at all points on the orbit.

    R : Planet is revolving around the sun in elliptical orbit.

Sol. Answer (1)

During motion of a planet around sun, the centripetal force is not always perpendicular to the velocity of planet in an elliptical orbit. Thus work done is not zero. Although, incase of circular orbits centripetal force is always perpendicular to velocity.

12. A : Angular momentum of a satellite about a planet is constant.

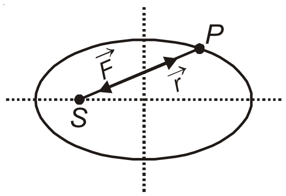
    R : Gravitational force is a central force so its torque about the sun is zero.

Sol. Answer (1)

$$\vec{\tau} = \vec{r} \times \vec{F} = rF\sin\theta$$

$$= rF\sin 180^\circ$$

$$= 0$$



Also, $\vec{\tau} = \dfrac{d\vec{L}}{dt} = 0, \;\Rightarrow$ Angular momentum is constant.

13. A : Gravitational potential is constant everywhere inside a spherical shell.

R : Gravitational field inside a spherical shell is zero everywhere.

Sol. Answer (1)

Gravitation field, $\vec{I} = \frac{-\partial v}{\partial \vec{r}}$

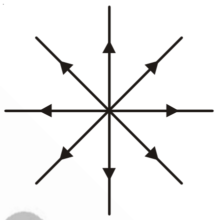
Inside a spherical shell, $I = 0$

$\Rightarrow$ V is constant everywhere.

14. A : Field created by the point mass in its surroundings is a non-uniform gravitational field.

R : Since the field is $E = \frac{GM}{r^2}$ and it is dependent on r, hence Non-uniform.

Sol. Answer (1)



Field due to point mass, $E = \frac{GM}{r^2}$

Dependent on distance r from the mass, thus non-uniform.

15. A : If the force of gravitation is inversely proportional to the distance r rather than r^2 given by Newton, then orbital velocity of the satellite around the earth is independent of r.

R : $\frac{GMm}{r} = \frac{mv^2}{r}$

So, $v = \sqrt{GM}$

Hence independent of r.

Sol. Answer (1)

Force of gravitation provides the necessary centripetal force,

$$\frac{GMm}{r} = \frac{mv^2}{r}$$

$\Rightarrow$ $v = \sqrt{GM}$

Independent of r.

16. A : Work done by the gravitational force is positive when the two point masses are brought from infinity to any two points in space.

R : Gravitational potential energy increases during the above process.

Sol. Answer (3)

Force of gravitation is attractive, thus when masses are brought from infinity to any two points in space, displacement of masses is in the direction of force.

$\Rightarrow$ Work done is positive.

Also, $W_{\text{gravity}} = -\Delta U = U_i - U_f$

$\Rightarrow$ During this process potential energy decreases.

❑ ❑ ❑

Chapter 9

Mechanical Properties of Solids

Solutions

SECTION - A

Objective Type Questions

1. Due to addition of impurities, the modulus of elasticity

(1) Decreases (2) Increases

(3) Remains constant (4) May increase or decrease

Sol. Answer (4)

It depends on the elastic property of impurities if they themselves more elastic, elasticity will increase. If they are less elastic, elasticity will decrease.

2. The shear strain is possible in

(1) Solids (2) Liquids (3) Gases (4) All of these

Sol. Answer (1)

Shear strain is possible in solids only, as only solids have a definite surface.

3. The ratio of radii of two wires of same material is 2 : 1. If these wires are stretched by equal force, the ratio of stresses produced in them is

(1) 2 : 1 (2) 1 : 2 (3) 1 : 4 (4) 4 : 1

Sol. Answer (3)

We know,

$$\text{Stress} = \frac{\text{Force}}{\text{Area}}$$

$$\left\{\begin{array}{l} S = \text{Stress} \\ F = \text{Force} \\ A = \text{Area} \\ r = \text{radius} \end{array}\right\}$$

So, Stress × Area = Force

$S \times A = F$

∵ (Since) Force applied on the wires is equal we can relate two conditions as

$$\left\{\begin{array}{l} \text{Where} \\ S_1 - \text{Stress in } 1^{\text{st}} \text{ wire} \\ A_1 - \text{Area of } 1^{\text{st}} \text{ wire} \\ r_1 - \text{Radius of } 1^{\text{st}} \text{ wire} \\ S_2 - \text{Stress in } 2^{\text{nd}} \text{ wire} \\ A_2 - \text{Area of } 2^{\text{nd}} \text{ wire} \\ r_2 - \text{Radius of } 2^{\text{nd}} \text{ wire} \end{array}\right\}$$

$S_1A_1 = S_2A_2$

$$\frac{S_1}{S_2} = \frac{A_2}{A_1} = \frac{\pi r_2^2}{\pi r_1^2}$$

$$\frac{S_1}{S_2} = \frac{r^2}{(2r)^2} = \frac{r^2}{4r^2} = \frac{1}{4}$$

4. A load of 2 kg produces an extension of 1 mm in a wire of 3 m in length and 1 mm in diameter. The Young's modulus of wire will be

   (1) 3.25×10^{10} Nm^{-2} (2) 7.48×10^{12} Nm^{2}

   (3) 7.48×10^{10} Nm^{-2} (4) 7.48×10^{-10} Nm^{-2}

Sol. Answer (3)

We know

$$\frac{\text{Force} \times \text{Length}}{\text{Area of cross-section} \times \text{elongation}} = \text{Young's Modulus}$$

$$\frac{F \times L}{A \times \Delta L} = Y \qquad \left\{\begin{matrix} F = 2 \times 10 \text{ N}, \ A = \pi \times (1/2)^2 \times 10^{-6} \text{ m}^2 \\ L = 3 \text{ m} \qquad , \Delta L = 1 \times 10^{-3} \text{ m} \end{matrix}\right\}$$

Substituting values

$$\frac{20 \times 3}{\pi \times \frac{1}{4} \times 10^{-6} \times 1 \times 10^{-3}} = Y$$

$$\frac{20 \times 3 \times 4}{3.14 \times 10^{-9}} = Y$$

$$7.48 \times 10^{10} \text{ Nm}^{-2} = Y$$

5. Young's modulus depends upon

   (1) Stress applied on material (2) Strain produced in material

   (3) Temperature of material (4) All of these

Sol. Answer (3)

Young's modulus is a material property and it also depends on temperature of material.

6. The value of Young's modulus for a perfectly rigid body is

   (1) 1 (2) Less than 1 (3) Zero (4) Infinite

Sol. Answer (4)

For perfectly rigid body the condition is that there should not be any elognation ($\Delta L = 0$) for any value of force

So from the formulae we know $\frac{FL}{A \cdot \Delta L} = Y$

If we put $\Delta L = 0$

We get Y as ∞

7. The breaking stress of aluminium is 7.5×10^{7} Nm^{-2}. The greatest length of aluminium wire that can hang vertically without breaking is (Density of aluminium is 2.7×10^{3} kg m^{-3})

   (1) 283×10^{3} m (2) 28.3×10^{3} m (3) 2.83×10^{3} m (4) 0.283×10^{3} m

Sol. Answer (3)

Breaking stress = $\rho \times g \times L$

Substitute values from the question

Breaking stress = 7.5×10^7 Nm^{-2}

$$\left\{\begin{array}{l}\rho = \text{Density of material}\\ g = \text{Acceleration due to gravity}\\ L = \text{Length of wire that can hang without breaking}\end{array}\right\}$$

$\rho = 2.7 \times 10^3$ kg m^{-3}

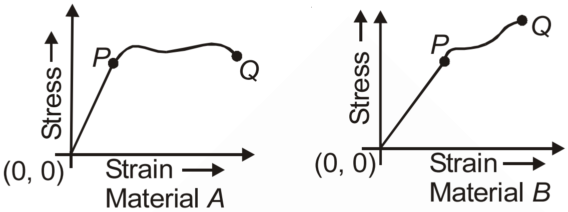
$g = 9.8$ m/s

$7.5 \times 10^7 = 2.7 \times 10^3 \times 9.8 \times L$

$$\frac{7.5\times10^7}{2.7\times10^3\times9.8} = L$$

2.83×10^3 m = L

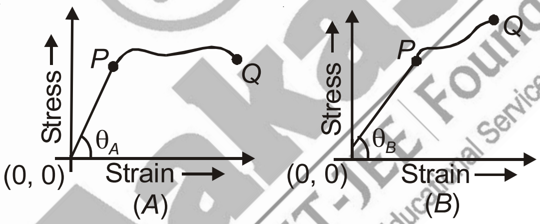
8. The stress strain graphs for two materials *A* and *B* are shown in figure. The graphs are drawn to the same scale. Select the correct statement



(1) Material *A* has greater Young's Modulus (2) Material *A* is ductile

(3) Material *B* is brittle (4) All of these

Sol. Answer (4)



Slope of stress strain curve (tan θ) gives the value of young's modulus for given material

$\Rightarrow$ $\tan\theta = y$

And from the graph we can clearly see

$\tan\theta_A > \tan\theta_B$

So material *A* has greater young's modulus

P to *Q* distance in material *A* is greater than *P* to *Q* distance in material *B*

Which implies more deformation is possible in *A* as compared to *B*

Hence we can say *A* is ductile, *B* is brittle.

9. A steel wire of diameter 2 mm has a breaking strength of 4×10^5 N. What is the breaking force of similar steel wire of diameter 1.5 mm?

(1) 2.3×10^5 N (2) 2.6×10^5 N (3) 3×10^5 N (4) 1.5×10^5 N

Sol. Answer (1)

We know

$$\frac{\text{Force}\times\text{Length}}{\text{Area}\times\text{young's modulus}} = \text{elongation} \qquad \left\{\frac{FL}{Ay} = \Delta x\right\}$$

$$\Rightarrow \quad F = \left(\frac{\Delta x \cdot y}{L}\right)A$$

$$F = \left(\frac{\Delta x \cdot y}{L} \cdot \frac{\pi}{4}\right)d^2$$

We can say $F \propto d^2$

So we can use

$$\frac{F_1}{F_2} = \frac{d_1^2}{d_2^2} \qquad \left\{\begin{array}{l} F_1 = 4\times10^5\ \text{N} \\ d_1 = 2\ \text{mm} \\ F_2 = ? \\ d_2 = 1.5\ \text{mm} \end{array}\right\}$$

Substituting values

$$\frac{4\times10^5}{F_2} = \frac{(2)^2}{(1.5)^2}$$

$F_2 = 2.3 \times 10^5$ N

10. A steel wire is 1 m long and 1 mm^2 in area of cross-section. If it takes 200 N to stretch this wire by 1 mm, how much force will be required to stretch a wire of the same material as well as diameter from its normal length of 10 m to a length of 1002 cm?

(1) 1000 N (2) 200 N (3) 400 N (4) 2000 N

Sol. Answer (3)

$$\frac{FL}{AY} = \Delta x$$

Since A, Y remain constant in given case

We can say

$FL \propto \Delta x$

$$\text{or} \quad \frac{F_1L_1}{F_2L_2} = \frac{\Delta x_1}{\Delta x_2} \qquad \left\{\begin{array}{l} F_1 = 200\ \text{N} \\ \Delta x_1 = 1\ \text{mm} \\ \Delta x_2 = 10.02\ \text{m} - 10\ \text{m} = 0.02\ \text{m} = 20\ \text{mm} \\ L_1 = 1\ \text{m} \\ L_2 = 10\ \text{m} \end{array}\right.$$

Substitute the values

$$\frac{200\times1}{F_2\times10} = \frac{1\ \text{mm}}{20\ \text{mm}}$$

$F_2 = 400$ N

11. A wire 2 m in length suspended vertically stretches by 10 mm when mass of 10 kg is attached to the lower end. The elastic potential energy gain by the wire is (take g = 10 m/s^2)

(1) 0.5 J (2) 5 J (3) 50 J (4) 500 J

Sol. Answer (1)

$$\text{Potential energy per unit volume } = \frac{1}{2}\times\text{stress}\times\text{strain}$$

$$= \frac{1}{2}\times\frac{F}{A}\times\frac{\Delta L}{L}$$

So, Potential energy = potential energy per unit volume × volume

$$= \frac{1}{2} \times \frac{F \cdot \Delta L}{A \cdot L} \times A \cdot L \qquad \{\text{Volume = Length × cross-sectional area}\}$$

$$\Delta U = \frac{1}{2} \cdot F \cdot \Delta L$$

Substituting values $\begin{cases} F = 10 \times 10 \text{ N} \\ \Delta L = 10 \text{ mm} = 10 \times 10^{-3} \text{ m} \end{cases}$

$$\Delta U = \frac{1}{2} \times 100 \times \frac{10}{1000}$$

ΔU = 0.5 J

12. A wire of length L and cross-sectional area A is made of material of Young's modulus Y. The work done in stretching the wire by an amount x is

(1) $\frac{YAx^2}{L}$ (2) $\frac{YAx^2}{2L}$ (3) $\frac{2YAx^2}{L}$ (4) $\frac{4YAx^2}{L}$

Sol. Answer (2)

$$\because \quad W = \frac{1}{2} Fx$$

and $Y = \frac{FL}{Ax}$

$$\therefore \quad F = \frac{YAx}{L}$$

$$W = \frac{1}{2}\left(\frac{YAx}{L}\right)x$$

$$W = \frac{1}{2}\frac{YAx^2}{L}$$

13. A spherical ball contracts in volume by 0.01% when subjected to a normal uniform pressure of 100 atm. The Bulk modulus of its material is

(1) 1.01 × 10^{11} Nm^{-2} (2) 1.01 × 10^{12} Nm^{-2} (3) 1.01 × 10^{10} Nm^{-2} (4) 1.0 × 10^{13} Nm^{-2}

Sol. Answer (1)

We know $\frac{\Delta V}{V} = -\frac{P}{B}$

Substituting values

$$\frac{-\frac{0.01}{100} \times V}{V} = \frac{-100}{B} \times 1.01 \times 10^5 \qquad \{1 \text{ atm} = 1.01 \times 10^5 \text{ Pa or Nm}^{-2}\}$$

B = 1.01 × 10^{11} Nm^{-2}

14. What is the percentage increase in length of a wire of diameter 2.5 mm, stretched by a force of 100 kg wt? Young's modulus of elasticity of wire = 12.5×10^{11} dyne/cm^2

(1) 0.16% (2) 0.32% (3) 0.08% (4) 0.12%

Sol. Answer (1)

$Y = \frac{FL}{A\Delta L}$ $\Rightarrow$ Percentage increase $\frac{\Delta L}{L}\times 100 = \frac{F}{AY}\times 100$

Diameter = 2.5 mm $d = \frac{2.5}{1000}$ m

Area $= \frac{\pi d^2}{4}$ $Y = 12.5 \times 10^{11}$ dyne/cm^2 $\left\{\frac{1\,\text{dyne}}{\text{cm}^2} = \frac{0.1\,\text{N}}{\text{m}^2}\right\}$

$\Rightarrow A = \frac{\pi \times (2.5)^2}{4}$ $F = 100 \times 10 = 1000$ N

$$\Rightarrow \frac{1000 \times L}{\frac{3.14 \times (2.5)^2}{4 \times (1000)^2} \times 12.5 \times 10^{11} \times 0.1} = \frac{\Delta L}{L} \times 100$$

= 0.16%

15. Two exactly similar wires of steel and copper are stretched by equal forces. If the total elongation is 2 cm, then how much is the elongation in steel and copper wire respectively? Given, $Y_{\text{steel}} = 20 \times 10^{11}$ dyne/cm^2, $Y_{\text{copper}} = 12 \times 10^{11}$ dyne/cm^2.

(1) 1.25 cm; 0.75 cm (2) 0.75 cm; 1.25 cm (3) 1.15 cm; 0.85 cm (4) 0.85 cm; 1.15 cm

Sol. Answer (2)

Let us say that elongation in copper = x

Than elongation in steel = $2 - x$

We know

$$\frac{FL}{AY} = \Delta x$$

$\because$ F, A, L are same only material is different

We can say

$$\frac{1}{Y} \propto \Delta x$$

$$\frac{Y_2}{Y_1} = \frac{\Delta x_1}{\Delta x_2}$$

$$\left\{\begin{array}{l}\text{Where} \\ Y_2 = Y_{\text{steel}} \\ Y_1 = Y_{\text{copper}} \\ \Delta x_1 = \text{elongation in copper} = x \\ \Delta x_2 = 2 - x\end{array}\right.$$

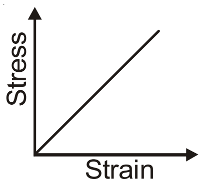
Substituting values

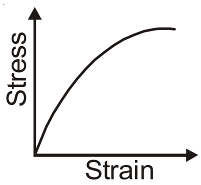
$$\frac{20 \times 10^{11}}{12 \times 10^{11}} = \frac{x}{2 - x}$$

$x = 1.25$ cm

So $\Delta x_{\text{copper}} = 1.25$ cm, $\Delta x_{\text{steel}} = 0.75$ cm

16. Which of the following is the graph showing stress-strain variation for elastomers?

(1)


(2)


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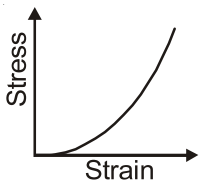

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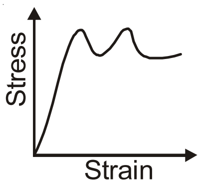
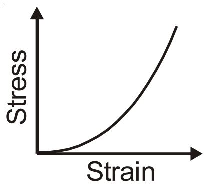


Sol. Answer (3)

In elastomers stress varies exponentially with strain e.g. Rubber



17. A steel rod has a radius 10 mm and a length of 1.0 m. A force stretches it along its length and produces a strain of 0.32%. Young's modulus of the steel is 2.0×10^{11} Nm^{-2}. What is the magnitude of the force stretching the rod?

(1) 100.5 kN (2) 201 kN (3) 78 kN (4) 150 kN

Sol. Answer (2)

Strain = 0.32%

$$\Rightarrow \frac{\Delta L}{L} \times 100 = 0.32$$

$$\Rightarrow \frac{\Delta L}{L} = \frac{0.32}{100}$$

$$A = \pi r^2 = 3.14 \times \left(\frac{10}{1000}\right)^2$$

$$Y = 2 \times 10^{11} \text{ Nm}^2$$

We know

$$\frac{FL}{AY} = \Delta L$$

$$F = \left(\frac{\Delta L}{L}\right) \times A \times Y$$

Substituting values

$$F = \frac{0.32}{100} \times 3.14 \times \left(\frac{10}{1000}\right)^2 \times 2 \times 10^{11}$$

F = 201 kN

18. The proportional limit of steel is 8×10^8 N/m^2 and its Young's modulus is 2×10^{11} N/m^2. The maximum elongation, a one metre long steel wire can be given without exceeding the elastic limit is

(1) 2 mm (2) 4 mm (3) 1 mm (4) 8 mm

Sol. Answer (2)

At proportional limit

Stress $\propto$ strain

Stress = Y × strain {Y = Young's Modulus}

$$\text{Stress} = Y \times \frac{\Delta L}{L}$$

$$\left\{\begin{array}{l} \text{Stress} = 8 \times 10^8 \text{ N/m}^2 \\ Y = 2 \times 10^{11} \text{ N/m}^2 \\ L = 1 \text{ m} \end{array}\right.$$

Substituting values

$$\frac{8 \times 10^8 \times 1}{2 \times 10^{11}} = \Delta L$$

4 mm = ΔL

19. In a series combination of copper and steel wires of same length and same diameter, a force is applied at one of their ends while the other end is kept fixed. The combined length is increased by 2 cm. The wires will have

(1) Same stress and same strain (2) Different stress and different strain

(3) Different stress and same strain (4) Same stress and different strain

Sol. Answer (4)

Stress = $\frac{F}{A}$

Force is same, A is same

So same stress

Strain = $\frac{\Delta L}{L}$

L is same, but due to different young's modulus

(Material's different)

ΔL would be different so strain is different

20. Select the correct alternative(s)

(1) Elastic forces are not always conservative

(2) Elastic forces are always conservative

(3) Elastic forces are conservative only when Hooke's law is obeyed

(4) Elastic forces are not conservative

Sol. Answer (1)

Since at every value of force material is not able to gain its shape. Therefore elastic forces are not always conservative.

21. A metallic rod of length l and cross-sectional area A is made of a material of Young's modulus Y. If the rod is elongated by an amount y, then the work done is proportional to

(1) y (2) $\frac{1}{y}$ (3) y^2 (4) $\frac{1}{y^2}$

Sol. Answer (3)

Work done = energy stored

$W = \frac{1}{2}\times$ force × elongation $\left\{\text{Force} = \frac{\Delta L}{L}\cdot AY\right.$

$W = \frac{1}{2}\times\frac{\Delta L}{L}\times A\times Y\times\Delta L$

$W = \frac{1}{2}\frac{AY}{L}\times\Delta L^2$

$W \propto \Delta L^2$

22. The Poisson's ratio of a material is 0.5. If a force is applied to a wire of this material, there is a decrease in the cross-sectional area by 4%. The percentage increase in the length is

(1) 1% (2) 2% (3) 2.5% (4) 4%

Sol. Answer (4)

$$\frac{\text{Lateral strain}}{\text{Longitudinal strain}} = \eta$$

$$\frac{\Delta r / r}{\Delta l / l} = 0.5$$

Substitute $\Delta r/r = 2/100$

$$\frac{\Delta l}{l} = \frac{4}{100}$$

$\therefore$ % increase $= \frac{\Delta l}{l} \times 100 = 4\%$

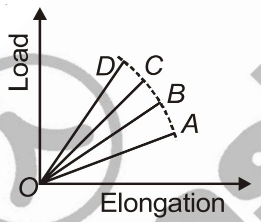
$\because A \propto r^2$

So $\frac{\Delta A}{A} = \frac{2\Delta r}{r}$

$$\frac{4}{100} = 2 \times \frac{\Delta r}{r}$$

$$\frac{2}{100} = \frac{\Delta r}{r}$$

23. The load versus elongation graph for four wires of same length and the same material is shown in figure. The thinnest wire is represented by line



(1) *OC* (2) *OD* (3) *OA* (4) *OB*

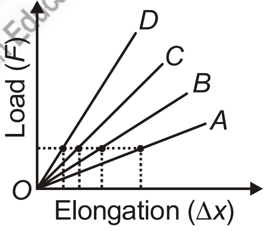
Sol. Answer (3)

For the same load wire with maximum elongation has minimum cross-section area

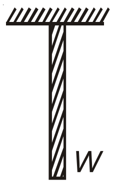
As $\frac{FL}{AY} = \Delta x$

F, L, Y are fixed so $\frac{1}{A} \propto \Delta x$

$\Rightarrow$ *OA* is the thinnest.



24. A rod of uniform cross-sectional area A and length L has a weight W. It is suspended vertically from a fixed support. If Young's modulus for rod is Y, then elongation produced in rod is



(1) $\frac{WL}{YA}$

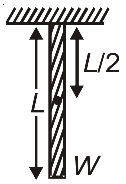
(2) $\frac{WL}{2YA}$

(3) $\frac{WL}{4YA}$

(4) $\frac{3WL}{4YA}$

Sol. Answer (2)

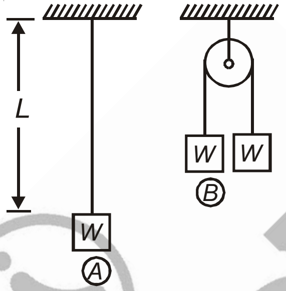
Center of mass is at $\frac{L}{2}$ distance from top so it can be assumed for easy calculation that W weight is hanged to a $\frac{L}{2}$ length string



Now use $\frac{FL}{AY}\cdot\Delta L$

$$\Delta L=\frac{W\times L}{2AY}$$

25. If in case A, elongation in wire of length L is l, then for same wire elongation in case B will be



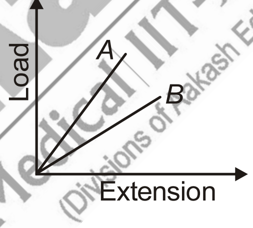
(1) $4l$ (2) $2l$ (3) l (4) $l/2$

Sol. Answer (3)

Since tension in both cases is same and all other parametrs (Y, A, L) are also same

⇒ Elongation will be same in both cases.

26. In the given figure, if the dimensions of the two wires are same but materials are different, then Young's modulus is

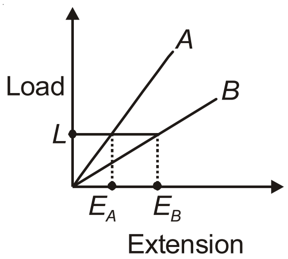


(1) More for A than B (2) More for B than A (3) Equal for A and B (4) None of these

Sol. Answer (1)

At same value of load

A has less elongation than B ...(1)



$\frac{FL}{AY}=\Delta L$ $\left\{\begin{matrix}\because\ L, A \text{ are same}\\ F-\text{Load is also taken same}\end{matrix}\right\}$

So $\frac{1}{Y}\propto\Delta L$ ...(2)

Using conditions (1) and (2)

We can say

$Y_A > Y_B$ {Young's modulus of A greater than B}

27. If the Bulk modulus of lead is 8.0 × 10^9 N/m^2 and the initial density of the lead is 11.4 g/cc, then under the pressure of 2.0 × 10^8 N/m^2, the density of the lead is

(1) 11.3 g/cc (2) 11.5 g/cc (3) 11.6 g/cc (4) 11.7 g/cc

Sol. Answer (4)

We know,

$$\left[\frac{1}{\rho_2}-\frac{1}{\rho_1}\right]=-\frac{P}{B} \qquad \left\{\begin{array}{l}\text{Where}\\ P=2\times10^8\ \text{N/m}^2\\ B=8\times10^9\ \text{N/m}^2\\ \rho_1=11.4\ \text{g/cc}\\ \rho_2=?\end{array}\right.$$

Substitute value's

$$\left[\frac{1}{\rho_2}-\frac{1}{114}\right]=-\frac{2\times10^8}{8\times10^9}$$

After solving, we get

ρ_2 = 11.7 g/cc

28. Two wires *A* and *B* of same material have radii in the ratio 2 : 1 and lengths in the ratio 4 : 1. The ratio of the normal forces required to produce the same change in the lengths of these two wires is

(1) 1 : 1 (2) 2 : 1 (3) 1 : 2 (4) 1 : 4

Sol. Answer (1)

From $\frac{FL}{AY}=\Delta x$ $\{\because\ \Delta x,\ Y\ \text{same}\}$

We using $F\propto\frac{L}{A}\propto\frac{L}{r^2}$

So $\frac{F_1}{F_2}=\frac{L_1}{r_1^2}\times\frac{r_2^2}{L_2}=\left(\frac{L_1}{L_2}\right)\times\left(\frac{r_2}{r_1}\right)^2$

Substitute the ratio's

We get $\frac{F_1}{F_2}=\frac{1}{1}$ or $F_1 : F_2 :: 1 : 1$

29. For a given material, the Young's modulus is 2.4 times its modulus of rigidity. Its Poisson's ratio is

(1) 0.2 (2) 0.4 (3) 1.2 (4) 2.4

Sol. Answer (1)

$Y = 3B\,[1 - 2\sigma]$ ...(1)

$Y = 2.4B$ (given) ...(2)

$$\left\{\begin{array}{l}\text{Where}\\ Y=\text{Young's modulus}\\ B=\text{Bulk's modulus}\\ \sigma=\text{Poisson's ratio}\end{array}\right.$$

Using both (1) and (2)

$$\frac{2.4B}{3B}=1-2\sigma$$

$0.2 = \sigma$

30. When the temperature of a gas is 20°C and pressure is changed from P_1 = 1.01 × 10^5 Pa to P_2 = 1.165 × 10^5 Pa, then the volume changes by 10%. The Bulk modulus is

(1) 1.55 × 10^5 Pa (2) 1.01 × 10^5 Pa (3) 1.4 × 10^5 Pa (4) 0.115 × 10^5 Pa

Sol. Answer (1)

$$\frac{\Delta V}{V} = \frac{-\Delta P}{B}$$

Substituting the values

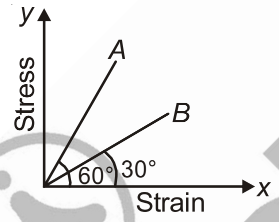
$$\frac{-10}{100} = \frac{-(1.165\times10^6 - 1.01\times10^6)}{B}$$

$$\frac{1}{10} = \frac{.155\times10^5}{B}$$

$B = 1.55 \times 10^5$ Pa

$$\left\{\begin{array}{l} \Delta V = 10\% \text{ of } V \; (\because \text{ Pressure increases volume must} \\ \qquad \text{decreases by 10\% so we will use a +ve sign)} \\ \text{If } V = 100 \text{ cc} \\ \Rightarrow \Delta V = -10 \text{ cc} \\ \Delta P = P_2 - P_1 \\ \quad = 1.165\times10^5 - 1.01\times10^5 \end{array}\right.$$

31. The stress versus strain graph for wires of two materials A and B are as shown in the figure. If Y_A and Y_B are the Young's moduli of the materials, then



(1) $Y_B = 2Y_A$ (2) $Y_A = 3Y_B$ (3) $Y_B = 3Y_A$ (4) $Y_A = Y_B$

Sol. Answer (2)

$Y = \tan\theta$

$Y_A = \tan 60°$, $Y_B = \tan 30°$

$= \sqrt{3}$ $= 1/\sqrt{3}$

$\Rightarrow Y_A = 3Y_B$

32. Hooke's law is applicable for

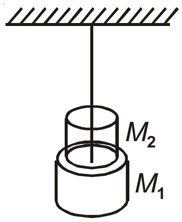
(1) Elastic materials only (2) Plastic materials only

(3) Elastomers only (4) All of these

Sol. Answer (1)

Hooke's law is applicable only for elastic materials as only they follow the stress-strain proportionality.

33. The length of wire, when M_1 is hung from it, is l_1 and is l_2 with both M_1 and M_2 hanging. The natural length of wire is



(1) $\frac{M_1}{M_2}(l_1 - l_2) + l_1$ (2) $\frac{M_2 l_1 - M_1 l_2}{M_1 + M_2}$ (3) $\frac{l_1 + l_2}{2}$ (4) $\sqrt{l_1 l_2}$

Sol. Answer (1)

Let the natural length of wire be = l

When only M_1 hanging

Using $\Delta l = \dfrac{FL}{AY}$

$$(l_1 - l) = \frac{M_1 g \cdot l}{AY} \qquad \text{...(1)}$$

When both M_1, M_2 hanging

$$(l_2 - l) = \frac{(M_1 + M_2)\, g \cdot l}{AY} \quad \text{...(2)}$$

Dividing (1) by (2)

$$\frac{l_1 - l}{l_2 - l} = \frac{M_1}{M_1 + M_2}$$

Solving this we get

$$l = \frac{M_1}{M_2}(l_1 - l_2) + l_1$$

34. When a load of 10 kg is suspended on a metallic wire, its length increase by 2 mm. The force constant of the wire is

(1) 3×10^4 N/m (2) 2.5×10^3 N/m (3) 5×10^4 N/m (4) 7.5×10^3 N/m

Sol. Answer (3)

$$\text{Force constant } (K) = \frac{\text{Force}}{\text{Elongation}} = \frac{F}{\Delta x} \qquad \begin{cases} F = 10 \text{ kg} = 100 \text{ N} \\ \Delta x = 2 \text{ mm} = 0.002 \text{ m} \end{cases}$$

Substituting values

$$K = \frac{100}{0.002} = 5 \times 10^4 \text{ N/m}$$

35. A rod of length l and radius r is held between two rigid walls so that it is not allowed to expand. If its temperature is increased, then the force developed in it is proportional to

(1) L (2) $1/L$ (3) r^2 (4) r^{-2}

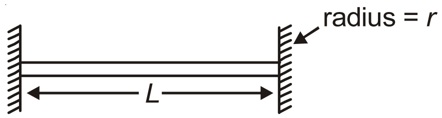
Sol. Answer (3)

(ΔL) Thermal expansion = $L \propto \Delta Q$

Where L = Length original

$\propto$ = Coeffcient of linear expansion

ΔQ = Change in temperature



Or we can say

$\Delta L \propto L$

And force required to produce similar elongation can be calculated by

$$F = AY \cdot \frac{\Delta L}{L} \qquad [\because Y \text{ is constant}]$$

So $F \propto r^2 \cdot \frac{\Delta L}{L}$

Also $\Delta L \propto L$

So F only proportional to r^2

36. If the temperature of a wire of length 2 m and area of cross-section 1 cm^2 is increased from 0° C to 80°C and is not allowed to increase in length, then force required for it is $\{Y = 10^{10}\ \text{N/m}^2,\ \alpha = 10^{-6}/°\text{C}\}$

(1) 80 N (2) 160 N (3) 400 N (4) 120 N

Sol. Answer (1)

Thermal expansion would be = $L \propto \Delta T$

Where L = original length

α = coefficient of linear expansion

ΔT = Change in temperature

So substituting values

$\Delta L = 2 \times 10^{-6} \times 80$

$\Delta L = 1.6 \times 10^{-4}$ m

Now $\Delta L = \frac{FL}{AY}$

$$\frac{\Delta L \times AY}{L} = F$$

Substitute values

$$\frac{1.6 \times 10^{-4} \times 10^{10} \times 1}{2 \times 10000} = F$$

80 N = F

37. Energy stored per unit volume in a stretched wire having Young's modulus Y and stress 'S' is

(1) $\frac{YS}{2}$ (2) $\frac{S^2Y}{2}$ (3) $\frac{S^2}{2Y}$ (4) $\frac{S}{2Y}$

Sol. Answer (3)

$$\Delta U = \frac{1}{2} \times \text{stress} \times \text{strain}$$

$$= \frac{1}{2} \times \text{stress} \times \frac{\text{stress}}{Y} \qquad \{\because \text{ Stress} = Y \cdot \text{strain}\}$$

$$= \frac{1}{2} \times \frac{S^2}{Y}$$

38. A wire suspended vertically from one end is stretched by attaching a weight 200 N to the lower end. The weight stretches the wire by 1 mm. The elastic potential energy gained by the wire is

(1) 0.1 J (2) 0.2 J (3) 0.4 J (4) 10 J

Sol. Answer (1)

Elastic potential energy = $\frac{1}{2}$ × force × elongation

$$= \frac{1}{2} \times 200 \times \frac{1}{1000} = 0.1\text{ J}$$

39. Work done by restoring force in a string within elastic limit is –10 J. Maximum amount of heat produced in the string is

(1) 10 J (2) 20 J (3) 5 J (4) 15 J

Sol. Answer (1)

Within elastic limit there is no loss of energy in deforming because no permanent deformation.

$\therefore$ We can say

Work done by external force = heat produced

Or (–)ve of work done by restoring force = heat produced

$-1 \times -10\text{ J} = \Delta H$

$10\text{ J} = \Delta H$

40. The work done per unit volume to stretch the length of area of cross-section 2 mm^2 by 2% will be [$Y = 8 \times 10^{10}$ N/m^2]

(1) 40 MJ/m^3 (2) 16 MJ/m^3 (3) 64 MJ/m^3 (4) 32 MJ/m^3

Sol. Answer (4)

Work done = Force × elongation

$W = F \cdot \Delta x$.... $\left\{F = \Delta x \cdot \frac{AY}{L}\right\}$

$\Rightarrow W = \frac{AY}{L} \times \Delta x^2$

Multiply and divide by L

We get

$$W = \frac{\text{Volume} \cdot Y}{L^2} \Delta x^2$$

Cross multiply ($L \cdot A$) volume

$$\frac{W}{\underbrace{L \cdot A}} = Y \cdot \left(\frac{\Delta x}{L}\right)^2$$

Work done per unit volume

Substitute values

$$= 8 \times 10^{10} \cdot \left(\frac{2}{100}\right)^2$$

= 32 MJ/m^3

41. Which of the following affects the elasticity of a substance?

(1) Change in temperature (2) Impurity in substance

(3) Hammering (4) All of these

Sol. Answer (4)

Elasticity is hampered by change in temperature as it changes the structure of grains of the material impurity if elastic increases the elasticity if plastic increases plasticity.

By hammering also grain shape gets changes and effects elasticity.

42. Select the wrong definition

(1) Deforming Force – force that changes configuration of body

(2) Elasticity – property of regaining original configuration

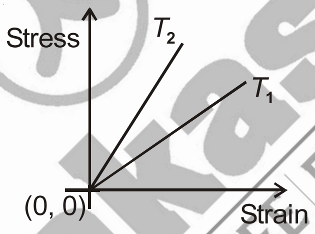
(3) Plastic body – which can be easily melted

(4) Elastic limit – beyond which property of elasticity vanishes

Sol. Answer (3)

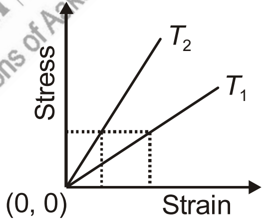
Plastic body is defined as a body which cannot regain its shape after deforming force is removed.

43. Figure shows graph between stress and strain for a uniform wire at two different temperatures. Then



(1) $T_1 > T_2$ (2) $T_2 > T_1$ (3) $T_1 = T_2$ (4) None of these

Sol. Answer (1)



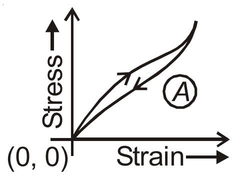
From the graph we can see young's modulus is less for T_1 as compared to T_2

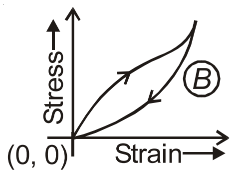
(Y = slope of stress-strain curve)

As T increases Y decreases

So $T_1 > T_2$

44. Two different types of rubber are found to have the stress-strain curves as shown. Then





(1) A is suitable for shock absorber (2) B is suitable for shock absorber

(3) B is suitable for car tyres (4) None of these

Sol. Answer (2)

One with higher hysterysis loss suitable for shock absorber because high hysterysis loss will lead to dampen shocks in a easy manner.

One with lower hysterysis loss suitable for types because it will have low relaxation time.

Area between loop gives amount of hysterysis loss. More area more loss, less area less loss.

Therefore, *B* is suitable for shock absorber and *A* for types.

45. The ratio of adiabatic to isothermal elasticity of a diatomic gas is

(1) 1.67 (2) 1.4 (3) 1.33 (4) 1.27

Sol. Answer (2)

$K_{\text{isothermal}}$ = Pressure of gas (P)

$K_{\text{adiabatic}}$ = γ × pressure of gas ($\gamma \cdot P$)

$$\text{Ratio} = \frac{\gamma P}{P} = \gamma$$

$$\gamma \text{ of diatomic gas } = \frac{7}{5} = 1.4$$

46. A uniform cubical block is subjected to volumetric compression, which decreases its each side by 2%. The Bulk strain produced in it is

(1) 0.03 (2) 0.02 (3) 0.06 (4) 0.12

Sol. Answer (3)

Volume = (side)^3

$v = (a)^3$

$$\text{So } \frac{\Delta v}{v} = \frac{3\Delta a}{a} \qquad \left\{\text{given } \frac{\Delta a}{a} = -2\%\right\}$$

$$\therefore \frac{\Delta v}{v} = 3 \times -2$$ Side decreases so we used (–)ve sign

$= -6\%$

We know

$$\frac{\Delta v}{v} = -\frac{P}{B}$$

Substituting value of $\Delta v/v$

$$-\frac{6}{100} = -\frac{P}{B}$$

So bulk strain produced is 0.06

47. When a rubber ball is taken to the bottom of a sea of depth 1400 m, its volume decreases by 2%. The Bulk modulus of rubber ball is [density of water is 1 g cc and g = 10 m/s^2]

(1) 7×10^8 N/m^2 (2) 6×10^8 N/m^2 (3) 14×10^8 N/m^2 (4) 9×10^8 N/m^2

Sol. Answer (1)

Pressure at the bottom of sea = $\rho_w gh$ = 1000 kg/m^3 × 10 m/s^2 × 1400 m = 14000000 N/m^2

Also we know

$$\frac{\Delta v}{v} = -\frac{P}{B} \qquad \left\{\frac{\Delta v}{v} = \frac{-2}{100}\right\}$$

$$\frac{-2}{100} = \frac{-14000000}{B}$$

$B = 7 \times 10^8$ N/m^2

48. A spherical ball contracts in volume by 0.02%, when subjected to a normal uniform pressure of 50 atmosphere. The Bulk modulus of its material is

(1) 1×10^{11} N/m^2 (2) 2×10^{10} N/m^2 (3) 2.5×10^{10} N/m^2 (4) 1×10^{13} N/m^2

Sol. Answer (3)

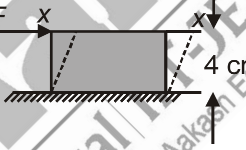
$$\frac{\Delta v}{v} = -\frac{P}{B} \qquad \left\{\frac{\Delta v}{v} = \frac{-0.02}{100}\right\}$$

P = 50 atm = 50 × 1.01 × 10^5 Pa or N/m^2

So $B = 50 \times 1.01 \times 10^5 \times \dfrac{100}{0.02}$

$= 2.5 \times 10^{10}$ N/m^2

49. A steel plate of face area 1 cm^2 and thickness 4 cm is fixed rigidly at the lower surface. A tangential force F = 10 kN is applied on the upper surface as shown in the figure. The lateral displacement x of upper surface w.r.t. the lower surface is (Modulus of rigidity for steel is 8×10^{11} N/m^2)



(1) 5×10^{-5} m (2) 5×10^{-6} m (3) 2.5×10^{-3} m (4) 2.5×10^{-4} m

Sol. Answer (2)

$$\text{Modulus of rigidity } (G) = \frac{\text{Force} \times \text{Length}}{\text{Area} \times \text{Lateral displacement}} = \frac{FL}{A \times \Delta x}$$

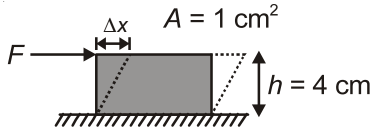
F = 10 kN = 10 × 10^3 N

L = 4 cm = 0.04 m

A = 1 cm^2 = 1 × 10^{-4} m^2

G = 8 × 10^{11} N/m^2

Substituting values



$$8 \times 10^{11} = \frac{10 \times 10^3 \times 0.04}{1 \times 10^{-4} \times \Delta x}$$

$$\Delta x = \frac{10 \times 10^3 \times 0.04}{1 \times 10^{-4} \times 8 \times 10^{11}} = 5 \times 10^{-6} \text{ m}$$

50. The Poisson's ratio cannot have a value of

(1) 0.7 (2) 0.2 (3) 0.1 (4) 0.5

Sol. Answer (1)

Poisson's ratios value can't be practically more than 1/2 so only value above 1/2 is 0.7

51. A material has Poisson’s ratio 0.5. If a uniform rod of it suffers a longitudinal strain of 3×10^{-3}, what will be percentage increase in volume?

(1) 2% (2) 3% (3) 5% (4) 0%

Sol. Answer (4)

$$\frac{\text{Lateral strain}}{\text{Longitudinal strain}} = \eta = 0.5$$

$$\frac{-\Delta r / r}{\Delta l / l} = \frac{1}{2}$$

$$\frac{-2\Delta r}{r} = \frac{\Delta l}{l}$$

Magnitute wise both are equal but sign's would

be different as both quantities cannot increase

Now volume ∝ area × length

$v \propto r^2 \cdot L$

$$\frac{\Delta v}{v} = \frac{2\Delta r}{r} + \frac{\Delta L}{L}$$

Substituting value of $\frac{\Delta L}{L}$

$$\frac{\Delta v}{v} = 0$$

$\therefore$ No change in volume

52. When a uniform metallic wire is stretched the lateral strain produced in it is β. If σ and Y are the Poisson’s ratio and Young’s modulus for wire, then elastic potential energy density of wire is

(1) $\frac{Y\beta^2}{2}$ (2) $\frac{Y\beta^2}{2\sigma^2}$ (3) $\frac{Y\sigma\beta^2}{2}$ (4) $\frac{Y\sigma^2}{2\beta}$

Sol. Answer (2)

β = Strain (lateral)

σ = Poisson's ratio

Y = Young's modulus

Elastic potential energy density = $\frac{1}{2} \times Y \times (\text{strain longitudinal})^2$ ...(1)

Also $\frac{\text{Lateral strain}}{\text{Longitudinal strain}} = \text{Poisson's ratio}$

$$\frac{\beta}{\text{Longitudinal strain}} = \sigma$$

$\Rightarrow$ Longitudinal strain $= \frac{\beta}{\sigma}$

Substituting the value in equation (1)

$$E.P.E = \frac{1}{2} Y \times \left(\frac{\beta}{\sigma}\right)^2 = \frac{1Y\beta^2}{2\sigma^2}$$

53. The substances having very short plastic region are

(1) Ductile (2) Brittle (3) Malleable (4) All of these

Sol. Answer (2)

Substances with short plastic region are brittle because less amount of permanent deformation could be done in them.

54. For an elastic material

(1) $Y > \eta$ (2) $Y < \eta$ (3) $Y\eta = 1$ (4) $Y = \eta$

Sol. Answer (1)

Y = Young's modulus

η = modulus of rigidity

We have a formulae

$Y = 2\eta\,[1 + \sigma]$

$0 < \sigma \leq 0.5$

$$\begin{bmatrix}\text{Where } \sigma = \text{poisson's ratio practical} \\ \text{value of } \sigma \text{ lies between 0 to 0.5}\end{bmatrix}$$

Using maximum value of σ

$Y = 3\eta$

$\Rightarrow$ $Y > \eta$

55. Correct pair is

(1) Change in shape – Longitudinal strain (2) Change in volume – Shear strain

(3) Change in length – Bulk strain (4) Reciprocal of Bulk modulus – Compressibility

Sol. Answer (4)

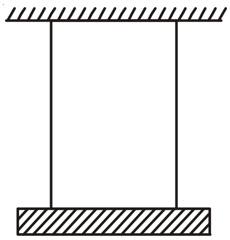
B = bulk modulus

and $\frac{1}{B}$ is defined as compressibility

SECTION - B

Objective Type Questions

1. Two wires of equal length and cross-sectional area are suspended as shown in figure. Their Young's modulii are Y_1 and Y_2 respectively. The equivalent Young’s modulii will be

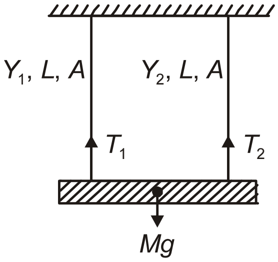


(1) $Y_1 + Y_2$ (2) $\frac{Y_1 Y_2}{Y_1 + Y_2}$ (3) $\frac{Y_1 + Y_2}{2}$ (4) $\sqrt{Y_1 Y_2}$

Sol. Answer (3)

Forces acting on both wires would be equal to T_1 and T_2 respectively by free body diagram

Let equivalent force constant of wire = K



$$K_1 + K_2 = K \qquad \left[\begin{array}{l}\text{Crossectional area will double}\\ \text{when both wires taken together}\end{array}\right]$$

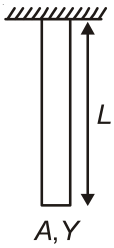
$$\frac{AY_1}{L} + \frac{AY_2}{L} = \frac{2AY}{L} \Rightarrow Y = \frac{Y_1 + Y_2}{2}$$

2. A uniform rod of length L has a mass per unit length λ and area of cross-section A. If the Young's modulus of the rod is Y. Then elongation in the rod due to its own weight is

(1) $\frac{2\lambda gL^2}{AY}$ (2) $\frac{\lambda gL^2}{AY}$ (3) $\frac{\lambda gL^2}{4AY}$ (4) $\frac{\lambda gL^2}{2AY}$

Sol. Answer (4)

Total mass can be assumed to be concentrated at center of mass at distance $\frac{L}{2}$ from top



$$\frac{M}{L} = \lambda$$

$$M = \lambda L$$

$$\Delta x = \frac{FL/2}{AY} = \frac{1}{2} \times \frac{\lambda L^2 g}{AY}$$

3. When a small mass m is suspended at lower end of an elastic wire having upper end fixed with ceiling. There is loss in gravitational potential energy, let it be x, due to extension of wire, mark correct option

(1) The lost energy can be recovered (2) The lost energy is irrecoverable

(3) Only $\frac{x}{2}$ amount of energy is recoverable (4) Only $\frac{x}{3}$ amount of energy is recoverable

Sol. Answer (3)

ΔU (loss in gravitational potential energy) = $mg \times \Delta l$

$\Delta U = x$ (given)

So $x = mg \times \Delta l$

$$\begin{cases}\text{Where}\\ m = \text{mass suspended}\\ \Delta l = \text{elongation in wire}\end{cases}$$

$$\text{Elastic potential energy gained} = \frac{1}{2} \times \text{Force} \times \text{Elongation}$$

$$= \frac{1}{2} \times Mg \times \Delta l$$

$$= \frac{1}{2} Mg \times \Delta l \qquad [\because Mg\Delta l = x]$$

$$= \frac{1}{2} x$$

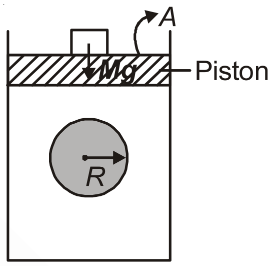
So only $\frac{x}{2}$ amount of energy is recoverable which is stored as elastic potential energy in wire.

4. A solid sphere of radius R made of a material of bulk modulus B surrounded by a liquid in a cylindrical container. A massless piston of area A floats on the surface of the liquid. Find the fractional decrease in the radius of the sphere $\left(\frac{\Delta R}{R}\right)$ when a mass M is placed on the piston to compress the liquid

(1) $\frac{Mg}{AB}$ (2) $\frac{Mg}{4AB}$ (3) $\frac{Mg}{3AB}$ (4) $\frac{Mg}{2AB}$

Sol. Answer (3)

Pressure increased to weight M



$$P = \frac{\text{Force}}{\text{Area}} = \frac{Mg}{A} \qquad ...(1)$$

And we know,

$$\frac{-\Delta V}{V} = \frac{P}{B}$$

$$\frac{-\Delta V}{V} = \frac{Mg}{AB} \qquad \left[\because P = \frac{Mg}{A}\right] \qquad ...(2)$$

$\left\{\begin{array}{l}\text{Where } -\frac{\Delta V}{V} = \text{Fractional decrease in volume} \\ P = \text{Pressure increased} \\ B = \text{Bulk modulus}\end{array}\right.$

Volume of a sphere is $V = \frac{4}{3}\pi r^3$ $\left\{\begin{array}{l}\text{Where} \\ r \text{ is radius}\end{array}\right\}$

$$\Rightarrow \quad \frac{\Delta V}{V} = \frac{3\Delta R}{R}$$

Using (2)

$$-\frac{Mg}{3AB} = \frac{\Delta R}{R} \qquad \text{[(–)ive sign indicates decrease]}$$

$\therefore$ Fractional decrease in radius is $\frac{Mg}{3AB}$

5. A sphere contracts in volume by 0.01% when taken to the bottom of sea 1 km deep. Find Bulk modulus of the material of sphere

(1) 9.8×10^6 N/m^2 (2) 1.2×10^{10} N/m^2 (3) 9.8×10^{10} N/m^2 (4) 9.8×10^{11} N/m^2

Sol. Answer (3)

Pressure at bottom of sea = $\rho_w gh$

$\rho_w = 1000$ kg/m^3 = 1 g/cc, $g = 9.8$ m/s^2, $h = 1000$ m

$P = 10^3 \times 9.8 \times 1000$ N/m^2

Now $\frac{-\Delta V}{V} = \frac{P}{B}$ $\left\{\frac{-\Delta V}{V} = \frac{0.01}{100} \text{ (given)}\right.$

$$\frac{0.01}{100} = \frac{10^3 \times 9.8 \times 1000}{B}$$

$B = 9.8 \times 10^{10}$ N/m^2

6. A mild steel wire of length 2l meter cross-sectional area A m^2 is fixed horizontally between two pillars. A small mass m kg is suspended from the mid point of the wire. If extension in wire are within elastic limit. Then depression at the mid point of wire will be

(1) $\left(\frac{Mg}{YA}\right)^{1/3}$ (2) $\left(\frac{Mg}{lA}\right)^{1/3}$ (3) $\left(\frac{Mgl^3}{YA}\right)^{1/3}$ (4) $\frac{Mg}{2YA}$

Sol. Answer (3)

Let $OC = x$ [depression]

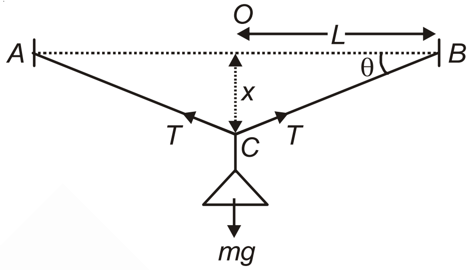
and θ be small angle

$\because$ x is small

ΔL (Extension in OB part of wire) = $BC - OB$

$BC = (L^2 + x^2)^{1/2}$ and $OB = L$

$\Delta L = \{(L^2 + x^2)^{1/2} - L\}$



We know $F = \frac{YA\,\Delta L}{L}$

So $F = \frac{YA}{L}\left\{(L^2 + x^2)^{1/2} - L\right\}$

$$= YA\left\{\left(1+\frac{x^2}{L^2}\right)^{1/2} - 1\right\}$$

$$= YA\left\{1+\frac{x^2}{2L^2} - 1\right\}$$

$\left\{\text{Using binomial theorem} \quad \frac{x^2}{L^2} << 1\right.$

$$F = \frac{YAx^2}{2L^2}$$

So $\left(1+\frac{x^2}{L^2}\right)^{1/2} \simeq 1 + \frac{x^2}{2L^2}$

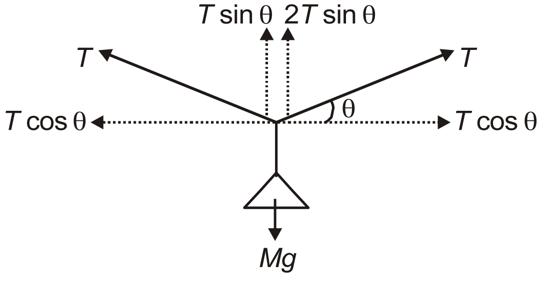
Tension in each part of wire will be equal to 'F'

By vertical equilibrium

$Mg = 2T\sin\theta$

$= 2T\theta$ {If θ is small. So $\sin\theta \simeq \theta$}

$\because$ $T = F$



$$Mg = 2\times\frac{YAx^2}{2L^2}\times\theta$$

$\left\{\begin{array}{l}\text{in } \Delta\, OBC \\ \frac{x}{L} = \tan\theta\end{array}\right.$

$$Mg = 2\times\frac{YAx^2}{2L^2}\times\frac{x}{L}$$

$\because$ θ is small, $\tan\theta \simeq \sin\theta \simeq \theta$

We get,

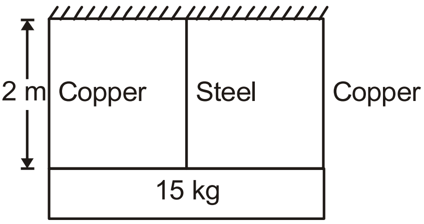
$$\left(\frac{MgL^3}{YA}\right)^{1/3} = x$$

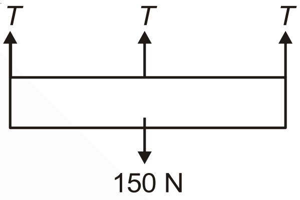
So $\frac{x}{L} = \theta$

7. A rigid bar of mass 15 kg is supported symmetrically by three wire each of 2 m long. These at each end are of copper and middle one is of steel. Young's modulus of elasticity for copper and steel are 110 × 10^9 N/m^2 and 190 × 10^9 N/m^2 respectively. If each wire is to have same tension, ratio of their diameters will be

(1) $\sqrt{\frac{11}{19}}$ (2) $\sqrt{\frac{19}{11}}$ (3) $\sqrt{\frac{30}{11}}$ (4) $\sqrt{\frac{11}{30}}$

Sol. Answer (2)





Tension is same (given)

From free body diagram

$3T = 150$ N

$T = 50$ N

Since the bar has to be supported symmetrically

Therefore extension in each wire will be same

We know $\Delta x = \frac{FL}{AY}$

Compare 1 copper wire with another steel wire

$$\frac{FL}{A_C Y_C} = \frac{FL}{A_S Y_S}$$

$$\Rightarrow \frac{A_S}{A_C} = \frac{Y_C}{Y_S}$$

Where,
A_C – Area of copper wire
Y_C – Young's modulus copper
A_S – Area of steel wire
Y_S – Young's modulus steel

Substitutuing value of Y_C and Y_s

$$\frac{\pi d_S^2}{4 \times \frac{\pi}{4} \times d_C^2} = \frac{110 \times 10^9}{190 \times 10^9}$$

$$\frac{d_S}{d_C} = \sqrt{\frac{11}{19}}$$

d_S – diameter of steel wire
d_C – diameter of copper wire

$$\frac{d_C}{d_S} = \sqrt{\frac{19}{11}}$$

8. A solid cube of copper of edge 10 cm subjected to a hydraulic pressure of 7 × 10^6 pascal. If Bulk modulus of copper is 140 GPa, then contraction in its volume will be

(1) 5 × 10^{-8} m^3 (2) 4 × 10^{-8} m^3 (3) 2 × 10^{-8} m^3 (4) 10^8 m^3

Sol. Answer (1)

Initial volume $V = (\text{side})^3 = (10 \times 10^{-2})^3$

$P = 7 \times 10^6$ Pa

$B = 140 \times 10^9$ Pa

We know

$$\frac{-\Delta V}{V} = \frac{P}{B}$$ {$-\Delta V$ = Contraction in volume}

$$\frac{-\Delta V}{10^{-3}} = \frac{7 \times 10^6}{140 \times 10^9}$$

$-\Delta V = 5 \times 10^{-8}$ m^3

9. Three bars having length l, $2l$ and $3l$ and area of cross-section A, $2A$ and $3A$ are joined rigidly end to end. Compound rod is subjected to a stretching force F. The increase in length of rod is (Young's modulus of material is Y and bars are massless)

(1) $\frac{13Fl}{2AY}$ (2) $\frac{Fl}{AY}$ (3) $\frac{9Fl}{AY}$ (4) $\frac{3Fl}{AY}$

Sol. Answer (4)

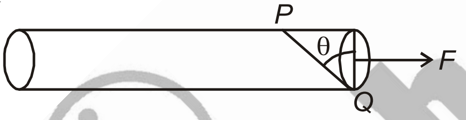
If extension of rod = x

$x = x_1 + x_2 + x_3$ Where x_1, x_2, x_3 are individual extensions in rod 1, 2, 3

$$x_1 = \frac{Fl}{AY},\ x_2 = \frac{2Fl}{2AY},\ x_3 = \frac{3Fl}{3AY}$$

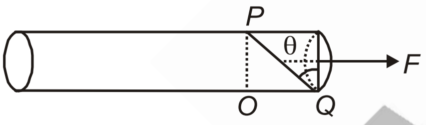
So $x = \frac{3Fl}{AY}$

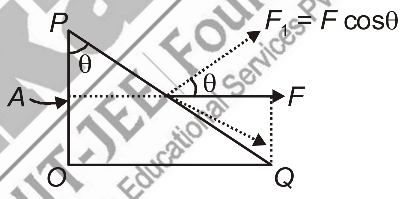
10. A force F is applied along a rod of transverse sectional area A. The normal stress to a section PQ inclined θ to transverse section is



(1) $\frac{F\sin\theta}{A}$ (2) $\frac{F}{A}\cos\theta$ (3) $\frac{F}{2A}\sin 2\theta$ (4) $\frac{F}{A}\cos^2\theta$

Sol. Answer (4)





$$\text{Stress} = \frac{F_{\text{normal}}}{\text{Area}} = \frac{F_1}{\text{Area}}$$

Crossectional area $PO = A$

$$= \frac{F\cos\theta}{A/\cos\theta}$$

Crossectional area of $PQ = \frac{PO}{\cos\theta} = \frac{A}{\cos\theta}$

$$= \frac{F}{A}\cos^2\theta$$

11. The strain energy stored in a body of volume V due to shear strain ϕ is (shear modulus is η)

(1) $\frac{\phi^2 V}{2\eta}$ (2) $\frac{\phi V^2}{2\eta}$ (3) $\frac{\phi^2 V}{\eta}$ (4) $\frac{1}{2}\eta\phi^2 V$

Sol. Answer (4)

$$\text{Shear modulus} = \frac{\text{Shear stress}}{\text{Shear stress}}$$

$$\eta = \frac{\text{Shear stress}}{\phi}$$

$\eta\phi$ = Shear stress

Strain energy per unit volume = $\frac{1}{2}$ × shear stress × shear strain

$$\Rightarrow \quad \frac{\text{Strain energy}}{\text{Volume}} = \frac{1}{2} \times \eta\phi \times \phi \quad \text{(Cross multiply volume)}$$

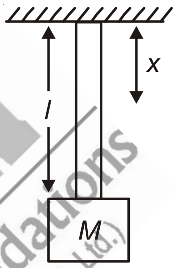
$$\text{Strain energy} = \frac{1}{2}\eta\phi^2 V$$

12. A vertical hanging bar of length l and mass m per unit length carries a load of mass M at lower end, its upper end is clamped to a rigid support. The tensile stress a distance x from support is ($A \rightarrow$ area of cross-section of bar)

(1) $\frac{Mg + mg(l - x)}{A}$ (2) $\frac{Mg}{A}$ (3) $\frac{Mg + mgl}{A}$ (4) $\frac{(M+m)gx}{Al}$

Sol. Answer (1)

$$\text{Tensile stress} = \frac{\text{Tension at point}}{\text{Area}}$$



Tension at distance x from top would be the amount of force acting due to all the weight below it

= Mass per unit length of rod × length of rod + Mg

= $m \times (l - x)\, g + Mg$

So Tensile stress $= \frac{m(l - x)g + Mg}{A}$

13. A metal wire having Poisson's ratio 1/4 and Young's modulus 8×10^{10} N/m^2 is stretched by a force, which produces a lateral strain of 0.02% in it. The elastic potential energy stored per unit volume in wire is [in J/m^3]

(1) 2.56×10^4 (2) 1.78×10^6 (3) 3.72×10^2 (4) 2.18×10^5

Sol. Answer (1)

$$\frac{\text{Lateral strain}}{\text{Longitudinal strain}} = \text{Poisson's ratio}$$

$$\frac{0.02/100}{\Delta l / l} = \frac{1}{4}$$

$$\frac{\Delta l}{l} = \frac{0.08}{100}$$

$$\left\{\begin{array}{l} Y = \text{(Young's modulus)} \\ \quad = 8 \times 10^{10} \quad \text{(given)} \\ \text{Poission's ratio} = \frac{1}{4} \quad \text{(given)} \\ \text{Lateral strain} = 0.02\% \quad \text{(given)} \end{array}\right.$$

ΔU (Elastic potential energy per unit volume = $\frac{1}{2}$ × Y × (Longitudinal strain))

Substituting values

$$\Delta U = \frac{1}{2} \times 8 \times 10^{10} \times \left(\frac{0.08}{100}\right)^2$$

$\Delta U = 2.56 \times 10^4$ J/m^3

14. An ideal gas has adiabatic exponent γ . It expands according to the law $P = \alpha V$, where α is constant. For this process, the Bulk modulus of the gas is

(1) P (2) $\frac{P}{\alpha}$ (3) αP (4) $(1-\alpha)P$

Sol. Answer (1)

$$B = \frac{\Delta P}{\Delta V / V}$$

$$B = \frac{\alpha \Delta V}{\Delta V / V} = \alpha V$$

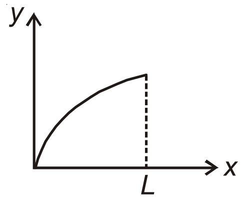
And $\alpha V = P$

So $B = P$

Where,
ΔP = increase in pressure
$= \alpha \Delta V \; \{\because P = \alpha V\}$
B = Bulk modulus
ΔV = Change in volume
V = Initial volume

15. Which of the following curve represents the correctly distribution of elongation (y) along heavy rod under its own weight $L \rightarrow$ length of rod, $x \rightarrow$ distance of point from lower end?

(1)



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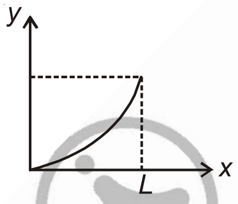

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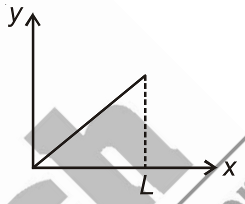

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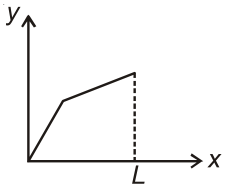


Sol. Answer (2)

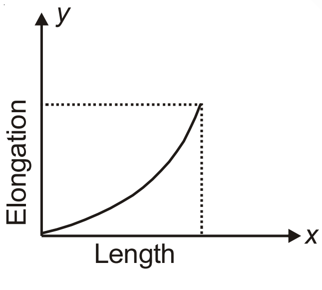
For elongation of rod under its own weight

We know $\Delta x = \frac{\rho g x^2}{2Y}$

We can clearly see that elongation $\propto (x^2)$

So graph of Δx *vsx* should be a upward parabola.

Where,
Δx = Elongation
ρ = Density of rod
Y = Young's modulus
L = Length
g = Acceleration due to gravity
x = Distance of point from lower end



16. The length of a metal wire is l_1, when tension in it is T_1 and l_2 when its tension is T_2. The natural length of the wire is

(1) $\sqrt{l_1 l_2}$ (2) $\frac{l_1T_2 - l_2T_1}{T_2 - T_1}$ (3) $\frac{l_2T_2 - l_1T_1}{T_1 + T_2}$ (4) $\frac{l_1 + l_2}{2}$

Sol. Answer (2)

Let natural length of wire = l

Case I : when tension in wire is T_1

$$l_1 - l = \frac{T_1 l}{AY} \quad ...(1) \quad \left\{\Delta l = \frac{FL}{AY}\right\}$$

Case II : when tension in wire is T_2

$$l_2 - l = \frac{T_2 l}{AY} \qquad ...(2)$$

Dividing (2) by (1)

$$\frac{l_2 - l}{l_1 - l} = \frac{T_2}{T_1}$$

Solving this we get

$$l = \frac{l_1 T_2 - l_2 T_1}{T_2 - T_1}$$

17. A wire can sustain a weight of 15 kg. If it cut into four equal parts, then each part can sustain a weight

(1) 5 kg (2) 45 kg (3) 15 kg (4) 30 kg

Sol. Answer (3)

$$\text{Stress} = \frac{F}{A}$$

So $\text{Stress} \propto \dfrac{1}{A}$

Since, we are not reducing the crossectional area of the wire. Therefore each part can still sustain same force i.e, 15 kg weight.

18. Two wire A and B are stretched by same force. If, for A and B, $Y_A : Y_B = 1 : 2$, $r_A : r_B = 3 : 1$ and $l_A : l_B = 4 : 1$, then ratio of their extension $\left(\dfrac{\Delta l_A}{\Delta l_B}\right)$ will be

(1) 10 : 13 (2) 11 : 7 (3) 8 : 9 (4) 6 : 5

Sol. Answer (3)

$$\Delta x = \frac{FL}{AY}$$

For wire A

$$\Delta L_A = \frac{F \cdot L_A}{\pi r_A^2 \cdot Y_A} \qquad ...(1)$$

For wire B

$$\Delta L_B = \frac{F \cdot L_B}{\pi r_B^2 \cdot Y_B} \qquad ...(2)$$

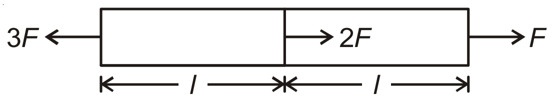
Divide (1) by (2)

$$\frac{\Delta L_A}{\Delta L_B} = \frac{F \cdot L_A}{\pi r_A^2 \cdot Y_A} \times \frac{\pi r_B^2 \cdot Y_B}{F \times L_B} = \frac{L_A}{L_B} \times \left(\frac{r_B}{r_A}\right)^2 \times \frac{Y_B}{Y_A}$$

Substituting the value of ratio's

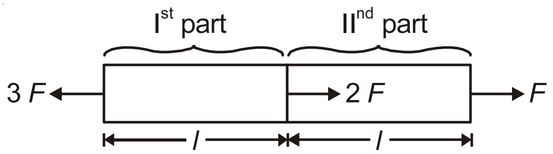
$$\frac{\Delta L_A}{\Delta L_B} = \frac{4}{1} \times \left(\frac{1}{3}\right)^2 \times \frac{2}{1} = \frac{8}{9}$$

19. A bar is subjected to axial forces as shown. If E is the modulus of elasticity of the bar and A is its cross-section area. Its elongation will be



(1) $\dfrac{Fl}{AE}$ (2) $\dfrac{2Fl}{AE}$ (3) $\dfrac{3Fl}{AE}$ (4) $\dfrac{4Fl}{AE}$

Sol. Answer (4)



Elongation in Ist part

$$\Delta x_1 = \frac{\text{Net force} \times L}{AY}$$

$$= \frac{(3+2)FL}{AE}$$

$$= \frac{5FL}{AE}$$

Elongation in IInd part

$$\Delta x_2 = \frac{(F-2F)L}{AE} = -\frac{FL}{AE}$$

So net elongation

$$\Delta x = \Delta x_1 + \Delta x_2$$

$$= \frac{5FL}{AE} - \frac{FL}{AE} = \frac{4FL}{AE}$$

20. A metal ring of initial radius r and cross-sectional area A is fitted onto a wooden disc of radius $R > r$. If Young's modulus of metal is Y then tension in the ring is

(1) $\dfrac{AYR}{r}$ (2) $\dfrac{AY(R-r)}{r}$ (3) $\dfrac{Y}{A}\left(\dfrac{R-r}{r}\right)$ (4) $\dfrac{Yr}{AR}$

Sol. Answer (2)

r – radius of metal ring

R – radius of wooden disc

Given

$R > r$

So $2\pi R > 2\pi r$

To get the metal ring fitted on wooden disc the circumfrence should be increased by $(2\pi R - 2\pi r)$ of metal ring

$\therefore$ $\Delta L = 2\pi(R - r)$

F = tension developed in ring

$$\therefore \quad 2\pi(R-r) = \frac{T(2\pi r)}{AY} \qquad \left(\Delta L = \frac{FL}{AY}\right)$$

$$\frac{AY(R-r)}{r} = T$$

21. The normal density of gold is ρ and its modulus is B. The increase in density of piece of gold when pressure P is applied uniformly from all sides

(1) $\frac{\rho P}{2B}$ (2) $\frac{\rho B}{2P}$ (3) $\frac{\rho P}{B-P}$ (4) $\frac{\rho B}{B-P}$

Sol. Answer (3)

We know

$$\frac{\Delta V}{V}=\frac{P}{B} \qquad ...(1)$$

$$\begin{cases}\Delta V - \text{Change in volume}\\ P - \text{Pressure applied}\\ B - \text{Bulk modulus}\end{cases}$$

And $\rho=\frac{M}{V}$ ...(2)

$$\begin{cases}\rho = \text{Density}\\ M = \text{Mass}\\ V = \text{Volume}\end{cases}$$

From (2)

$$\Delta\rho=\frac{M}{V-\Delta V}-\frac{M}{V}$$

$$\Delta\rho=\frac{M}{V}\times\frac{\Delta V}{V-\Delta V}$$

$$\Delta\rho=\rho\times\frac{1}{\frac{V}{\Delta V}-1} \qquad \text{[From eq. (2)]}$$

$$\Delta\rho=\rho\times\frac{1}{\frac{B}{P}-1} \qquad \text{[From eq. (1)]}$$

$$\Delta\rho=\frac{\rho P}{B-P}$$

22. A wire of length 5 m is twisted through 30° at free end. If the radius of wire is 1 mm, the shearing strain in the wire is

(1) 30° (2) 0.36′ (3) 1° (4) 0.18°

Sol. Answer (2)

$$\theta=\frac{r}{L}\phi$$

$$\begin{cases}\text{Where}\\ \theta = \text{Angle of shear}\\ \phi = \text{Angle of twist}\\ r = \text{Radius of rod}\\ l = \text{length or rod}\end{cases}$$

$$\theta=\frac{1\times10^{-3}\times30^\circ}{5}$$

$$\theta = 6\times10^{-3}$$

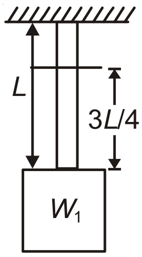
$$= 0.36'$$

23. One end of uniform wire of length L and of weight W is attached rigidly to a point in roof and a weight W_1 is suspended from the lower end. If A is area of cross-section of the wire, the stress in the wire at a height $\frac{3L}{4}$ from its lower end is

(1) $\frac{W_1}{A}$ (2) $\frac{\left(W_1+\frac{W}{4}\right)}{A}$ (3) $\frac{\left(W_1+\frac{3W}{4}\right)}{A}$ (4) $\frac{W_1+W}{A}$

Sol. Answer (3)

$$\text{Stress} = \frac{\text{Tension at point}}{\text{Area of cross-section}}$$



Tension = force due to weight hanging below the choosen point

That is $\left(\frac{3W}{4} + W_1\right)$

$$\text{Stress } = \frac{3W/4 + W_1}{A}$$

24. Two wires *A* and *B* of same length and of same material have radii r_1 and r_2 respectively. Their one end is fixed with a rigid support and at other end equal twisting couple is applied. Then ratio of the angle of twist at the end of *A* and the angle of twist at the end of *B* will be

(1) $\frac{r_1^2}{r_2^2}$ (2) $\frac{r_2^2}{r_1^2}$ (3) $\frac{r_2^4}{r_1^4}$ (4) $\frac{r_1^4}{r_2^4}$

Sol. Answer (3)

$$r_1^4\ \phi_1 = r_2^4\ \phi_2$$

$$\frac{\phi_A}{\phi_B} = \frac{(r_B)^4}{(r_A)^4} = \left(\frac{r_2}{r_1}\right)^4$$

25. A uniform wire of length *L* and radius *r* is twisted by an angle α. If modulus of rigidity of the wire is η, then the elastic potential energy stored in wire, is

(1) $\frac{\pi\eta r^4\alpha}{2L^2}$ (2) $\frac{\pi\eta r^4\alpha^2}{4L}$ (3) $\frac{\pi\eta r^4\alpha}{4L^2}$ (4) $\frac{\pi\eta r^4\alpha^2}{2L}$

Sol. Answer (2)

U = work done

We know

$$\text{Work done } = \frac{\pi S r^4 \phi^2}{4L} \qquad \left\{\begin{array}{l}\text{Where,}\\ \phi = \text{Angle of twist} = \alpha \\ S = \text{Modulus of rigidity} = 4\end{array}\right.$$

Substituting values

$$U = \frac{\pi\eta r^4\alpha^2}{4L}$$

26. What is called the ratio of the breaking stress and the working stress?

(1) Elastic fatigue (2) Elastic after effect (3) Yield point (4) Power of safety

Sol. Answer (4)

$$\frac{\text{Breaking stress}}{\text{Working stress}} = n$$

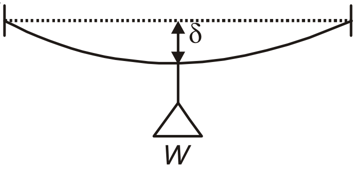
n = power of safely

27. If δ is the depression produced in a beam of length L, breadth b and thickness d, when a load is placed at the mid point, then

(1) $\delta \propto L^3$ (2) $\delta \propto \frac{1}{b^3}$ (3) $\delta \propto \frac{1}{d}$ (4) All of these

Sol. Answer (1)

Since we know



$$\delta = \frac{WL^3}{4Y\,bd^3}$$

So we can say $\delta \propto L^3$

SECTION - C

Previous Years Questions

1. The following four wires of length L and radius r are made of the same material. Which of these will have the largest extension, when the same tension is applied?

(1) $L = 400$ cm, $r = 0.8$ mm (2) $L = 300$ cm, $r = 0.6$ mm

(3) $L = 200$ cm, $r = 0.4$ mm (4) $L = 100$ cm, $r = 0.2$ mm

Sol. Answer (4)

We know

$$\Delta x = \frac{FL}{AY} = \frac{FL}{\pi r^2 Y}$$

$$\Rightarrow \quad \Delta x \propto \frac{L}{r^2}$$

Δx directly proportional to L

And Δx inversely proportional to r^2

For option (1)

$$\frac{L}{r^2} = \frac{400\times10}{(0.8)^2} = 6250$$

For option (2)

$$\frac{L}{r^2} = \frac{300\times10}{(0.6)^2} = 8333.33$$

For option (3)

$$\frac{L}{r^2} = \frac{200\times10}{(0.4)^2} = 12,500$$

For option (4)

$$\frac{L}{r^2} = \frac{100\times10}{(0.2)^2} = 25,000$$

For option (4) we are getting maximum value of $\frac{L}{r^2}$

$\Rightarrow$ Δx also maximum for $L = 100$ cm and $r = 0.2$ mm

2. A rope 1 cm in diameter breaks, if the tension in it exceeds 500 N. The maximum tension that may be given to similar rope of diameter 3 cm is

(1) 500 N (2) 3000 N (3) 4500 N (4) 2000 N

Sol. Answer (3)

Tension $\propto$ (radius)^2 $\quad \left[\Delta x = \dfrac{FL}{\pi r^2 Y}\right]$

$$\frac{T_1}{T_2} = \left(\frac{r_1}{r_2}\right)^2 \qquad \text{So } T \propto r^2$$

Substituting values

Let $T_2 = x$ $\quad \left.\begin{matrix} T_1 = 500 \text{ N} \\ r_1 = 1 \text{ cm} \\ r_2 = 3 \text{ cm} \end{matrix}\right\}$ given

$$\frac{500}{x} = \frac{1^2}{3^2}$$

$x = 4500$ N

$\Rightarrow$ $T_2 = 4500$ N

3. A wire of length L and radius r fixed at one end and a force F applied to the other end produces an extension l. The extension produced in another wire of the same material of length $2L$ and radius $2r$ by a force $2F$, is

(1) l (2) $2l$ (3) $4l$ (4) $\dfrac{l}{2}$

Sol. Answer (1)

$$L = \frac{FL}{\pi r^2 Y} \quad ...(1) \qquad \left[\Delta x = \frac{FL}{AY}\right]$$

Now, new parameters

$F = 2F$

$L = 2L$

$r = 2r$

Substituting new parameters in eq. (1)

$$L' = \frac{2F \times 2L}{\pi (2r)^2 Y}$$

$$= \frac{FL}{\pi r^2 Y} \qquad \left\{\because \ \frac{FL}{\pi r^2 Y} = l \ \text{ from equation 1}\right\}$$

$L' = L$

4. The increase in pressure required to decrease the 200 L volume of a liquid by 0.008% in kPa is (Bulk modulus of the liquid = 2100 MPa is)

(1) 8.4 (2) 84 (3) 92.4 (4) 168

Sol. Answer (4)

$V = 200$ L

$\Delta V = -0.008\%$ of 200 L (Decrease in volume so we use (–)ive sign)

$$= \frac{0.008}{100} \times 200 = -0.016 \text{ L}$$

$B = 2100$ MPa $= 21 \times 10^8$ Pa

We know

$$\frac{-\Delta V}{V} = \frac{\Delta P}{B}$$

$$\frac{0.016}{200} = \frac{\Delta P}{21 \times 10^8}$$

168×10^3 Pa $= \Delta P$

168 kPa $= \Delta P$

5. Which of the following relations is true?

(1) $Y = 2\eta(1 - 2\sigma)$ (2) $Y = 2\eta(1 + 2\sigma)$ (3) $Y = 2\eta(1 - \sigma)$ (4) $(1 + \sigma)2\eta = Y$

Sol. Answer (4)

$Y = 2\eta(1 + \sigma)$

$$\left\{\begin{array}{l}\text{Where,}\\ Y = \text{Young's modulus}\\ \eta = \text{Shear modulus}\\ \sigma = \text{Poisson's ratio}\end{array}\right.$$

6. A 5 m long aluminium wire ($Y = 7 \times 10^{10}$ Nm^{-2}) of diameter 3 mm supports a 40 kg mass. In order to have the same elongation in the copper wire ($Y = 12 \times 10^{10}$ Nm^{-2}) of the same length under the same weight, the diameter should now be (in mm)

(1) 1.75 (2) 1.5 (3) 2.3 (4) 5.0

Sol. Answer (3)

For aluminium wire

$$\Delta x_1 = \frac{FL}{AY} = \frac{4FL}{\pi d^2 Y}$$

$$\left\{\begin{array}{l}F = 400 \text{ N}\\ L = 5 \text{ m}\\ d = 3 \text{ mm}\\ Y = 7 \times 10^{10} \text{ Nm}^{-2}\end{array}\right.$$

Substituting values

$$\Delta x_1 = \frac{4 \times 400 \times 5}{\pi \times (3)^2 \times 7 \times 10^{10}} \quad ...(1)$$

For copper wire

Using same formulae

$$\Delta x_2 = \frac{4FL}{\pi d^2 Y}$$

$$\left\{\begin{array}{l}F = 400 \text{ N}\\ L = 5 \text{ m}\\ Y = 12 \times 10^{10}\\ d = ?\end{array}\right.$$

Let diameter be = d

$$\Delta x_2 = \frac{4 \times 400 \times 5}{\pi d^2 \times 12 \times 10^{10}} \quad ...(2)$$

Equating (1) and (2)

Because $\Delta x_1 = \Delta x_2$ [given condition]

$$\frac{4\times 400\times 5}{\pi\times(3)^2\times 7\times 10^{10}} = \frac{4\times 400\times 5}{\pi d^2\times 12\times 10^{10}}$$

Solving this we get

$$d = \frac{\sqrt{21}}{2} \simeq 2.3\text{ mm}$$

7. Two wires of same material and radius have their lengths in ratio 1 : 2. If these wires are stretched by the same force, the strain produced in the two wires will be in the ratio

(1) 2 : 1 (2) 1 : 1 (3) 1 : 2 (4) 1 : 4

Sol. Answer (2)

$$\text{Strain} = \frac{\Delta l}{l}$$

We know

$$\Delta l = \frac{FL}{AY}$$

$$\frac{\Delta l}{l} = \frac{F}{AY} = \frac{F}{\pi r^2 Y}$$

For wire 1

$$S_1 = \text{strain} = \frac{\Delta l_1}{L} = \frac{F}{\pi r^2 Y} \quad ...(1)$$

For wire 2

$$S_2 = \text{strain} = \frac{\Delta l_2}{2L} = \frac{F}{\pi r^2 Y} \quad ...(2)$$

Therefore,

$$\text{Ratio of strains } = \frac{S_1}{S_2} = \frac{F\times \pi r^2 Y}{\pi r^2 Y\times F} = \frac{1}{1}$$

1 : 1

8. A steel wire of cross-sectional area 3×10^{-6} m^2 can withstand a maximum strain of 10^{-3}. Young's modulus of steel is 2×10^{11} Nm^{-2}. The maximum mass the wire can hold is (take g = 10 ms^{-2})

(1) 40 kg (2) 60 kg (3) 80 kg (4) 100 kg

Sol. Answer (2)

$$\text{Strain} = \frac{\Delta l}{l} = \frac{F}{AY}$$

$$\left\{\begin{array}{l}\text{Given,}\\ \dfrac{\Delta l}{l} = 10^{-3}\\ A = 3\times 10^{-6}\text{ m}^2\\ Y = 2\times 10^{11}\text{ Nm}^{-2}\end{array}\right.$$

Substituting values

$$10^{-3} = \frac{F}{3\times 10^{-6}\times 2\times 10^{11}}$$

600 N = F

$$\text{Therefore maximum mass } = \frac{F}{g} = \frac{600}{10} = 60\text{ kg}$$

9. The hollow shaft is ...... than a solid shaft of same mass, material and length.

(1) Less stiff (2) More stiff (3) Equally stiff (4) None of these

Sol. Answer (2)

Let C' = restoring couple per unit twist for hollow cylinder

So $C' = \frac{\pi S(r_2^4 - r_1^4)}{2L}$ $\left\{\begin{matrix}\text{Where,} \\ r_2 \text{ and } r_1 \text{ are outer and inner radii}\end{matrix}\right\}$

And

C = restoring couple per unit twist for solid cylinder

$$C = \frac{\pi S r^4}{2L}$$

$$\Rightarrow \frac{C'}{C} = \frac{r_2^4 - r_1^4}{r^4} = \frac{(r_2^2 - r_1^2)(r_2^2 + r_1^2)}{r^4} \qquad \left\{\begin{matrix}\text{If mass of both cylinder same than} \\ \pi r^2 L\rho = \pi(r_2^2 - r_1^2)L\rho \\ \text{or } r^2 = r_2^2 - r_1^2\end{matrix}\right.$$

$\therefore \frac{C'}{C} = \frac{r_2^2 + r_1^2}{r_2^2 - r_1^2} > 1$ Hence hollow cylinder more stronger than solid one.

10. The Bulk modulus for an incompressible liquid is

(1) Zero (2) Unity (3) Infinity (4) Between 0 and 1

Sol. Answer (3)

We know

$$\frac{-\Delta V}{V} = \frac{P}{B}$$

$$B = \frac{-P \cdot V}{\Delta V}$$

For incompressible liquid

ΔV (Change in volume) = 0

For every value of pressure applied

Put $\Delta V = 0$

$\Rightarrow$ $B = \infty$ (Infinity)

11. A copper rod length L and radius r is suspended from the ceilling by one of its ends. What will be elongation of the rod due to its own weight when ρ and Y are the density and Young's modulus of the copper respectively?

(1) $\frac{\rho^2 g L^2}{2Y}$ (2) $\frac{\rho g L^2}{2Y}$ (3) $\frac{\rho^2 g^2 L^2}{2Y}$ (4) $\frac{\rho g L}{2Y}$

Sol. Answer (2)

Let W be the total weight acting downwards

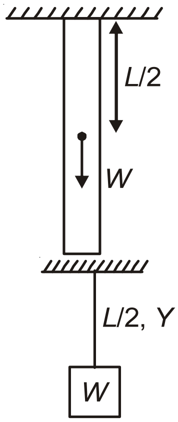
Let the centre of mass

which is at the distance of $\frac{L}{2}$ for the top

So it can be assumed that a mass W is hung by a massless

wire of length $\frac{L}{2}$, Young's modulus Y,

ρ = density of wire, $W = Mg = \rho \times \pi r^2 L \times g$



Using $\Delta L = \frac{FL}{AY} = \frac{\rho \pi r^2 Lg}{\pi r^2} \times \frac{L}{2} \times \frac{1}{Y} = \frac{\rho g L^2}{2Y}$

12. Which of the following substances has the highest elasticity?

(1) Steel (2) Copper (3) Rubber (4) Sponge

Sol. Answer (1)

Substance which requires more force for per unit elongation have more elasticity

OR

Less stretchable means more elastic

So, steel is least stretchable

$\Rightarrow$ Most elastic.

13. When a wire of length 10 m is subjected to a force of 100 N along its length, the lateral strain produced is 0.01×10^{-3} m. The Poisson's ratio was found to be 0.4. If the area of cross-section of wire is 0.025 m^2, its Young's modulus is

(1) 1.6×10^8 Nm^{-2} (2) 2.5×10^{10} Nm^{-2} (3) 1.25×10^{11} Nm^{-2} (4) 16×10^9 Nm^{-2}

Sol. Answer (1)

$$\text{Poisson's ratio} = \frac{\text{Lateral strain}}{\text{Longitudinal strain}}$$

$$\underbrace{\frac{\Delta l}{l}}_{\text{Longitudinal strain}} = \frac{F}{AY}$$

So $\eta = \frac{\text{Lateral strain}}{F / AY}$

$$\left\{ \begin{array}{l} \text{Given,} \\ F = 100 \text{ N} \\ \text{Lateral strain} = 0.01 \times 10^{-3} \text{ m} \\ \eta = 0.4 \\ A = 0.025 \text{ m}^2 \end{array} \right.$$

Therefore

$$Y = \frac{\eta \times F}{\text{Lateral strain} \times A}$$

Substituting values

$$Y = \frac{0.4 \times 100}{0.01 \times 10^{-3} \times 0.025} = 1.6 \times 10^8 \text{ Nm}^{-2}$$

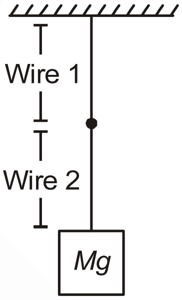
14. Two wires of length l, radius r and length $2l$, radius $2r$ respectively having same Young's modulus are hung with a weight mg. Net elongation is

(1) $\frac{3\,mgl}{\pi r^2 Y}$ (2) $\frac{2\,mgl}{3\pi r^2 Y}$ (3) $\frac{3\,mgl}{2\pi r^2 Y}$ (4) $\frac{3\,mgl}{4\pi r^2 Y}$

Sol. Answer (3)

Tension in both wires will be same

Let elongation in wire 1 be = Δl_1



$$\Delta l_1 = \frac{mgl}{\pi r^2 Y} \qquad \left[\Delta x = \frac{FL}{AY}\right]$$

Let elongation in wire 2 be = Δl^2

$$\Delta l_2 = \frac{mg\times 2l}{\pi(2r^2)Y}$$

Net elongation = $\Delta l_1 + \Delta l_2$

$$= \frac{mgl}{\pi r^2 Y} + \frac{mgl}{2\pi r^2 Y}$$

$$= \frac{3mgl}{2\pi r^2 Y}$$

15. A cube of side 40 mm has its upper face displaced by 0.1 mm by a tangential force of 8 kN. The shearing modulus of cube is

(1) 2×10^9 Nm^{-2} (2) 4×10^9 Nm^{-2} (3) 8×10^9 Nm^{-2} (4) 16×10^9 Nm^{-2}

Sol. Answer (1)

Shear modulus $= \frac{F \cdot h}{A \cdot x}$

Substituting values

$$\left\{\begin{array}{l} \text{Given,} \\ F = 8\text{ kN} = 8000\text{ N} \\ A = 40\times 40 = 1600\times 10^{-6}\text{ m}^2 \\ x = 0.1\,\text{mm} = 0.1\times 10^{-3}\text{ m} \\ h = 40\times 10^{-3}\text{ m} \end{array}\right.$$

$$= \frac{8000\times 40\times 10^{-3}}{1600\times 10^{-6}\times 0.1\times 10^{-3}}$$

$= 2 \times 10^9$ Nm^{-2}

16. A rod of length l and radius r is joined to a rod of length $\frac{l}{2}$ and radius $\frac{r}{2}$ of same material. The free end of small rod is fixed to a rigid base and the free end of larger rod is given a twist of θ°, the twist angle at the joint will be

(1) $\frac{\theta}{4}$ (2) $\frac{\theta}{2}$ (3) $\frac{5\theta}{6}$ (4) $\frac{8\theta}{9}$

Sol. Answer (4)

Torque will be same

⇒ ϕ × Restoring couple per unit twist will be same for both the rods

$$\frac{\pi S r^4}{2L}\times\phi = \tau$$

We can use

$$\frac{\pi S r_1^4}{2L_1}\phi_1 = \frac{\pi S r_2^4}{2L_2}\phi_2$$

$$\left\{\begin{array}{l}\text{given}\\ r_1 = r\\ r_2 = r/2\\ l_l = l\\ l_2 = l/2\end{array}\right.$$

$$\frac{r_1^4}{L_1}\times\phi_1 = \frac{r_2^4}{L_2}\phi_2$$

Substituting values

$$\frac{r^4}{L}\times\phi_1 = \frac{(r/2)^4}{l/2}\times\phi_2$$

$$\phi_1 = \frac{\phi_2}{8}$$

Also $\phi_1 + \phi_2 = \theta$ (given)

$$\frac{\phi_2}{8} + \phi_2 = \theta$$

$$\phi_2 = \frac{8\theta}{9}$$

17. The Young's modulus of the material of a wire is 2×10^{10} Nm^{-2}. If the elongation strain is 1%, then the energy stored in the wire per unit volume is Jm^{-3} is

(1) 10^6 (2) 10^8 (3) 2×10^6 (4) 2×10^8

Sol. Answer (1)

$$U = \frac{1}{2}Y(\text{strain})^2 \qquad \text{(given)}$$

Substituting values $\left(\frac{\Delta l}{l} = \frac{1}{100}\right)$

$$U = \frac{1}{2}\times 2\times 10^{10}\times\left(\frac{1}{100}\right)^2$$

$U = 10^6$

18. A wire is stretched under a force. If the wire suddenly snaps, the temperature of the wire

(1) Remains the same (2) Decreases

(3) Increases (4) First decreases then increases

Sol. Answer (3)

We know

$$\Delta L = \frac{FL}{AY} \quad \text{and} \quad \Delta L = \propto L\Delta\theta$$

$$\left\{\begin{array}{l}\text{Where,}\\ \Delta\theta - \text{Change in temperature}\\ \propto - \text{Coefficeince of linear expansion}\\ \Delta L - \text{Elongation}\\ L - \text{Original length}\end{array}\right.$$

Equating both

$$\frac{FL}{AY} = \propto L\Delta\theta \Rightarrow F \propto \Delta\theta$$

So whenever stretching is there $\Delta\theta$ will be (+)ive hence temperature will increase.

19. A wire of natural length *l*, Young's modulus *Y* and area of cross-section *A* is extended by *x*. Then the energy stored in the wires is given by

(1) $\frac{1}{2}\frac{YA}{l}x^2$ (2) $\frac{1}{3}\frac{YA}{l}x^2$ (3) $\frac{1}{2}\frac{Yl}{A}x^2$ (4) $\frac{1}{2}\frac{YA}{l^2}x^2$

Sol. Answer (1)

Energy density per unit volume $= \frac{1}{2} \times (\text{strain})^2 \times Y$

Volume = length × area of cross-section

$\therefore$ Energy (total) $= \frac{1}{2} \times (\text{strain})^2 \times Y \times L \times A$

$$\left\{\begin{array}{l}\text{Where,}\\ \text{Strain} = \dfrac{x}{l}\\ Y = \text{Young's modulus}\end{array}\right.$$

$$= \frac{1}{2}\frac{x^2}{L^2} Y L A$$

$$E = \frac{1}{2}\frac{YA}{L}x^2$$

20. When a force is applied on a wire of uniform cross-sectional area 3×10^{-6} m^2 and length 4 m, the increase in length is 1 mm. Energy stored in it will be ($Y = 2 \times 10^{11}$ N/m^2)

(1) 6250 J (2) 0.177 J (3) 0.075 J (4) 0.150 J

Sol. Answer (3)

Energy stored $= \frac{1}{2}$ × work done

$$= \frac{1}{2} \times F \times \Delta x$$

$$= \frac{1}{2} \times \frac{YA}{L} \Delta x \cdot \Delta x \qquad \left[F = \frac{YA\Delta x}{L}\right]$$

Substituting values

$$E = \frac{1}{2} \times \frac{2 \times 10^{11} \times 3 \times 10^{-6} \times 1 \times 10^{-3} \times 10^{-3}}{4}$$

$E = 0.075$ J

21. If in a wire of Young's modulus *Y*, longitudinal strain *X* is produced then the potential energy stored in its unit volume will be

(1) 0.5 YX^2 (2) 0.5 Y^2X (3) 2 YX^2 (4) YX^2

Sol. Answer (1)

Potential energy per unit volume $= \frac{1}{2} \times (\text{strain})^2 \times \text{Young's modulus}$

Substituting data from question

We get

$$U = \frac{1}{2}X^2Y$$

22. A uniform metal rod of 2 mm^2 cross-section is heated from 0°C to 20°C. The coefficient of the linear expansion of the rod is 12×10^{-6}/°C. Its Young's modulus of elasticity is 10^{11} Nm^{-2}. The energy stored per unit volume of the rod is

(1) 1440 Jm^{-3} (2) 15750 Jm^{-3} (3) 1500 Jm^{-3} (4) 2880 Jm^{-3}

Sol. Answer (4)

We know

$$\Delta L = \alpha\, L\Delta\theta$$

$$\Rightarrow \quad \frac{\Delta L}{L} = \alpha\,\Delta\theta$$

Also $\frac{\Delta L}{L} = \text{strain}$

$\Rightarrow$ Strain $= \alpha\Delta\theta$ ...(i)

Energy stored per unit volume $= \frac{1}{2}(\text{strain})^2 Y$

$$= \frac{1}{2} \times \alpha^2 \Delta\theta^2 \times Y \quad \text{[Using eqn. (i)]}$$

Substituting values $= \frac{1}{2} \times (12 \times 10^{-6})^2 \times (20)^2 \times 10^{11}$

$= 2880$ Jm^{-3}

23. A material has Poisson's ratio 0.50. If a uniform rod of it suffers a longitudinal strain of 2×10^{-3}, then the percentage change in volume is

(1) 0.6 (2) 0.4 (3) 0.2 (4) Zero

Sol. Answer (4)

Poisson's ratio = 0.50

$$\frac{-\text{Lateral strain}}{\text{Longitudinal strain}} = 0.50$$

$$\Rightarrow \quad \frac{-\Delta r / r}{\Delta L / L} = \frac{1}{2}$$

$$\frac{-2\Delta r}{r} = \frac{\Delta L}{L} \quad ...(1)$$

Volume = area × length

$$\Rightarrow \quad \frac{\Delta V}{V} = \frac{\Delta A}{A} + \frac{\Delta L}{L}$$

$$\frac{\Delta V}{V} = \frac{2\Delta r}{r} + \frac{\Delta L}{L} \qquad \begin{bmatrix} A \propto r^2 \\ \dfrac{\Delta A}{A} = \dfrac{2\Delta r}{r} \end{bmatrix}$$

Using equation (1)

We get

$$\frac{\Delta V}{V} = 0$$

So $\frac{\Delta V}{V} \times 100 = 0\%$

24. There is no change in the volume of a wire due to the change in its length on stretching. The Poisson's ratio of the material of the wire is

(1) $+\frac{1}{2}$ (2) $-\frac{1}{2}$ (3) $+\frac{1}{4}$ (4) $-\frac{1}{4}$

Sol. Answer (1)

$V = A \times L$

$V = \pi r^2 L$

$$\frac{\Delta V}{V} = \frac{2\Delta r}{r} + \frac{\Delta L}{L}$$

$$\frac{\Delta V}{V} = 0 \qquad \text{[given]}$$

$$\frac{-2\Delta r}{r} = \frac{\Delta L}{L} \qquad ...(1)$$

Poisson's ratio $= \frac{-\Delta r}{r} \Big/ \frac{\Delta L}{L}$ ...(2)

Using equation (1) in (2)

$$\sigma = \frac{-\Delta r}{r} \Big/ 2\left(\frac{-\Delta r}{r}\right)$$

$$\sigma = \frac{1}{2}$$

25. If Young's modulus of elasticity Y for a material is one and half times its rigidity coefficient η, the Poisson's ratio σ will be

(1) $+\frac{2}{3}$ (2) $-\frac{1}{4}$ (3) $+\frac{1}{4}$ (4) $-\frac{2}{3}$

Sol. Answer (2)

$Y = \frac{3}{2}\eta$ [given]

$\sigma = ?$

And we know

$Y = 2\eta(1 + \sigma)$

$$\frac{3\eta}{2} = 2\eta(1+\sigma)$$

Solving we get

$$\sigma = -\frac{1}{4}$$

SECTION - D

Assertion - Reason Type Questions

1. A : Hooke's law is obeyed only for small values of strain.

R : The deformation beyond elastic limit is called plasticity.

Sol. Answer (2)

Statement (A) is true

Statement (R) is also true

But (R) is not the correct explaination of (A)

Because correct reason is Hooke's law is obeyed in elastic limit only.

2. A : Strain is a dimensionless quantity.

R : Strain is internal force per unit area of a body.

Sol. Answer (3)

(A) Is true

Strain = $\frac{\Delta L}{L}$

(R) Is false because strain is change in dimension by original dimension.

3. A : Diamond is more elastic than rubber.

R : When same deforming force is applied diamond deforms less than rubber.

Sol. Answer (1)

(A) Is true because modulus of elasticity is more for diamond so less deformation in diamond than rubber when same deforming force applied

(R) Is true and correct explanation.

4. A : Bulk modulus for a perfectly plastic body is zero.

R : For perfect plastic material, there is no restoring force.

Sol. Answer (1)

(A) Is true because a perfectly plastic body cannot regain its shape even when the deforming forces are removed because restoring forces are absent

(R) Is true and correct explanation for (A)

5. A : The railway bridges are declared unfit after their use for a long period.

R : Due to repeated strain the elasticity of material decreases.

Sol. Answer (1)

(A) Is true because after a long use the material weakens and shows dangerous deformation when load is applied because its elasticity has decreased gradually over the time.

(R) Is true and correct explanation for (A)

6. A : Spring balances show wrong readings after they have been used for a long time.

R : Spring in spring balance temporary losses elasticity due to repeated alternating deforming force.

Sol. Answer (1)

(A) Is true because after a long use elasticity decreases and small temporary deformation remains these which in turn tend to be the reason of wrong readings.

(R) Is true and correct explanation for (A)

7. A : Modulus of elasticity is independent of dimensions of the body.

R : Modulus of elasticity depends on the material of the body.

Sol. Answer (2)

(A) True because modulus of elasticity is a material property

(R) True

But (R) is not the correct explanation because no where it reasons why modulus of elasticity is independent of dimensions of the body.

8. A : Adiabatic elasticity of a gas is greater than isothermal elasticity.

R : $\frac{E_{\text{adiabatic}}}{E_{\text{isothermal}}} = \gamma$.

Sol. Answer (1)

(A) True

Because $\frac{E_{\text{adiabatic}}}{E_{\text{isothermal}}} = \gamma$ and γ always greater than 1

So $E_{\text{adiabatic}}$ is always greater than $E_{\text{isothermal}}$

(R) True and also correct explanation.

9. A : When a beam is bent only tensile strain is produced.

R : The depression produced in a rectangular beam is directly proportional to its width.

Sol. Answer (4)

(A) Is false because strain is there so stress will also be present

$\because$ Stress $\propto$ strain

(R) False depression $\propto \dfrac{1}{\text{width}}$

10. A : To minimise the depression in a beam, it is designed as 'I' shape girder.

R : The 'I' shape girders have large load bearing surface, which decreases the stress.

Sol. Answer (1)

(A) Is true because having more surface area means less force per unit area i.e. less stress

(R) Is true and correct explanation of (A)

11. A : Iron is more elastic than copper.

R : Under a given deforming force, Iron is deformed less than copper.

Sol. Answer (1)

(A) Is true because less deformation under a similar deforming force means more elasticity

(R) Is true and correct explanation of (A)

12. A : Lateral strain is directly proportional to the longitudinal strain within the elastic limit.

R : Poisson's ratio for a given material at a constant temperature is constant.

Sol. Answer (1)

(A) Is true because,

$$\frac{\text{Lateral strain}}{\text{Longitudinal strain}} = \sigma$$

$\Rightarrow$ Lateral strain $\propto$ longitudinal strain

As σ is constant

(R) Is true and correct explanation of (A)

13. A : Equal amount of work is done when two identical springs of steel and copper are equally stretched.

R : Both springs have same spring constant.

Sol. Answer (4)

(A) Is wrong because amount of work done is not same because the spring constants are different.

(R) Is wrong.

14. A : Increase in temperature of a substance decreases the modulus of elasticity.

R : The graph between potential energy of molecules and separation between them is asymmetric.

Sol. Answer (1)

(A) Is true because when we increase the temperature the average distance between the molecules tend to increase hence decreasing the modulus of elasticity.

(R) Is true and correct explanation.

15. A : It is the breaking stress and not the breaking strength which depends on the material.

R : Breaking strength = $\frac{\text{Breaking stress}}{\text{Area}}$.

Sol. Answer (4)

(A) Is wrong both depend on the material because breaking strength is maximum stress a body can take

(R) Is wrong

Breaking strength = breaking stress × area

❑ ❑ ❑

Chapter 10

Mechanical Properties of Fluids

Solutions

SECTION - A

Objective Type Questions

1. The term ‘fluid’ is used for

(1) Liquids only
(2) Gases only
(3) A mixture of liquid and gas only
(4) Both liquids and gases

Sol. Answer (4)

Substances that can flow is called fluid. Thus both liquids and gases are fluids.

2. Select wrong statement about pressure

(1) Pressure is a scalar quantity
(2) Pressure is always compressive in nature
(3) Pressure at a point is same in all directions
(4) None of these

Sol. Answer (4)

Pressure is scalar as it is not added vectorially. Pressure is compressive in nature, it is same in all the directions at a point.

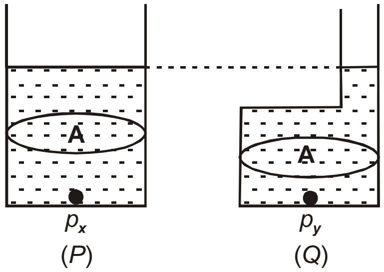
3. Gauge pressure

(1) May be positive
(2) May be negative
(3) May be zero
(4) All of these

Sol. Answer (4)

Gauge pressure depends on the reference chosen, it can be positive, negative or zero.

4. Figure shows two containers P and Q with same base area A and each filled upto same height with same liquid. Select the correct alternative



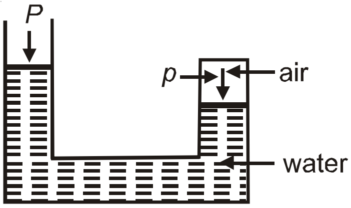
(1) $p_x = p_y$
(2) $p_x > p_y$
(3) $p_y > p_x$
(4) Cannot say

Sol. Answer (1)

The level of water above both points is same so by hydrostatic paradox.

$p_x = p_y$

5. The pressure of confined air is p. If the atmospheric pressure is P, then



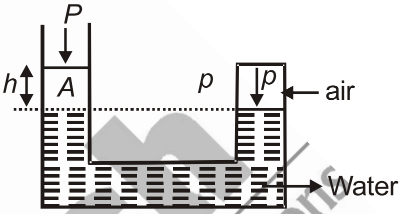
(1) P is equal to p

(2) P is less than p

(3) P is greater than p

(4) P may be less or greater than p depending on the mass of the confined air

Sol. Answer (2)



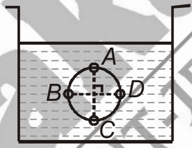
Pressure at point $A = P$ (Hydrostatic paradox)

and $P + \rho_w gh$ = pressure at $A = p$

$\Rightarrow$ $P = p - \rho_w gh$

So, $P < p$

6. Figure shows a container filled with a liquid of density ρ. Four points A, B, C and D lie on the diametrically opposite points of a circle as shown. Points A and C lie on vertical line and points B and D lie on horizontal line. The incorrect statement is (p_A, p_B, p_C, p_D are absolute pressure at the respective points)



(1) $p_D = p_B$

(2) $p_A < p_B = p_D < p_C$

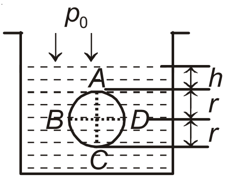
(3) $p_D = p_B = \dfrac{p_C - p_A}{2}$

(4) $p_D = p_B = \dfrac{p_C + p_A}{2}$

Sol. Answer (3)

Points at same height have same pressure, points with height difference say 'h' will have difference of ρgh.

Let radius of circle is r



$p_A = p_0 + h\rho g$

$p_B = p_D = p_0 + (h + r)\rho g$

$p_C = p_0 + (h + 2r)\rho g$

Then,

$p_C + p_A = [p_0 + (h + 2r)\rho g] - [p_0 + h\rho g]$

$= p_0 + h\rho g + 2r\rho g + p_0 + h\rho g$

$= 2[p_0 + (h + r)\rho g]$

$$\frac{p_C + p_A}{2} = p_0 + (h + r)\rho g$$

$$\frac{p_C + p_A}{2} = p_B = p_D$$

i.e., option (1), (2) and (4) gives correct statement but incorrect statement is (3)

7. The volume of an air bubble is doubled as it rises from the bottom of lake to its surface. The atmospheric pressure is 75 cm of mercury. The ratio of density of mercury to that of lake water is $\frac{40}{3}$. The depth of the lake in metre is

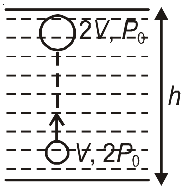
(1) 10 (2) 15 (3) 20 (4) 25

Sol. Answer (1)

$2P_0 = P_0 + \rho gh$

$\Rightarrow P_0 = \rho gh$

$\Rightarrow P_0 = 75$ cm mercury [Atmospheric pressure]



$$\Rightarrow \rho_{\text{mercury}} \times g \times \frac{75}{100} = \rho_{\text{water}} \times g \times h$$

$$\Rightarrow \frac{\rho_m}{\rho_w} \times \frac{75}{100} = h$$

$$\Rightarrow \frac{40}{3} \times \frac{75}{100} = h \qquad \left[\because \frac{\rho_m}{\rho_w} = \frac{40}{3} \text{ (given)}\right]$$

$\Rightarrow h = 10$ m

8. A beaker containing a liquid of density ρ moves up with an acceleration 'a'. The pressure due to the liquid at a depth h below free surface of the liquid is

(1) $h\rho g$ (2) $h\rho (g - a)$

(3) $h\rho (g + a)$ (4) $2h\rho g \left(\frac{g+a}{g-a}\right)$

Sol. Answer (3)

Due to upward acceleration pseudo force will act downwards so value of acceleration due to gravity will increase by 'a'

$\therefore g' = (g + a)$

$P = \rho g' h$

$\Rightarrow P = \rho (g + a)h$ (Substitute g')

9. A barometer kept in an elevator reads 76 cm when it is at rest. If the elevator goes up with some acceleration, the reading will be

(1) 76 cm (2) > 76 cm (3) < 76 cm (4) Zero

Sol. Answer (3)

When elevator goes up with some acceleration upward, due to pseudo force acting downwards. Value of g increases to g'.

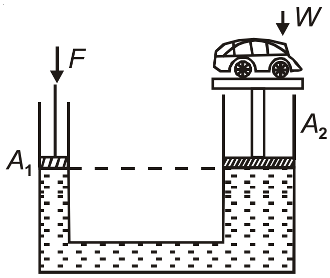
If g increases to g', *i.e.*, $g' = g + a$

$\because P = \rho gh = \rho(9 + a)h' =$ constant

Then, $h' < h$

i.e., $h' < 76$ cm

10. In a hydraulic jack as shown, mass of the car $W = 800$ kg, $A_1 = 10\text{ cm}^2$, $A_2 = 10\text{ m}^2$. The minimum force F required to lift the car is



(1) 1 N (2) 0.8 N (3) 8 N (4) 16 N

Sol. Answer (2)

Pressure in a liquid is divided equally so we can say pressure at both the pistons should be same

$$\Rightarrow \frac{F_1}{A_1} = \frac{F_2}{A_2} \qquad \left\{ \begin{array}{l} \text{Where,} \\ F_1 = F \\ A_1 = 10\text{ cm}^2 \\ A_2 = 10\text{ m}^2 = 10 \times 10^4\text{ cm}^2 \\ F_2 = 8000\text{ N} \end{array} \right.$$

Substituting values,

$$\frac{F}{10} = \frac{8000}{10 \times 10^4}$$

$$\Rightarrow F = 0.8\text{ N} \qquad \left\{ \begin{array}{l} \text{Take} \\ g = 10\text{ m/s}^2 \end{array} \right\}$$

11. A wooden cube just floats inside water with a 200 gm mass placed on it. When the mass is removed, the cube floats with its top surface 2 cm above the water level. What is the side of the cube ?

(1) 6 cm (2) 8 cm (3) 10 cm (4) 12 cm

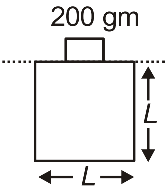
Sol. Answer (3)

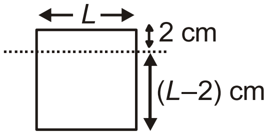
Mass × g = Volume of part of cube × ρ × g

$\Rightarrow 200 \times g = L^2 (2 \times \rho_w \times g)$

$\Rightarrow 100 = L^2 \qquad \{\because \rho_w = 1\}$

$\Rightarrow 10\text{ cm} = L$





From the two figures we can see that the 200 gm block is provided with required buoyant force but a part of cube which is afloat in 2nd figure.

12. A block of steel of size 5 × 5 × 5 cm^3 is weighed in water. If relative density of steel is 7, its apparent weight is

(1) 6 × 5 × 5 × 5 g wt (2) 4 × 4 × 4 × 7 g wt

(3) 5 × 5 × 5 × 7 g wt (4) 4 × 4 × 4 × 6 g wt

Sol. Answer (1)

$$\text{Apparent weight} = \rho_s v_b g - \rho_w v_b g \qquad \left\{ \begin{array}{l} \text{Where,} \\ \rho_s - \text{density of steel} \\ \rho_w - \text{density of water} \\ v_b - \text{volume of block} \\ \quad (\text{side} \times \text{side} \times \text{side}) \end{array} \right.$$

$$= v_b g (\rho_s - \rho_w)$$

$$= 5 \times 5 \times 5 \times g \times (7 - 1) \qquad \left[\begin{array}{l} \rho_w = 1 \\ \rho_s = 7 \ \ (\text{given}) \end{array} \right.$$

$$= 6 \times 5 \times 5 \times 5 \times g\text{ wt}$$

13. A block of wood floats in water with $\frac{4}{5}$th of its volume submerged, but it just floats in another liquid. The density of liquid is (in kg/m^3)

(1) 750 (2) 800 (3) 1000 (4) 1250

Sol. Answer (2)

$$\frac{4}{5} v_b \times \rho_w \times g = v_b \times \rho_b \times g \qquad \begin{cases} \text{Where,} \\ v_b = \text{volume of block} \\ \rho_w = \text{density of water} = 1000 \text{ kg/m}^3 \\ \rho_b = \text{density of block} \end{cases}$$

$$\Rightarrow \frac{\rho_w}{\rho_b} = \frac{5}{4}$$

$$\rho_b = \frac{4}{5} \times 1000 = 800 \text{ kg/m}^3$$

And when block is put in liquid of density ρ_l it just floats

So, $v_b \times \rho_b \times g = v_b \times \rho_l \times g$

$\Rightarrow \rho_b = \rho_l$

So, $\rho_l = 800$ kg/m^3

14. A cubical block is floating in a liquid with one fourth of its volume immersed in the liquid. If whole of the system accelerates upward with acceleration $g/4$, the fraction of volume immersed in the liquid will be

(1) 1/4 (2) 1/2 (3) 3/4 (4) 2/3

Sol. Answer (1)

Upward acceleration just causes the acceleration due to gravity increases by some value, but since the term of 'g' gets cancelled out in the buoyancy equation.

Volume immersed × $\rho_w \times g$ = Total volume × $\rho_{cube} \times g$

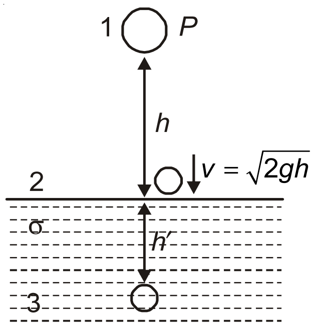
So, increasing it will not have any effect on the immersed volume.

15. A body of density ρ is dropped from rest from a height h into a lake of density σ, where $\sigma > \rho$. Neglecting all dissipative forces, the maximum depth to which the body sinks before returning to float on surface

(1) $\frac{h}{\sigma - \rho}$ (2) $\frac{h\rho}{\sigma}$ (3) $\frac{h\rho}{\sigma - \rho}$ (4) $\frac{h\sigma}{\sigma - \rho}$

Sol. Answer (3)

Between point 2 and 3



$$P_0 + \rho g h' + \frac{1}{2}\rho v^2 = \sigma g h' + P_0 \qquad [P_0 = \text{atmospheric pressure}]$$

$$\Rightarrow \rho g h' + \rho g h = \sigma g h' \qquad \left[\because v = \sqrt{2gh}\right]$$

So, $h' = \frac{h\rho}{\sigma - \rho}$

16. A boat carrying a number of stones is floating in a water tank. If the stones are unloaded into water, the water level in the tank will

(1) Remain unchanged

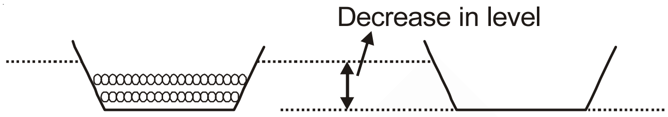
(2) Rise

(3) Fall

(4) Rise or fall depends on the number of stones unloaded

Sol. Answer (3)

Previously when stones are on the boat they are increasing the weight on the boat and to balance this weight boat needs to generate buoyancy force by displacing more water, but when stones are removed the boat starts displacing less amount of water hence the level of water in tank falls.



17. A block of ice is floating in a liquid of specific gravity 1.2 contained in a beaker. When the ice melts completely, the level of liquid in the vessel

(1) Increases (2) Decreases

(3) Remain unchanged (4) First increases then decreases

Sol. Answer (1)

Density of ice is less than water and density of liquid is more than water. So even when ice melts the level will rise.

If $\rho_{\text{liquid}} > \rho_{\text{water}}$ then level (liquid + water) will rise.

18. Two liquids having densities d_1 and d_2 are mixed in such a way that both have same mass. The density of the mixture is

(1) $\dfrac{d_1+d_2}{2}$ (2) $\dfrac{d_1+d_2}{d_1d_2}$ (3) $\dfrac{d_1d_2}{d_1+d_2}$ (4) $\dfrac{2d_1d_2}{d_1+d_2}$

Sol. Answer (4)

Let each have mass = M and densities d_1 and d_2

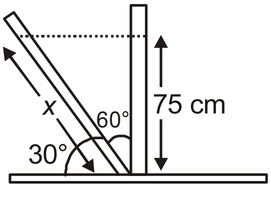
$$d_{\text{mix}} = \frac{M_{\text{mix}}}{V_{\text{mix}}} = \frac{M+M}{\left(\dfrac{M}{d_1}\right)+\left(\dfrac{M}{d_2}\right)} = \frac{2d_1d_2}{d_1+d_2}$$

19. A barometer tube reads 75 cm of Hg. If tube is gradually inclined at an angle of 30° with horizontal, keeping the open end in the mercury container, then find the length of mercury column in the barometer tube

(1) 86.7 cm (2) 150 cm (3) 75 cm (4) 92.5 cm

Sol. Answer (2)

∵ We are not changing the atmospheric pressure, so height of Hg from the surface should not change.



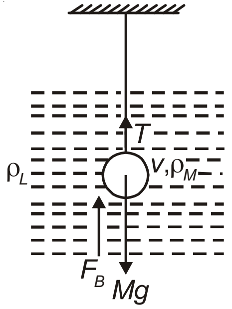
$$\frac{75}{x} = \cos 60^\circ$$

$\Rightarrow$ $x = 150$ cm

20. A metallic sphere weighing 3 kg in air is held by a string so as to be completely immersed in a liquid of relative density 0.8. The relative density of metallic is 10. The tension in the string is

(1) 18.7 N (2) 42.5 N (3) 32.7 N (4) 27.6 N

Sol. Answer (4)



$$\begin{cases} \text{Where,} \\ F_B - \text{Force of Buoyancy} \\ \rho_L - \text{Density of liquid} \\ \rho_M - \text{Density of metal} \\ M - \text{Mass of sphere} \\ T - \text{Tension in string} \end{cases}$$

$T = Mg$ – Buoyant Force

$\Rightarrow \quad T = \rho_M Vg - \rho_L Vg \qquad \left(\rho_M = \dfrac{M}{V}\right)$

$= (\rho_M - \rho_L)\, Vg$

$= (10 - 0.8) \times \dfrac{3}{10} \times 10$

$\Rightarrow \quad T = 9.2 \times 3 = 27.6$ N

21. A rectangular block is 10 cm × 10 cm × 15 cm in size is floating in water with 10 cm side vertical. If it floats with 15 cm side vertical, then the level of water will

(1) Rise (2) Fall

(3) Remain same (4) Change according to density of block

Sol. Answer (3)

Mass of block remains same, volume displaced of water will also remain same so level of water will not change.

22. Two cubical blocks identical in dimensions float in water in such a way that 1st block floats with half part immersed in water and second block floats with 3/4 of its volume inside the water. The ratio of densities of blocks is

(1) 2 : 3 (2) 3 : 4 (3) 1 : 3 (4) 1 : 4

Sol. Answer (1)

$\dfrac{3}{4} V \times \rho_2 \times g = \dfrac{1}{2} V \times \rho_1 \times g$

$\Rightarrow \quad \dfrac{\rho_2}{\rho_1} = \dfrac{2}{3}$

$$\begin{cases} \text{Where,} \\ V = \text{Volume of block} \\ \rho_1 = \text{density of liquid 1} \\ \rho_2 = \text{density of liquid 2} \end{cases}$$

23. On putting a capillary tube in a pot filled with water, the level of water rises upto a height of 4 cm in the tube. If a tube of half the diameter is used instead, the water will rise to a height of nearly

(1) 2 cm (2) 4 cm (3) 8 cm (4) 11 cm

Sol. Answer (3)

For capillary tube

$h = \dfrac{2T}{r\rho g}$

We can say

$$h \propto \frac{1}{r} \text{ or } h \propto \frac{1}{d}$$

So, $\frac{h_1}{h_2} = \frac{d_2}{d_1}$

$\Rightarrow \frac{4}{x} = \frac{d}{2d}$

$\Rightarrow x = 8$ cm

24. A flat plate of area 0.1 m^2 is placed on a flat surface and is separated from it by a film of oil 10^{-5} m thick whose coefficient of viscosity is 1.5 N sm^{-2}. The force required to cause the plate to slide on the surface at constant speed of 1 mm s^{-1} is

(1) 10 N (2) 15 N (3) 20 N (4) 25 N

Sol. Answer (2)

$$F = \eta A \frac{v}{l}$$

Substituting values,

$$= 1.5 \times 0.1 \times \frac{1 \times 10^{-3}}{10^{-5}}$$

= 15 N

25. A ball of density σ and radius *r* is dropped on the surface of a liquid of density ρ from certain height. If speed of ball does not change even on entering in liquid and viscosity of liquid is η, then the height from which ball dropped is

(1) $2g\left[\frac{(\sigma-\rho)r}{9\eta}\right]^2$ (2) $\frac{2g(\sigma-\rho)^2 r^2}{9\eta}$ (3) $\frac{2(\sigma-\rho)gr^2}{9\eta}$ (4) $2g\left[\frac{(\sigma-\rho)r^2}{9\eta}\right]^2$

Sol. Answer (4)

The ball has already reached the magnitude of velocity which is equal to its terminal velocity in fluid.

$v = \sqrt{2gh}$ {Velocity of body fallen form height $h = \sqrt{2gh}$ }

$$v_{\text{Terminal}} = \frac{2r^2}{9\eta}(\sigma-\rho)g$$

Equating both

$$\sqrt{2gh} = \frac{2r^2}{9\eta}(\sigma-\rho)g$$

$$\Rightarrow \quad h = 2g\left[\frac{(\sigma-\rho)r^2}{9\eta}\right]^2$$

26. Viscous drag force depends on

(1) Size of body
(2) Velocity with which it moves
(3) Viscosity of fluid
(4) All of these

Sol. Answer (4)

$$F = \eta A \frac{V}{d}$$

$$\begin{cases} \text{Where,} \\ F = \text{Drag Force} \\ \eta = \text{Viscosity of fluids} \\ A = \text{Area} \propto \text{size of body} \\ V = \text{Velocity} \end{cases}$$

27. The terminal velocity of a small sized spherical body of radius *r* falling vertically in a viscous liquid is given by the proportionality

(1) $v \propto \frac{1}{r^2}$
(2) $v \propto r^2$
(3) $v \propto \frac{1}{r}$
(4) $v \propto r$

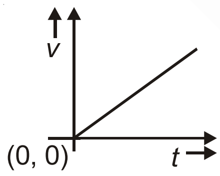
Sol. Answer (2)

$$v_T = \frac{2r^2}{9\eta}[\sigma - \rho]g$$

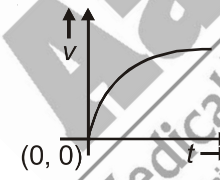
So, $v_T \propto r^2$

28. A spherical ball is dropped in a long column of viscous liquid. The speed *v* of the ball varies as function of time as

(1)



(2)



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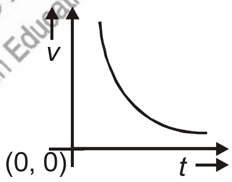

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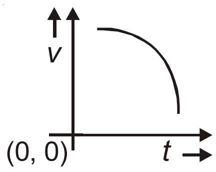
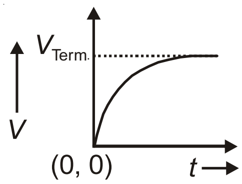


Sol. Answer (2)



Velocity does not increases after terminal speed is achieved.

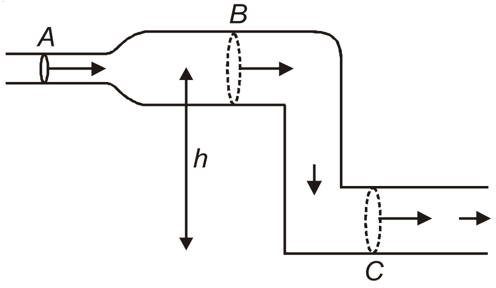
29. Which of the following is not the property of an ideal fluid?

(1) Fluid flow is irrotational
(2) Fluid flow is streamline
(3) Fluid is incompressible
(4) Fluid is viscous

Sol. Answer (4)

An ideal fluid is not viscous.

30. Water is flowing through a channel (lying in a vertical plane) as shown in the figure. Three sections *A*, *B* and *C* are shown. Sections *B* and *C* have equal area of cross section. If P_A, P_B and P_C are the pressures at *A*, *B* and *C* respectively then



(1) $P_A > P_B = P_C$ (2) $P_A < P_B < P_C$

(3) $P_A < P_B = P_C$ (4) $P_A > P_B > P_C$

Sol. Answer (2)

Solution by using Bernoulli's principle and equation of continuity

Comparing points *A* and *B*

$A_A v_A = A_B v_B$ {equation of continuity}

$\because\ A_A < A_B$

$v_A > v_B$

$$P_A + \frac{1}{2}\rho V_A^2 + \rho g h = P_B + \frac{1}{2}\rho V_B^2 + \rho g h \qquad \text{\{Bernoulli's equation\}}$$

$\because\ v_A > v_B$

$$\Rightarrow\ \frac{1}{2}\rho V_A^2 > \frac{1}{2}\rho V_B^2$$

$\therefore\ P_A < P_B$ ...(1)

Now comparing *C* and *B*

$A_B = A_C \Rightarrow v_B = v_C$ [equation of continuity]

$$P_B + \frac{1}{2}\rho V^2 + \rho g h_B = P_C + \frac{1}{2}\rho V^2 + \rho g h_C$$

$\Rightarrow\ P_B + \rho g h_B = P_C + \rho g h_C$

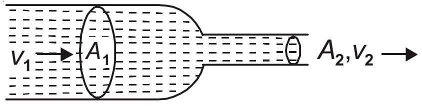
$\because\ h_B > h_C$ then ...(2)

$P_B < P_C$

Using (1) and (2)

We can say, $P_A < P_B < P_C$

31. A liquid flows in the tube from left to right as shown in figure. A_1 and A_2 are the cross-sections of the portions of the tube as shown. The ratio of speed $\frac{v_1}{v_2}$ will be



(1) $\frac{A_1}{A_2}$ (2) $\frac{A_2}{A_1}$ (3) $\sqrt{\frac{A_2}{A_1}}$ (4) $\sqrt{\frac{A_1}{A_2}}$

Sol. Answer (2)

By equation of continuity

$$v_1A_1 = v_2A_2$$

So, $\frac{v_1}{v_2} = \frac{A_2}{A_1}$

32. Water (ρ = 1000 kg/m^3) and kerosene (σ = 800kg/m^3) are filled in two identical cylindrical vessels. Both vessels have small holes at their bottom. The speed of the water and kerosene coming out of their holes are v_1 and v_2 respectively. Select the correct alternative

(1) $v_1 = v_2$ (2) $v_1 = 0.8\, v_2$ (3) $0.8\, v_1 = v_2$ (4) $v_1 = \sqrt{0.8}\, v_2$

Sol. Answer (1)

Velocity of efflux for small holes $= \sqrt{2gh}$

Which clearly is independent of 'ρ' (density)

So, $v_1 = v_2$

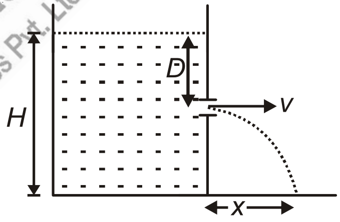
33. A tank is filled with water to a height H. A hole is made in one of the walls at a depth D below the water surface. The distance x from the foot of the wall at which the stream of water coming out of the tank strikes the ground is given by

(1) $x = 2\,[D\,(H - D)]^{1/2}$ (2) $x = 2\,(gD)^{1/2}$ (3) $x = 2\,[D\,(H + D)]^{1/2}$ (4) None of these

Sol. Answer (1)

Velocity of efflux $= \sqrt{2gD} = v$

Say time taken by water to travel the vertical distance of $(H - D)$ = 't'



Using $s = ut + \frac{1}{2}at^2$ $\left\{\begin{aligned} &\text{Where,}\\ &s = H - D\\ &u = 0\\ &a = g \end{aligned}\right.$

We get,

$$'t' = \sqrt{\frac{2(H-D)}{g}}$$

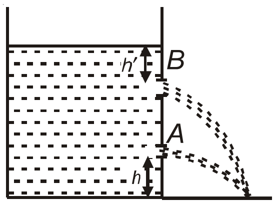
Now, $x = v \times t$

Substituting the values

$$x = \sqrt{2gD} \times \sqrt{\frac{2(H-D)}{g}}$$

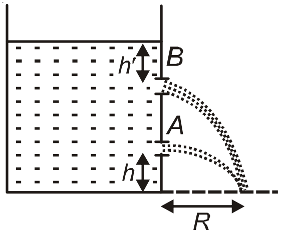
$\Rightarrow$ $x = 2[D\,(H - D)]^{1/2}$

34. A tank is filled with water and two holes A and B are made in it. For getting same range, ratio of h'/h is



(1) 2 (2) $\frac{1}{2}$ (3) $\frac{1}{3}$ (4) 1

Sol. Answer (4)



For hole '*A*'

Velocity of efflux $= \sqrt{2g(x+h')}$

$R = 2[(x + h')h]^{1/2}$ ...(1)

For hole '*B*'

Velocity of efflux $= \sqrt{2gh'}$

$R = 2[h'(x + h)]^{1/2}$ ...(2)

Equating (1) and (2)

We get

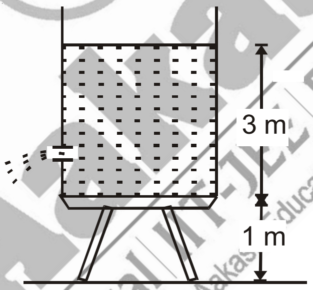
$2[(x + h')h]^{1/2} = 2[h'(x + h)]^{1/2}$

$\Rightarrow (x + h')h = h'(x + h)$

$\Rightarrow h = h'$

$\Rightarrow \frac{h'}{h} = 1$

35. Water is filled in a tank upto 3 m height. The base of the tank is at height 1 m above the ground. What should be the height of a hole made in it, so that water can be sprayed upto maximum horizontal distance on ground?



(1) 3 m from ground

(2) 1.5 m from ground

(3) 1.5 m from base of tank

(4) 2 m from ground

Sol. Answer (4)

Let height of hole from the base of container be *h*

Velocity of efflux $= \sqrt{2g(3-h)}$

$R = 2[(h + 1)(3 - h)]^{1/2}$ [R = Range proved in Q. 33]

$\Rightarrow R = 2(-h^2 + 2h + 3)^{1/2}$

$$\frac{dR}{dh} = -2h + 2$$

If $\frac{dR}{dh} = 0,$ then range would be more for corresponding height

So, $0 = -2h + 2 \quad \Rightarrow \quad h = 1$

$\therefore$ Height from the ground = 1 + 1 = 2 m

36. Soap helps in cleaning clothes, because
    (1) It attracts the dirt particles
    (2) It decreases the surface tension of water
    (3) It increases the cohesive force between water molecules
    (4) It increases the angle of contact

Sol. Answer (2)

Soap helps cleaning clothes because, it decreases the surface tension of water thus water molecules penetrate easily into dirt and oil.

37. On increasing temperature of a liquid, its surface tension generally
    (1) Increases (2) Decreases
    (3) Remains constant (4) First increases and then decreases

Sol. Answer (2)

On increasing the temperature energy increases hence surface tension decreases. Because surface tension is nothing but some extra energy required by surface molecules to stay at the place.

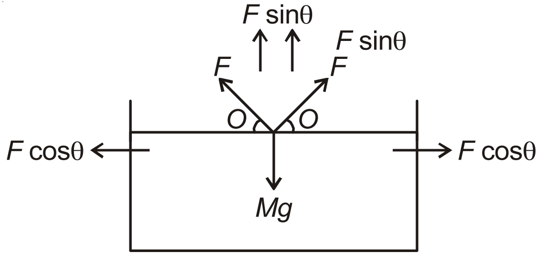
38. The raincoats are made water proof by coating it with a material, which
    (1) Absorb water (2) Increase surface tension of water
    (3) Increase the angle of contact (4) Decreases the density of water

Sol. Answer (3)

Raincoats are coated with material which increase the angle of contact, so water does not penetrates inside the layer.

39. An iron needle slowly placed on the surface of water floats because
    (1) It displaces water more than its weight
    (2) The density of material of needle is less than that of water
    (3) Of surface tension
    (4) Of its shape

Sol. Answer (3)



Needle floats due to surface tension of water which balances the weight of needle.

In equilibrium $2F\sin\theta = mg$

40. Two water droplets merge with each other to form a larger droplet. In this process

(1) Energy is liberated (2) Energy is absorbed

(3) Energy is neither liberated nor absorbed (4) Some mass is converted into energy

Sol. Answer (1)

Work is done when we break a drop into 'n' drops equal to $4\pi R^2\sigma(n^{1/3} - 1)$

So energy will be liberated if we merge back those drops.

41. The radius of a soap bubble is r. The surface tension of soap solution is 'S'. Keeping temperature constant, the radius of the soap bubble is doubled. The energy necessary for this will be

(1) $24\,\pi r^2S$ (2) $8\,\pi r^2S$ (3) $16\,\pi r^2S$ (4) $12\,\pi r^2S$

Sol. Answer (1)

Work done in making a soap bubble of radius $r = 4\,\pi r^2S \times 2 = 8\,\pi r^2S$ $\left\{\begin{matrix}\text{Multiply by 2 due}\\ \text{to two free surface}\end{matrix}\right\}$

$\therefore$ Energy of bubble $= 8\,\pi r^2S = E_r$

Work done in making a $2r$ radius soap bubble $= 4\,\pi(2r^2)\,S \times 2 = 32\,\pi r^2S$

$\therefore$ Energy of bubble $= 32\,\pi r^2S = E_{2r}$

So energy required to expand a bubble from r to $2r$ will be equal to $E_{2r} - E_r$

Substituting values

We get,

$32\,\pi r^2S - 8\,\pi r^2S = 24\,\pi r^2S$

42. The surface tension of a liquid is 5 N/m. If a film is held on a ring of area 0.02 m^2, its surface energy is about

(1) 5×10^{-2} J (2) 2.5×10^{-2} J (3) 2×10^{-1} J (4) 3×10^{-1} J

Sol. Answer (3)

Surface energy = surface tension × area of film × number of free surface

$= 5 \times 0.02 \times 2$

$= 2 \times 10^{-1}$ J

43. Two soap bubbles having radii 3 cm and 4 cm in vacuum, coalesce under isothermal conditions. The radius of the new bubble is

(1) 1 cm (2) 5 cm (3) 7 cm (4) 3.5 cm

Sol. Answer (2)

Energy initial = Energy final

$\Rightarrow$ $8\,\pi(3)^2S + 8\,\pi\,(4)^2S = 8\,\pi\,(r)^2S$ {Surface tension remains constant throughout process

$\Rightarrow$ $(3)^2 + (4)^2 = (r)^2$

$\Rightarrow$ $5\text{ cm} = r$

44. The excess pressure in a soap bubble is double that in other one. The ratio of their volume is

(1) 1 : 2 (2) 1 : 8 (3) 1 : 4 (4) 1 : 1

Sol. Answer (2)

Excess pressure in soap bubble $= \frac{4S}{R}$

Let for first bubble,

$$P = \frac{4S}{R} \qquad \begin{cases} S - \text{Surface tension} \\ R - \text{Radius} \end{cases}$$

For second bubble,

$$2P = \frac{4S}{x} \qquad \begin{cases} S - \text{Surface tension} \\ x - \text{Radius} \end{cases}$$

Substitute value of P

$$2 \times \frac{4S}{R} = \frac{4S}{x}$$

$$\Rightarrow \quad x = \frac{R}{2}$$

Ratio of Radii $= \frac{R/2}{R} = \frac{1}{2}$

So, Ratio of volume = (Ratio of Radii)^3

$$= \left(\frac{1}{2}\right)^3 = \frac{1}{8}$$

45. The work done to break a spherical drop of radius R in n drops of equal size is proportional to

(1) $\frac{1}{n^{2/3}} - 1$ (2) $\frac{1}{n^{1/3}} - 1$ (3) $n^{1/3} - 1$ (4) $n^{4/3} - 1$

Sol. Answer (3)

$\because$ Volume = constant

i.e., $\frac{4}{3}\pi R^3 = n \times \frac{4}{3}\pi r^3$

Radius of each new droplet $= \frac{R}{n^{1/3}}$

Work done to break into 'n' drops $= S\,[n \times 4\pi r^2 - 4\pi R^3]$

$= S \times 4\pi R^2\,[n^{1/3} - 1]$

46. The kerosene oil rises up in the wick of a lamp

(1) Due to high surface tension of oil

(2) Because the wick attract s the oil

(3) Because wick decreases the surface tension of oil

(4) Due to capillaries formed in the wick

Sol. Answer (4)

Capillary action is responsible.

Wick has a lot of capillaries which help the oil rise.

47. Ploughing help to retain water by soil

(1) By creating capillaries
(2) By breaking capillaries
(3) By turning the soil upside down
(4) None of these

Sol. Answer (2)

By breaking capillaries as they do not allow water to seep inside.

48. A capillary tube of radius r is immersed in a liquid and mass of liquid, which rises up in it is M. If the radius of tube is doubled, then the mass of liquid which will rise in capillary tube will be

(1) $2M$
(2) M
(3) $M/2$
(4) $M/4$

Sol. Answer (1)

$M = \rho v$

$\Rightarrow$ Mass $\propto$ volume of tube

Mass $\propto$ height × Area

$$\left\{\begin{array}{l}\text{Area} \propto r^2 \\ \text{Height} \propto \dfrac{1}{r} \\ \text{Where } r = \text{radius of cube}\end{array}\right. \qquad \left(h = \frac{2S}{rgh}\right)$$

$\Rightarrow$ Mass $\propto \frac{1}{r} \times r^2$

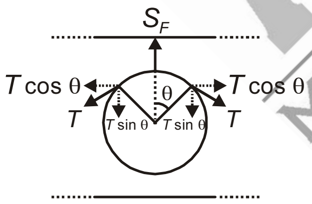
Mass $\propto r$

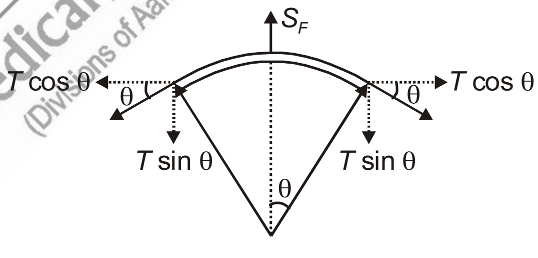
$\therefore$ If radius doubles, mass of liquid that rises up also doubles.

49. A massless inextensible string in the form of a loop is placed on a horizontal film of soap solution of surface tension T. If film is pierced inside the loop and it convert into a circular loop of diameter d, then the tension produced in string is

(1) Td
(2) πTd
(3) $\pi d^2 T$
(4) $\frac{\pi d^2 T}{4}$

Sol. Answer (1)





By force balancing in vertical direction

$S_F = 2T\sin\theta$

$S_F = 2T\theta$ $\quad \left\{\begin{array}{l}\because\ \theta \text{ is small} \\ \sin\theta \simeq \theta\end{array}\right.$

$S \times 2r \times 2\theta = 2 \times T \times \theta$

$S \times 2r = \text{Tension}$ $\quad \left\{\begin{array}{l}r - \text{radius} \\ d - \text{diameter}\end{array}\right.$

$S \times d = \text{Tension}$

$\because$ $S = T$

So, Tension = Td

$$\left\{\begin{array}{l}\text{Where,} \\ S_F = \text{Force due to surface tension} \\ T = \text{Tension in string} \\ \theta = \text{Small angle} \\ S = \text{Surface tension}\end{array}\right.$$

SECTION - B

Objective Type Questions

1. The atmospheric pressure at a place is 10^5 Pa. If tribromomethane (specific gravity = 2.9) be employed as the barometric liquid, the barometric height is

(1) 3.52 m (2) 1.52 m (3) 4.52 m (4) 2.52 m

Sol. Answer (1)

$1 \text{ atm} \simeq 10^5 \text{ Pa} = 76 \text{ cm of Hg}$

Density of Hg = 13.6

$\rho_{Hg} \times g \times h_{Hg} = \rho_{TBM} \times g \times h_{TBM}$

Substituting values

$13.6 \times 76 = 2.9 \times h$

$3.52 \text{ m} = h$

ρ_{Hg} = density of Hg
h_{Hg} = height of Hg
ρ_{TBM} = density of tribromomethane
h_{TBM} = height of tribromomethane

2. A large vessel of height H, is filled with a liquid of density ρ, upto the brim . A small hole of radius r is made at the side vertical face, close to the base. The horizontal force is required to stop the gushing of liquid is

(1) $(\rho gH)\pi r^2$ (2) ρgH (3) $\rho gH\pi r$ (4) $\rho g\pi r^2$

Sol. Answer (1)

Pressure close to the base = ρgH

Force required = pressure × area of hole = $\rho gH(\pi r^2)$

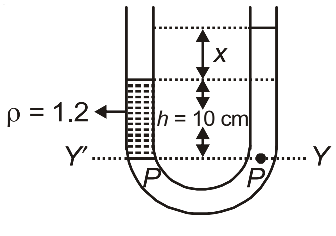
3. A vertical U-tube of uniform cross-section contains water in both the arms. A 10 cm glycerine column (R.D. = 1.2) is added to one of the limbs. The level difference between the two free surfaces in the two limbs will be

(1) 4 cm (2) 2 cm (3) 6 cm (4) 8 cm

Sol. Answer (2)

Let the difference between 2 limbs be x

Pressure on the line YY' should be same below both limbs, so



$\rho_{\text{glycerine}} \times g \times h = \rho_{\text{water}} \times g \times (h + x)$

$\Rightarrow \; 1.2 \times 10 = 1 \times (h + x)$

$\Rightarrow \; 2 \text{ cm} = x$

4. The pressure at the bottom of a water tank is 4 P, where P is atmospheric pressure. If water is drawn out till the water level decreases by $\frac{3}{5}$th, then pressure at the bottom of the tank is

(1) $\frac{3P}{8}$ (2) $\frac{7P}{6}$ (3) $\frac{11P}{5}$ (4) $\frac{9P}{4}$

Sol. Answer (3)

Let height of water in tank be h

So, $4P - P = \rho_w gh$ ...(1)

$\because$ $\frac{3}{5}$ water taken out $\frac{2}{5}$th water is left to exert pressure

$$P' = P + \frac{2}{5}\rho_w gh$$

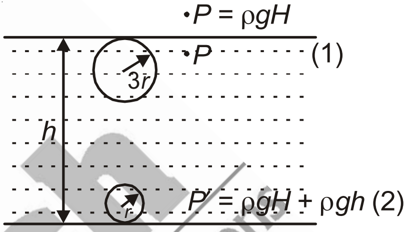
$$\Rightarrow \quad P' = P + \frac{2}{5} \times 3P \qquad \text{[From eq. (1)]}$$

$$\Rightarrow \quad P' = \frac{11P}{5}$$

5. A air bubble rises from bottom of a lake to surface. If its radius increases by 200% and atmospheric pressure is equal to water coloumn of height H, then depth of lake is

(1) 21 H (2) 8 H (3) 9 H (4) 26 H

Sol. Answer (4)



Let initial radius be = r

Final radius = r + 200% of r

= $3r$

Atmospheric pressure = ρgH

Let depth of the lake be h

So, pressure at the bottom of lake = $\rho gH + \rho gh$

Using $P_1V_1 = P_2V_2$

$$\rho gH \times \frac{4}{3}\pi(3r)^3 = (\rho gH + \rho gh) \times \frac{4}{3}\pi r^3$$

$$\rho gH \times \frac{4}{3}\pi \times 27r^3 = (\rho gH)\frac{4}{3}\pi r^3 + \rho gh \times \frac{4}{3}\pi r^3$$

Solving this equation we get

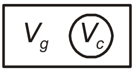
$26\,H = h$

6. A piece of gold weighs 10 g in air and 9 g in water. What is the volume of cavity?

(Density of gold = 19.3 g cm^{-3})

(1) 0.182 cc (2) 0.282 cc (3) 0.382 cc (4) 0.482 cc

Sol. Answer (4)



Where,
V_c = volume of cavity
V_g = volume of gold
W_{app} = 9 gm
W_{air} = 10 gm
F_B = force of buoyancy
ρ_w = density of water = 1
ρ_g = density of gold = 19.3

When dipped in water

$W_{\text{app}} = W_{\text{air}} - F_B$

$\Rightarrow$ 9 gm × g = 10 gm × g – F_B

$\Rightarrow$ 1 × g = F_B

Now (total volume displaced) × ρ_w × g = 1 × g

$(V_c + V_g) \times 1 = 1$

$$V_c = 1 - \frac{\text{Mass of gold in air}}{\rho_g} = 1 - \frac{10}{19.3} = 0.482 \text{ cc}$$

7. A block of ice floats in an oil in a vessel when the ice melts, the level of oil will

(1) Go up (2) Go down

(3) Remain same (4) Go up or down depending on quantity of ice

Sol. Answer (2)

Since block of ice is displacing some oils to stay afloat when the ice block melts level of oil will go down.

8. An object suspended by a wire stretches it by 10 mm. When object is immersed in a liquid the elongation in wire reduces by $\frac{10}{3}$ mm. The ratio of relative densities of the object and liquid is

(1) 3 : 1 (2) 1 : 3 (3) 1 : 2 (4) 2 : 1

Sol. Answer (1)

$$\Delta L = \frac{FL}{AY}$$

$$\left\{\begin{array}{l}\text{Let density of liquid} = \rho \\ \text{Let density of object} = \sigma \\ \text{Mass of object} = M\end{array}\right.$$

⇒ Elongation ∝ force and force is due to weight

So elongation ∝ weight

$\Delta L_1 \propto$ weight ...(1) {When not submerged in liquid}

$\Delta L_2 \propto$ apparant weight ...(2) {When submerged in liquid}

Dividing (1) by (2)

$$\frac{10}{10-\frac{10}{3}} = \frac{Mg}{Mg-\frac{Mg\rho}{\sigma}}$$

$$\Rightarrow \quad \frac{1}{1-\frac{1}{3}} = \frac{1}{1-\frac{\rho}{\sigma}}$$

Solving this we get

$$\frac{\rho}{\sigma} = \frac{1}{3}$$

So relative densities of object (σ) and liquid (ρ) is 3 : 1

9. Water flows in a stream line manner through a capillary tube of radius a. The pressure difference being P and the rate of flow is Q. If the radius is reduced to $\frac{a}{4}$ and the pressure is increased to $4P$, then the rate of flow becomes

(1) $4Q$ (2) $\frac{Q}{2}$ (3) Q (4) $\frac{Q}{64}$

Sol. Answer (4)

Rate of flow ∝ pressure difference × (radius)^4

$$Q \propto P \times a^4 \qquad \left\{\because \; Q = \frac{\pi P r^4}{8\eta L}\right\}$$

$$\text{So, } \frac{Q_1}{Q_2} = \frac{P_1 a_1^4}{P_2 a_2^4}$$

$$\frac{Q_1}{Q_2} = \frac{P \times a^4}{4P \times \left(\frac{a}{4}\right)^4} = \frac{64}{1}$$

$$\therefore \quad Q_2 = \frac{Q_1}{64} = \frac{Q}{64}$$

10. A vessel contain a liquid has a constant acceleration 19.6 m/s^2 in horizontal direction. The free surface of water get sloped with horizontal at angle

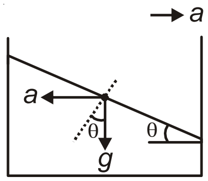
(1) $\tan^{-1}\left[\frac{1}{2}\right]$ (2) $\sin^{-1}\left[\frac{1}{\sqrt{3}}\right]$ (3) $\tan^{-1}\left[\sqrt{2}\right]$ (4) $\sin^{-1}\left[\frac{2}{\sqrt{5}}\right]$

Sol. Answer (4)

$$\tan\theta = \frac{a}{g} = \frac{19.6}{9.8} = 2$$

$$\tan\theta = 2$$

$$\Rightarrow \quad \sin\theta = \frac{2}{\sqrt{5}} \quad \Rightarrow \quad \theta = \sin^{-1}\left[\frac{2}{\sqrt{5}}\right]$$



11. A cylinder containing water, stands on a table of height H. A small hole is punched in the side of cylinder at its base. The stream of water strikes the ground at a horizontal distance R from the table. Then the depth of water in the cylinder is

(1) H (2) R (3) $\sqrt{RH}$ (4) $R^2/4H$

Sol. Answer (4)

Let depth of water in cylinder be x

So velocity (v) of efflux $= \sqrt{2gx}$

Time taken (t) by water to travel vertical distance of H

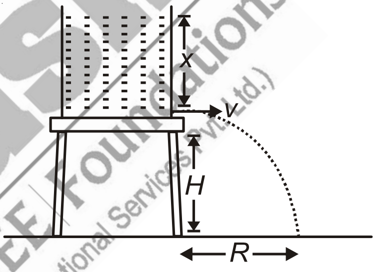
$$= \sqrt{\frac{2H}{g}}$$

$\Rightarrow$ Range = $v \times t$

$$R = \sqrt{2gx} \times \sqrt{\frac{2H}{g}}$$

Solving this we get

$$\frac{R^2}{4H} = x$$



12. Air streams horizontally past an air plane. The speed over the top surface is 60 m/s and that under the bottom surface is 45 m/s. The density of air is 1.293 kg/m^3, then the difference in pressure is

(1) 1018 N/m^2 (2) 516 N/m^2 (3) 1140 N/m^2 (4) 2250 N/m^2

Sol. Answer (1)

Applying Bernoullis equation

$$P_1 + \rho gh + \frac{1}{2}\rho v_1^2 = P_2 + \rho gh + \frac{1}{2}\rho v_2^2$$

$$\frac{1}{2} \times \rho\,[v_1^2 - v_2^2] = P_2 - P_1 = \Delta P$$

$$\Rightarrow \quad \frac{1}{2} \times 1.293\,[(60)^2 - (45)^2] = \Delta P$$

$$\Rightarrow \quad 1018 \text{ N/m}^2 \simeq \Delta P$$

13. Two water pipes P and Q having diameter 2×10^{-2} m and 4×10^{-2} m respectively are joined in series with the main supply line of water. The velocity of water flowing in pipe P is

(1) Four times that of Q (2) Two times that of Q

(3) $\frac{1}{2}$ times that of Q (4) $\frac{1}{4}$ times that of Q

Sol. Answer (1)

Rate of flow through both pipes will be same

i.e., $Q_1 = Q_2$

$$\frac{V_1}{t} = \frac{V_2}{t}$$

$$\frac{\pi r_1^2 l_1}{t} = \frac{\pi r_2^2 l_2}{t}$$

$$\left(\text{Where } \frac{l_1}{t} = V_P \text{ and } \frac{l_2}{t} = V_Q\right)$$

$$\Rightarrow \frac{\pi d_1^2}{4} V_P = \frac{\pi d_2^2}{4} \times V_Q$$

$$\Rightarrow V_P = \left(\frac{d_2}{d_1}\right)^2 V_Q$$

$$\Rightarrow V_P = \left(\frac{4 \times 10^{-2}}{2 \times 10^{-2}}\right)^2 V_Q$$

$$\Rightarrow V_P = 4V_Q$$

14. At what speed, the velocity head of water is equal to pressure head of 40 cm of mercury?

(1) 2.8 m/s (2) 10.32 m/s (3) 5.6 m/s (4) 8.4 m/s

Sol. Answer (2)

$$\frac{1}{2} \rho_{\text{water}} V^2 = \rho_{\text{mercury}}\, gh$$

$$V = \sqrt{2 \times \frac{\rho_{\text{mercury}}}{\rho_{\text{water}}} \times g \times h}$$

$$= \sqrt{2 \times 13.6 \times 9.8 \times \frac{40}{100}}$$

$$\Rightarrow V = 10.32 \text{ m/s}$$

15. If the terminal speed of a sphere of gold (density 19.5 kg/m^3) is 0.2 m/s in a viscous liquid (density = 1.5 kg/m^3), find the terminal speed of a sphere of silver (density = 10.5 kg/m^3) of the same size in the same liquid.

(1) 0.2 m/s (2) 0.4 m/s (3) 0.1 m/s (4) 0.133 m/s

Sol. Answer (3)

$$V_{\text{terminal}} = \frac{2a^2}{9\eta}(\rho - \sigma)g$$

Where
ρ = density of material
σ = density of liquid

$\Rightarrow\ V_T \propto (\rho - \sigma)$

$$\Rightarrow\ \frac{V_{T_1}}{V_{T_2}} = \frac{\rho_{\text{gold}} - \sigma_{\text{liquid}}}{\rho_{\text{silver}} - \sigma_{\text{liquid}}}$$

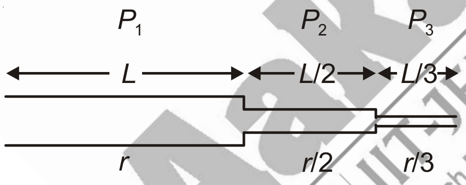
$$\Rightarrow\ \frac{0.2}{V} = \frac{19.5 - 1.5}{10.5 - 1.5}$$

$\Rightarrow\ V = 0.1$ m/s

Given,
$V_{T_1} = 0.2$ m/s
$V_{T_2} = V =$?
$\rho_{\text{gold}} = 19.5$ kg/m^3
$\sigma_{\text{liquid}} = 1.5$ kg/m^3
$\rho_{\text{silver}} = 10.5$ kg/m^3

16. Three capillaries of length L, $\frac{L}{2}$ and $\frac{L}{3}$ are connected in series. Their radii are r, $\frac{r}{2}$ and $\frac{r}{3}$ respectively. Then if stream-line flow is to be maintained and the pressure across the first capillary is P, then
(1) The pressure difference across the ends of second capillary is $8P$
(2) The pressure difference across the third capillary is $43P$
(3) The pressure difference across the ends of second capillary is $16P$
(4) The pressure difference across the third capillary is $59P$

Sol. Answer (1)



$P_1 = P$ (given)

$\because$ Rate of flow will be same across all pipes

So, pressure across the pipe $\propto \frac{\text{length}}{(\text{radius})^4}$

rate of flow of liquid (Q)

$$Q = \frac{\pi P r^4}{8\eta L}$$

$$\frac{P_1}{P_2} = \frac{\left(L/r^4\right)}{\left(\frac{L/2}{(r/2)^4}\right)} = \frac{1}{8}$$

Then $P_2 = 8P_1$

17. A large open tank has two holes in its wall. One is a square of side a at a depth x from the top and the other is a circular hole of radius r at depth $4x$ from the top. When the tank is completely filled with water, the quantities of water flowing out per second from both holes are the same. Then r is equal to

(1) $2\pi a$ (2) a (3) $\frac{a}{\sqrt{2\pi}}$ (4) $\frac{a}{\pi}$

Sol. Answer (3)

Since quantities of water flowing out of both holes is same

$\Rightarrow$ Area of hole × velocity of efflux = constant

So, $A_1 \times V_1 = A_2 \times V_2$

Substituting values.

$$a^2 \times \sqrt{2gx} = \pi r^2 \times \sqrt{8gx}$$

$$\Rightarrow a^2 = 2\pi r^2$$

$$\Rightarrow \frac{a}{\sqrt{2\pi}} = r$$

$$\begin{cases} A_1 = \text{Area of square hole} \\ V_1 = \text{Velocity of efflux from square hole} = \sqrt{2gx} \\ A_2 = \text{Area of circular hole} \\ V_2 = \text{Velocity of efflux from} \\ \quad \text{circular hole} = \sqrt{2g(4x)} \end{cases}$$

18. If T is the surface tension of a fluid, then the energy needed to break a liquid drop of radius R into 64 equal drops is

(1) $6\pi R^2T$ (2) πR^2T (3) $12\pi R^2T$ (4) $8\pi R^2T$

Sol. Answer (3)

Work done = surface tension × change in area

Since volume will remain equal

Let us assume radius of new drop = r each

$$\Rightarrow \frac{4}{3}\pi R^3 = 64 \times \frac{4}{3}\pi r^3$$

$$\Rightarrow \frac{R}{4} = r$$

$$W = T \cdot \Delta A$$

$$= T[n \times 4\pi r^2 - 4\pi R^2]$$

$$= T\left[64 \times 4\pi\left(\frac{R}{4}\right)^2 - 4\pi R^2\right] = 12\pi R^2 T$$

19. The excess pressure inside a spherical drop of water is four times that of another drop. Then their respective mass ratio is

(1) 1 : 16 (2) 1 : 64 (3) 1 : 4 (4) 1 : 8

Sol. Answer (2)

$$\Delta P = \frac{2T}{R}$$

$$\text{Pressure} \propto \frac{1}{\text{Radius}}$$

$$\begin{cases} \text{Where,} \\ P_0 = \text{Excess pressure} \\ T = \text{Surface tension} \\ R = \text{Radius} \end{cases}$$

$$\Rightarrow \frac{\Delta P_1}{\Delta P_2} = \frac{R_2}{R_1}$$

$$\Rightarrow \frac{4P}{P} = \frac{R_2}{R_1}$$

$$\Rightarrow 4R_1 = R_2$$

$$\Rightarrow \frac{R_1}{R_2} = \frac{1}{4}$$

$M = V \times \rho$

And $V \propto R^3 \Rightarrow M \propto \rho R^3$

ρ is same for both

$M \propto R^3$

$$\left\{\begin{array}{l}\text{Where,}\\ M = \text{Mass}\\ V = \text{Volume}\\ \rho = \text{Density}\end{array}\right.$$

So, $\dfrac{M_1}{M_2} = \left(\dfrac{R_1}{R_2}\right)^3 = \left(\dfrac{1}{4}\right)^3 = \dfrac{1}{64}$

20. The work done in blowing a soap bubble of 10 cm radius is (surface tension of soap solution is 0.03 N/m).

(1) 37.68×10^{-4} J (2) 75.36×10^{-4} J (3) 126.82×10^{-4} J (4) 75.36×10^{-3} J

Sol. Answer (2)

Work done = surface tension × change in area × number of free surfaces = $S \times \Delta A \times 2$

$= 0.03 \times 4\pi \times (10 \times 10^{-2})^2 \times 2$

$= 75.36 \times 10^{-4}$ J

21. A glass capillary tube of inner diameter 0.28 mm is lowered vertically into water in a vessel. The pressure to be applied on the water in the capillary tube so that water level in the tube is same as that in the vessel is (surface tension of water = 0.07 N/m and atmospheric pressure = 10^5 N/m^2).

(1) 10^3 (2) 99×10^3 (3) 100×10^3 (4) 101×10^3

Sol. Answer (4)

Height of liquid in capillary $= \dfrac{2T}{r\rho g} = h$

Pressure we need to apply = $\rho g h + P_0$

Substitute value of h

$$\left\{\begin{array}{l}\text{Where,}\\ T = \text{Surface tension}\\ r = \text{Radius of capillary}\\ \rho = \text{Density of liquid}\\ P_0 = \text{Atmospheric pressure}\end{array}\right.$$

$$P = \rho g \times \frac{2T}{r\rho g} + P_0 = \frac{2T}{r} + P_0 = \frac{4T}{d} + P_0$$

$$\Rightarrow P = \frac{4 \times 0.07}{(0.28 \times 10^{-3})} + P_0 = 1000 \text{ Nm}^{-2} + 10^5 \text{ Nm}^{-2}$$

$$\Rightarrow P = (10^3 + 10^5) \text{ Nm}^{-2} = 101 \times 10^3 \text{ Nm}^{-2}$$

$$\left\{\begin{array}{l}\text{Given,}\\ T = 0.07 \text{ N/m}\\ d = 0.28 \text{ mm}\end{array}\right.$$

22. Water rises to a height of 10 cm in a capillary tube and mercury falls to a depth of 3.42 cm in the same capillary tube. If the density of mercury is 13.6 kg/m^3 and angle of contact is 135°, the ratio of surface tension for water and mercury is (angle of contact for water and glass is 0°).

(1) 1 : 0.5 (2) 1 : 3 (3) 1 : 6.5 (4) 1.5 : 1

Sol. Answer (3)

$$h = \frac{2T\cos\theta}{r\rho g}$$

For water,

$$10\text{ cm} = \frac{2\times T_w \times \cos 0^\circ}{r\times 1\times g} \quad ...(1) \qquad \{T_w - \text{Surface tension of water}$$

For mercury,

$$-3.42\text{ cm} = \frac{2\times T_M \times \cos 135^\circ}{r\times 13.6\times g} \quad ...(2) \qquad \{T_M - \text{Surface tension of mercury}$$

Dividing Eq^n (1) by (2)

$$\frac{10}{-3.42} = \frac{2\times T_w\times 1\times r\times 13.6\times g}{r\times 1\times g\times 2\times T_M\times \frac{-1}{\sqrt{2}}}$$

$$\Rightarrow \frac{10}{3.42} = \sqrt{2}\times 13.6\times \frac{T_w}{T_M}$$

$$\Rightarrow \frac{10}{3.42\times 1.41\times 13.6} = \frac{T_w}{T_M}$$

$$\Rightarrow \frac{1}{6.5} = \frac{T_w}{T_M}$$

23. A spherical drop of water has 1 mm radius. If the surface tension of water is 75 × 10^{-3} N/m, then difference of pressure between inside and outside of the drop is

(1) 35 N/m^2 (2) 70 N/m^2 (3) 140 N/m^2 (4) 150 N/m^2

Sol. Answer (4)

$$\text{Excess pressure } = \frac{2T}{R} \qquad \begin{cases} T = \text{surface tension} \\ R = \text{radius} \end{cases}$$

$$= \frac{2\times 75\times 10^{-3}}{1\times 10^{-3}}$$

$$= 150\text{ N/m}^2$$

24. A capillary tube is dipped in water and it is 20 cm outside water. The water rises upto 8 cm. If the entire arrangement is put in freely falling elevator the length of water column in the capillary tube will be

(1) 20 cm (2) 4 cm (3) 10 cm (4) 8 cm

Sol. Answer (1)

If entire arrangement is in free fall then the weight of water in capillary will be balanced by pseudo force which would be equal to the weight of water.

Hence, surface tension has no weight to balance so full capillary will be filled with water.

25. If the excess pressure inside a soap bubble is balanced by an oil column of height 2 mm, then the surface tension of soap solution will be (r = 1 cm, density of oil = 0.8 g/cm^3)

(1) 3.9 N/m (2) 3.9×10^{-2} N/m (3) 3.9×10^{-3} N/m (4) 3.9×10^{-1} N/m

Sol. Answer (2)

Pressure due to oil column = $\rho_{oil} \times g \times h_{oil} = \dfrac{0.08\times10^{-3}}{(10^{-2})^3}\times9.8\times2\times10^{-3} = 15.68$

Now, excess pressure = pressure due to oil column

$\Rightarrow \dfrac{4T}{R} = 15.68$

$\Rightarrow \dfrac{4\times T}{1\times10^{-2}} = 15.68$

$\Rightarrow T = 3.92 \times 10^{-2}$ N/m

26. There is small hole in a hollow sphere. The water enters in it when it is taken to a depth of 40 cm under water. The surface tension of water is 0.07 N/m. The diameter of hole is

(1) 7 mm (2) 0.07 mm (3) 0.0007 mm (4) 0.7 m

Sol. Answer (2)

Let take g = 10 m/s^2

For water to enter the sphere, pressure required is = ρgh

$= 1\times10\times\dfrac{40}{100}\times1000$ (ρ = 1000 kg/m^3)

= 4000 $\dfrac{\text{N}}{\text{m}^2}$ = excess pressure

Let the hole have radius = R

Excess pressure $= \dfrac{2T}{R}$ [One surface air, one surface water]

$\Rightarrow 4000 = \dfrac{2\times0.07}{R}$

$\Rightarrow 2R = 0.07 \times 10^{-3}$ m

$\Rightarrow d = 0.07$ mm

27. Two equal drops are falling through air with a steady velocity of 5 cm/second. If two drops coalesce, then new terminal velocity will be

(1) $5 \times (4)^{1/3}$ cm/s (2) $5\sqrt{2}$ cm/s (3) $\dfrac{5}{\sqrt{2}}$ cm/s (4) 5×2 cm/s

Sol. Answer (1)

$V_{\text{Terminal}} \propto r^2$

If initial radius = r, let new radius = R

Then $2 \times \frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3$

$\Rightarrow (2)^{1/3} r = R$

$\Rightarrow V_T \propto R^2$

$\propto (2)^{2/3} r^2$ (For bigger drops)

$$\frac{V_{T\text{ smaller drop}}}{V_{T\text{ bigger drop}}} = \frac{r^2}{(2)^{2/3} r^2}$$

$$\Rightarrow \frac{5}{x} = \frac{1}{(2)^{2/3}}$$

$\Rightarrow 5 \times (2)^{2/3} = x$

$\Rightarrow 5 \times (4)^{1/3}$ cm/s $= x$

28. A small drop of water falls from rest through a large height h in air; the final velocity is

(1) Proportional to $\sqrt{h}$ (2) Proportional to h

(3) Inversely proportional to h (4) Almost independent of h

Sol. Answer (4)

Since drop is falling from a large height it achieves its terminal velocity and then there is no further increase in velocity so v is independent of 'h' if 'h' is very large.

29. A spring balance reads 200 gF when carrying a lump of lead in air. If the lead is now immersed with half of its volume in brine solution, what will be the new reading of the spring balance? specific gravity of lead and brine are 11.4 and 1.1 respectively

(1) 190.4 gF (2) 180.4 gF (3) 210 gF (4) 170.4 gF

Sol. Answer (1)

$W' = W - F_B$

$= v\sigma g - \frac{v}{2}\rho g$

$= v\sigma g\left(1 - \frac{\rho}{2\sigma}\right)$

Where,
W' = apparent weight
W = read weight = actual weight of body in vaccum
ρ = density of solution (1.1)
σ = density of material (11.4)

$$W' = 200\left(1 - \frac{1.1}{11.4 \times 2}\right)$$

= 190.35 gF

30. A liquid mixture of volume V, has two liquids as its ingredients with densities α and β. If density of the mixture is σ, then mass of the first liquid in mixture is

(1) $\frac{\alpha V[\sigma\beta + 1]}{\beta[\alpha + \sigma]}$ (2) $\frac{\alpha V[\sigma - \beta]}{[\sigma + \beta]}$ (3) $\frac{\alpha V(\beta - \sigma)}{\beta - \alpha}$ (4) $\frac{\alpha V[1 - \sigma\alpha]}{\beta[\alpha - \sigma]}$

Sol. Answer (3)

Let mass of liquid with density $\alpha = M_1$

Let mass of liquid with density $\beta = M_2$

Total volume = V

Net density of mixture = σ

Now,

Total mass $= M_1 + M_2$

$$\Rightarrow \quad V\sigma = M_1 + M_2 \qquad \left[\because \ \frac{\text{Total mass}}{V} = \sigma\right]$$

$$\Rightarrow \quad M_2 = V\sigma - M_1 \qquad ...(1)$$

Now,

$$\sigma = \frac{\text{Total mass}}{\text{Total volume}} = \frac{(M_1 + M_2)}{\left(\frac{M_1}{\alpha}\right) + \left(\frac{M_2}{\beta}\right)}$$

Substituting value of M_2 from equation (1)

$$\sigma = \frac{M_1 + (V\sigma - M_1)}{\frac{M_1}{\alpha} + \frac{(V\sigma - M_1)}{\beta}}$$

Solving this we get

$$M_1 = \frac{\alpha V(\beta - \sigma)}{\beta - \alpha}$$

SECTION - C

Previous Years Questions

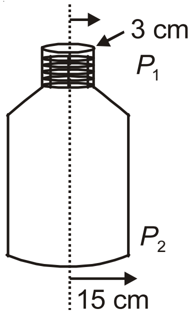
1. The neck and bottom of a bottle are 3 cm and 15 cm in radius respectively. If the cork is pressed with a force 12 N in the neck of the bottle, then force exerted on the bottom of the bottle is

(1) 30 N (2) 150 N (3) 300 N (4) 600 N

Sol. Answer (3)

Pressure applied on 1 point in a liquid spreads equally

So let P_1 be pressure at neck, P_2 be pressure at bottom



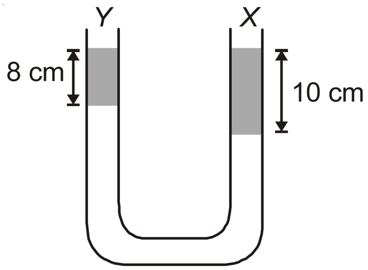
$$P_1 = P_2$$

$$\Rightarrow \frac{F_1}{A_1} = \frac{F_2}{A_2} \qquad \left[\because \ P = \frac{F}{A}\right]$$

$$\Rightarrow \frac{12}{\pi \times 9} = \frac{F_2}{\pi \times 225}$$

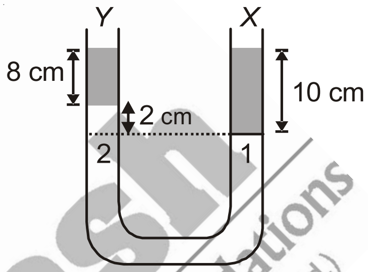
$$\Rightarrow 300 \text{ N} = F_2$$

2. A liquid X of density 3.36 g cm^{-3} is poured in a U-tube, which contains Hg. Another liquid Y is poured in left arm with height 8 cm, upper levels of X and Y are same what is density of Y?



(1) 0.8 gcc^{-1} (2) 1.2 gcc^{-1} (3) 1.4 gcc^{-1} (4) 1.6 gcc^{-1}

Sol. Answer (1)



Pressure at 1 and 2 will be same

$$\rho_X gH_X = \rho_Y gH_Y + \rho_{Hg} g \times 2$$

$$\Rightarrow \; 3.36 \times 10 = \rho_Y \times 8 + 13.6 \times 2$$

Solving this we get

$$\rho_Y = 0.8 \text{ g cc}^{-1}$$

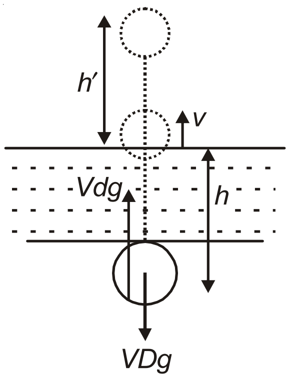
3. A wooden ball of density D is immersed in water of density d to a depth h below the surface of water and then released. Upto what height will the ball jump out of water?

(1) $\dfrac{d}{D}h$ (2) $\left(\dfrac{d}{D}-1\right)h$ (3) h (4) Zero

Sol. Answer (2)

Force acting on ball at depth 'h' (*i.e.* apparent weight)

$$F = Vg\,[d - D]$$



Acceleration $(a) = \dfrac{Vg[d-D]}{VD}$ [Mass = volume × density]

Velocity $= \sqrt{2ah} = v$ [Using $v^2 - u^2 = 2as$]

$$h' \text{ (height above water) } = \frac{v^2}{2g} = \frac{2\times Vg[d-D]h}{2\times gVD} = \left[\frac{d}{D}-1\right]h$$

4. A piece of solid weighs 120 g in air, 80 g in water and 60 g in a liquid. The relative density of the solid and that of the liquid are respectively

(1) 3, 2 (2) $2, \dfrac{3}{4}$ (3) $\dfrac{3}{2}, 2$ (4) $3, \dfrac{3}{2}$

Sol. Answer (4)

$$w' = w\left[1-\frac{\rho}{\sigma}\right] \qquad \begin{cases}\text{Where,}\\ \rho = \text{density of liquid}\\ \sigma = \text{density of body}\end{cases}$$

Inside water

$$\Rightarrow \quad 80 = 120\left[1-\frac{\rho_{\text{water}}}{\rho_{\text{solid}}}\right]$$

$\Rightarrow \quad \rho_{\text{solid}} = 3$ $\qquad [\because \quad \rho_{\text{water}} = 1]$

Inside liquid

$$60 = 120\left[1-\frac{\rho_{\text{liquid}}}{\rho_{\text{solid}}}\right]$$

Using $\rho_{\text{solid}} = 3$

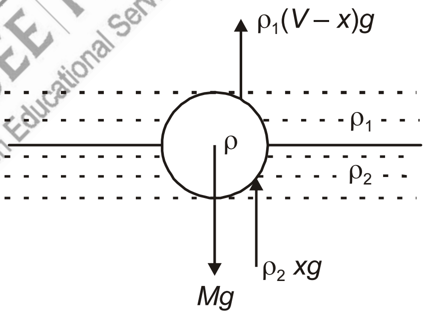
We get $\rho_{\text{liquid}} = \dfrac{3}{2}$

5. A solid sphere of volume V and density ρ floats at the interface of two immiscible liquids of densities ρ_1 and ρ_2 respectively. If $\rho_1 < \rho < \rho_2$, then the ratio of volume of the parts of the sphere in upper and lower liquids is

(1) $\dfrac{\rho_2-\rho}{\rho-\rho_1}$ (2) $\dfrac{\rho+\rho_1}{\rho+\rho_2}$ (3) $\dfrac{\rho+\rho_2}{\rho+\rho_1}$ (4) $\dfrac{\sqrt{\rho_1\rho_2}}{\rho}$

Sol. Answer (1)

$\rho_1 < \rho < \rho_2$ (given)



Let volume of sphere in lower liquid = x

Force of buoyancy by lower liquid = $\rho_2 xg$

Force of buoyancy by upper liquid = $\rho_1(V-x)g$

Force of gravity on sphere = $Mg = V\rho g$

Balancing all the forces for vertical equilibrium

We get

$V\rho g = \rho_1(V-x)\,g + \rho_2 xg$

Solving this we get

$$x = \frac{V(\rho-\rho_1)}{(\rho_2-\rho_1)}$$

So $\dfrac{V-x}{x} = \dfrac{\rho_2-\rho}{\rho-\rho_1}$ $\qquad \begin{cases}\text{Where,}\\ V-x = \text{volume of sphere in upper liquid}\\ x = \text{volume of sphere in lower liquid}\end{cases}$

6. Ice pieces are floating in a beaker A containing water and also in a beaker B containing miscible liquid of specific gravity 1.2. When ice melts, the level of

(1) Water increases in A (2) Water decreases in A

(3) Liquid in B decreases (4) Liquid in B increases

Sol. Answer (4)

For beaker '*A*'

Ice is floating in water

$$\rho_{ice}\, v_{ice}\, g = \rho_{water}\, v_{water\ displaced}\, g$$

$\because\quad \rho_{ice} \simeq \rho_{water}$

So we can say

$$v_{ice} \simeq v_{water\ displaced}$$

So after the ice melts the level of water will not change.

For beaker '*B*'

Ice is floating in liquid with density 1.2

clearly $\rho_{liquid} > \rho_{ice}$

So from above analogy

$$v_{ice} > v_{liquid\ displaced}$$

So when ice melts the level in beaker '*B*' increases.

7. A vessel contains oil (density 0.8 g cm^{-3}) over mercury (density 13.6 g cm^{-3}). A homogenous sphere floats with half volume immersed in mercury and the other half in oil. The density of the material of the sphere in g cm^{-3} is

(1) 12.8 (2) 7.2 (3) 6.4 (4) 3.3

Sol. Answer (2)

Let density of sphere be ρ

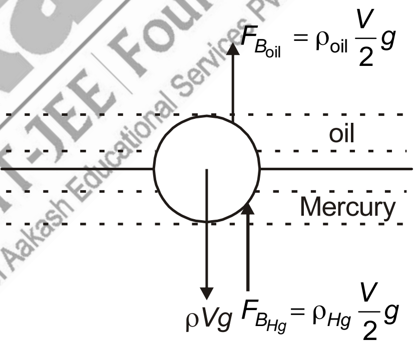
And volume be v

Balancing forces for vertical equilibrium

$$\rho Vg = \frac{\rho_{Hg}Vg}{2} + \frac{\rho_{oil}Vg}{2}$$

$$\Rightarrow\quad \rho = \frac{13.6}{2} + \frac{0.8}{2}$$

$$\Rightarrow\quad \rho = 7.2 \text{ g cm}^{-3}$$



8. Two solid pieces, one of steel and the other of aluminium when immersed completely in water have equal weights. When the solid pieces are weighed in air

(1) The weight of aluminium is half the weight of steel (2) Steel peice will weigh more

(3) They have the same weight (4) Aluminium piece will weigh more

Sol. Answer (4)

Apparent weight = weight in air – $F_{Buoyancy}$

$\because$ Apparent weight of steel and aluminium is same

So weight of aluminium – F_B on Aluminium = weight of steel – F_B on steel ...(1)

$$\rho_{Al}\, V_{Al}\, g - \rho_{water}\, V_{Al}\, g = \rho_{steel}\, V_{steel}\, g - \rho_{water}\, V_{steel}\, g$$

$\rho_{steel} > \rho_{Al}$ and $\rho_{water} = 1$

So $(\rho_{Al} - 1)\ V_{Al} = (\rho_{steel} - 1)\ V_{steel}$

$\because$ $\rho_{steel} > \rho_{Al}$

$(\rho_{steel} - 1) > (\rho_{Al} - 1)$

So $V_{Al} > V_{steel}$

Also $\rho_{water}\ V_{Al}\ g > \rho_{water}\ V_{steel}\ g$

$\Rightarrow$ Force of buoyancy on Aluminium > Force of buoyancy on steel.

Using this condition in equation (1)

We get,

weight of Aluminium – weight of steel > 0

$\Rightarrow$ weight of Aluminium > weight of steel

9. A piece of wood is floating in water. When the temperature of water rises, the apparent weight of the wood will

(1) Increase (2) Decrease

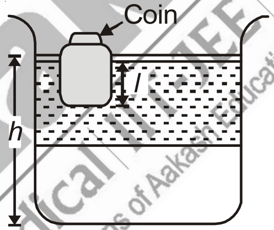
(3) May increase or decrease (4) Remain same

Sol. Answer (3)

When temperature of water is raised from 0 to 4°C, its density increases and after 4°C density decreases and apparent weight $\propto F_{Buoyancy} \propto$ density of water

So apparent weight may increase or decrease.

10. A wooden block, with a coin placed on its top, floats in water as shown in the figure. The distances *h* and *l* are shown there. After some time, the coin falls into the water, then



(1) Both *l* and *h* increase (2) Both *l* and *h* decrease

(3) *l* decreases and *h* increases (4) *l* increases and *h* decreases

Sol. Answer (2)

When coin falls into water block has to displace lesser volume to stay afloat.

Implies that block will go up and water will go down.

Hence both *l* and *h* will decrease.

11. An iceberg is floating in water. The density of ice in the iceberg is 917 kg m^{-3} and the density of water is 1024 kg m^{-3}. What percentage fraction of the iceberg would be visible?

(1) 5% (2) 10% (3) 12% (4) 8%

Sol. Answer (2)

ρ_{ice} × volume of ice × g = ρ_{water} × volume of ice inside water × g

917 × volume of ice = 1024 × volume of ice inside water

Let volume of ice = V

$$\therefore \quad \text{\% Volume visible} = \frac{V - \text{volume inside water}}{V} \times 100$$

$$= \left(\frac{V - \dfrac{917V}{1024}}{V} \right) \times 100$$

$$= \frac{\left(\dfrac{1024 - 917}{1024} \right) V}{V} \times 100$$

$$= 10\%$$

12. A piece of wax wieghs 18.03 g in air. A piece of metal is found to weigh 17.3 g in water. It is tied to the wax and both together weigh 15.23 g in water. Then, the specific gravity of wax is

(1) $\frac{18.03}{17.03}$ (2) $\frac{17.03}{18.03}$ (3) $\frac{18.03}{19.83}$ (4) $\frac{15.03}{17.03}$

Sol. Answer (3)

Weight of wax in air = 18.03 g

Apparent weight of metal in water = 17.3 g

Apparent weight = weight in air – $\rho_{water} V_{metal}\, g$

So weight of metal in air = apparent weight + $V_{metal}\, g$ $[\because \rho_{water} = 1]$

= 17.3 + $V_{metal} \times g$

When wax and metal are tied together

Total weight in air = 18.03 + 17.3 + $V_{metal} \times g$

And apparent weight in water = 15.23 = weight in air – $\rho_{water} V_{wax}\, g - \rho_{water} V_{metal}\, g$

$\Rightarrow$ 15.23 = 18.03 + 17.3 + $V_{metal}\, g - V_{wax}\, g - V_{metal}\, g$

$\Rightarrow$ $V_{wax}\, g = 20.1$

$$\Rightarrow \frac{\text{Mass of wax}}{\text{density}} \times g = 20.1 \qquad \left[\because \rho = \frac{M}{V} \right]$$

$$\Rightarrow \frac{18.03}{g \times \rho} \times g = 20.1 \qquad \left[\text{Mass} = \frac{\text{weight}}{g} \right]$$

$$\text{So specific gravity of wax} = \frac{18.03}{20.1} = 0.897 \sim 0.9$$

$$\Rightarrow \left(\frac{18.03}{19.83} = 0.9 \right)$$

13. Eight equal drops of water are falling through air with a steady velocity of 10 cm^{-1}. If the drops combine to form a single drop big in size, then the terminal velocity of this big drop is

(1) 80 cms^{-1} (2) 30 cms^{-1} (3) 10 cms^{-1} (4) 40 cms^{-1}

Sol. Answer (4)

Let radius of smaller drops be *r*, and bigger be *R*

When 8 such drops combine to form a bigger drop the total volume of water remains same

So, $8\times\frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3$

$\therefore\ 2r = R$

And we know,

$V_{\text{Terminal}} \propto r^2$

$\therefore\ \frac{V_{T\,\text{smaller}}}{V_{T\,\text{bigger}}} = \frac{r^2}{R^2} = \frac{r^2}{4r^2}$

$\Rightarrow\ \frac{10}{V_{T\,\text{bigger}}} = \frac{1}{4}$ $[\because\ V_{T\,\text{smaller}} = 10\ \text{cms}^{-1}\ \text{(given)}]$

$\Rightarrow\ V_{T\,\text{bigger}} = 40\ \text{cms}^{-1}$

14. A small spherical ball falling through a viscous medium of negligible density has terminal velocity ν. Another ball of the same mass but of radius twice that of the earlier falling through the same viscous medium will have terminal velocity

(1) ν (2) $\frac{\nu}{4}$ (3) $\frac{\nu}{2}$ (4) 4ν

Sol. Answer (4)

$v_{\text{Terminal}} \propto r^2$

$\frac{v_{T_1}}{v_{T_2}} = \frac{r_1^2}{r_2^2}$

$$\left\{\begin{array}{l}\text{Where,}\\ v_{T_1} = \nu\\ r_1 = r\\ r_2 = 2r\\ v_{T_2} = ?\end{array}\right.$$

Substituting values

$\frac{\nu}{v_{T_2}} = \frac{r^2}{4r^2}$

$\Rightarrow\ v_{T_2} = 4\nu$

15. Streamline flow is more likely for liquid with

(1) High density and low viscosity (2) Low density and high viscosity

(3) High density and high viscosity (4) Low density and low viscosity

Sol. Answer (2)

Streamline flow is more likely for liquid with low density and high viscosity.

16. An air bubble of radius 10^{-2} m is rising up at a steady rate of 2×10^{-3} ms^{-1} through a liquid of density 1.5×10^{3} kg m^{-3}, the coefficient of viscosity neglecting the density of air, will be (g = 10 ms^{-2})

(1) 23.2 units (2) 83.5 units (3) 334 units (4) 167 units

Sol. Answer (4)

$$V_T = \frac{2a^2}{9\eta} g(\rho - \sigma)$$

Substituting values

$$2\times10^{-3} = \frac{2\times10^{-4}\times10\times1.5\times10^{3}}{9\eta}$$

$\Rightarrow$ $\eta \sim 167$ units

$$\begin{cases} \text{Where given is} \\ V_T = 2\times10^{-3}\ \text{ms}^{-1} \\ a = 10^{-2}\ \text{m} \\ \rho = 1.5\times10^{3}\ \text{kg m}^{-3} \\ \sigma \sim 0 \\ g = 10\ \text{ms}^{-2} \end{cases}$$

17. The flow of liquid is laminar or streamline is determined by

(1) Rate of flow of liquid (2) Density of fluid

(3) Radius of the tube (4) Coefficient of viscosity of liquid

Sol. Answer (1)

It is decided by rate of flow of liquid

Given by Reynolds number $= \frac{\rho v d}{n}$

18. A boat carrying a number of large stones is floating in a water tank. What would happen to the water level, if a few stones are unloaded into water?

(1) Rises

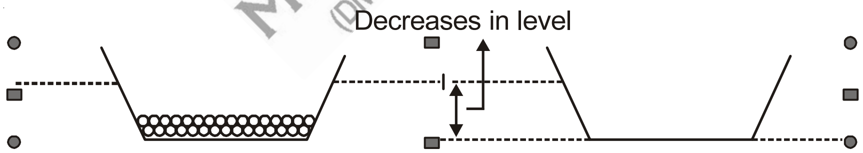
(2) Falls

(3) Remains unchanged

(4) Rises till half the number of stones are unloaded and then begins to fall

Sol. Answer (2)

Previously when stones are on the boat they are increasing the weight on the boat and to balance this weight boat needs to generate buoyancy force by displacing more water, but when stones are removed the boat starts displacing less amount of water hence the level of water in tank falls.

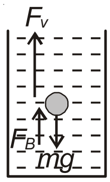


19. The velocity of a small ball of mass M and density d_1 when dropped in a container filled with glycerine becomes constant after some time. If the density of glycerine is d_2, the viscous force acting on the ball is

(1) $Mg\left(1-\frac{d_2}{d_1}\right)$ (2) $Mg\frac{d_1}{d_2}$ (3) $mg(d_1 - d_2)$ (4) mgd_1d_2

Sol. Answer (1)

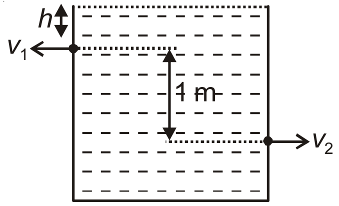
$$F_v = mg - F_v = vd_1g - vd_2g = vd_1g\left(1-\frac{d_2}{d_1}\right) = mg\left(1-\frac{d_2}{d_1}\right)$$



20. There are two holes one each along the opposite sides of a wide rectangular tank. The cross-section of each hole is 0.01 m^2 and the vertical distance between the holes is one metre. The tank is filled with water. The net force on the tank in newton when the water flows out of the holes is (density of water = 1000 kgm^{-3})

(1) 100 (2) 200 (3) 300 (4) 400

Sol. Answer (2)



Net force = $F_2 - F_1$

$= \rho A v_2^2 - \rho A v_1^2$

$$F = ma = v\rho \times \left(\frac{v}{t}\right) = Ah\rho\left(\frac{v}{t}\right) = A\rho v^2$$

$= 2\rho g\,(h + 1)\,A - 2\rho ghA \qquad \left[v = \sqrt{2gx}\right]$

$= 2\rho gA$

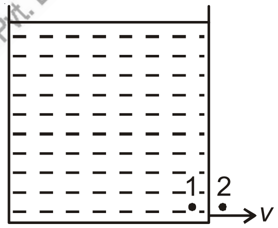
$= 1000 \times 10 \times 0.01 \times 2$

$= 200$ N

21. A hole is made at the bottom of the tank filled with water (density 1000 kg/m^3). If the total pressure at the bottom of the tank is 3 atm (1 atm = 10^5 N/m^2), then the velocity of efflux is

(1) $\sqrt{200}$ m/s (2) $\sqrt{400}$ m/s (3) $\sqrt{500}$ m/s (4) $\sqrt{800}$ m/s

Sol. Answer (2)



Apply Bernoulli's theorem

$$\underbrace{P + \rho gH}_{\text{Total pressure}} + \frac{1}{2}\rho v^2 = \text{constant} \qquad \left\{\begin{array}{l}\text{Given}\\ \text{Total pressure} = 3\text{ atm}\end{array}\right.$$

At point 1, 3 atm + 0 = constant ...(i)

At point 2, 1 atm + $\frac{1}{2}\rho v^2$ = constant ...(ii)

Equate (i) and (ii)

$3 = 1 + \frac{1}{2}\rho v^2$ [Use ρ = 1000 and 1 atm = 10^5 N/m^2]

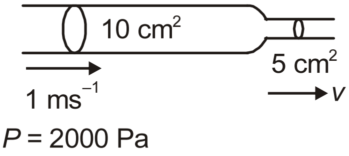
We get,

$v = \sqrt{400}$ m/s

22. A horizontal pipe line carries water in stremline flow. At a point where the cross-sectional area is 10 cm^2 the water velocity is 1 ms^{-1} and pressure is 2000 Pa. The pressure of water at another point where the cross-sectional area is 5 cm^2, is

(1) 200 Pa (2) 400 Pa (3) 500 Pa (4) 800 Pa

Sol. Answer (3)



$A_1V_1 = A_2V_2$ (equation of continuity)

$10 \times 1 = 5 \times v$

So, $v = 2\ \text{ms}^{-1}$

Apply Bernoulli theorem at both the points

$$2000 + \frac{1}{2} \times 1000 \times 1^2 = P + \frac{1}{2} \times 1000 \times 4$$

$\Rightarrow$ $P = 500$ Pa

23. A rectangular vessel when full of water, takes 10 min to be emptied through an orifice in its bottom. How much time will it take to be emptied when half filled with water?

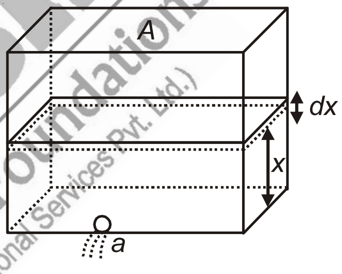
(1) 9 min (2) 7 min (3) 5 min (4) 3 min

Sol. Answer (2)

Let time taken by height 'x' to get reduced by $dx = dt$

$$\therefore \quad dt = \frac{\text{volume}}{\text{efflux speed}} = \frac{A \times dx}{\sqrt{2gx}} \qquad \{A \text{ is area of cross-section}\}$$

$$\int_0^T dt = \int_0^h \frac{A}{\sqrt{2g}} \frac{dx}{\sqrt{x}}$$



$$\Rightarrow \quad T = \frac{A}{a}\sqrt{\frac{2h}{g}}$$

$$\Rightarrow \quad T \propto \sqrt{h}$$

So we can use

$$\frac{T_1}{T_2} = \frac{\sqrt{h_1}}{\sqrt{h_2}}$$

$$\frac{10 \text{ min}}{t \text{ min}} = \frac{\sqrt{h}}{\sqrt{h/2}}$$

$$\Rightarrow \quad t = \frac{10}{\sqrt{2}} \sim 7 \text{ min}$$

24. A metal plate of area 10^3 cm^2 rests on a layer of oil 6 mm thick. A tangential force 10^{-2} N is applied on it to move it with a constant velocity of 6 cms^{-1}. The coefficient of viscosity of the liquid is

(1) 0.1 poise (2) 0.5 poise (3) 0.7 poise (4) 0.9 poise

Sol. Answer (1)

$$F = \eta A \frac{v}{d}$$

$$\Rightarrow \quad 10^{-2} = \eta \times (10^3 \times 10^{-4}) \times \frac{6 \times 10^{-2}}{6 \times 10^{-3}} = 0.01 \text{ poiseuille}$$

$$= 0.1 \text{ poise}$$

Where,

F = Force

η = Coefficient of viscosity

A = Area

v = Velocity

d = Thickness of layer

25. With an increase in temperature, surface tension of liquid (except molten copper and cadmium)

(1) Increases (2) Remain same

(3) Decreases (4) First decreases then increases

Sol. Answer (3)

When we increase the temperature, we are providing energy to the molecules. This increase in potential energy causes the surface energy to drop and become less negative hence decreasing surface tension because surface tension is nothing but surface energy per unit area.

26. Determine the energy stored in the surface of a soap bubble of radius 2.1 cm if its tension is 4.5×10^{-2} Nm^{-1}.

(1) 8 mJ (2) 2.46 mJ (3) 4.93×10^{-4} J (4) None of these

Sol. Answer (3)

Energy = surface tension × surface area × number of free surfaces

$= (4.5 \times 10^{-2}) \times 4\pi \times (2.1 \times 10^{-2}) \times 2$

$= 4.98 \times 10^{-4}$ J

27. A mercury drop of radius 1.0 cm is sprayed into 10^6 droplets of equal sizes. The energy expended in this process is (surface tension of mercury is equal to 32×10^{-2} Nm^{-1})

(1) 3.98×10^{-4} J (2) 8.46×10^{-4} J (3) 3.98×10^{-2} J (4) 8.46×10^{-2} J

Sol. Answer (3)

Energy expended = surface tension × increase in area (Formulae)

So, volume initially = volume of 10^6 drops

$$\Rightarrow \frac{4}{3}\pi\left(\frac{1}{100}\right)^3 = 10^6 \times \frac{4}{3}\pi r^3$$

$$\Rightarrow \left[\left(\frac{1}{100}\right)^3 \times \frac{1}{10^6}\right]^{1/3} = r \qquad \text{[Let radius of small drops = } r\text{]}$$

$\Rightarrow$ 10^{-4} m = r

$$\text{So increase in surface area } = 4\pi\left[\left(\frac{1}{10000}\right)^2 \times 10^6 - \left(\frac{1}{100}\right)^2\right]$$

$$= 4\pi\left[\frac{1}{100} - \frac{1}{10000}\right]$$

$$\Rightarrow \Delta A = \frac{4\pi \times 0.99}{100}$$

Using this value in formulae

$$\text{Energy } = 32 \times 10^{-2} \times \frac{4\pi \times 0.99}{100} \qquad [\because \text{ Surface tension} = 32 \times 10^{-2} \text{ (given)}]$$

$= 3.98 \times 10^{-2}$ J

28. When a glass capillary tube of radius 0.015 cm is dipped in water, the water rises to a height of 15 cm within it. Assuming contact angle between water and glass to be 0°, the surface tension of water is [ρ_{water} = 1000 kg m^{-3}, g = 9.81 ms^{-2}]

(1) 0.11 Nm^{-1} (2) 0.7 Nm^{-1} (3) 0.072 Nm^{-1} (4) None of these

Sol. Answer (1)

$$h = \frac{2\,S\cos\theta}{\rho rg}$$

Substituting values

$$\frac{15}{100} = \frac{2\times S\times 1\times 100}{1000\times 0.015\times 9.81}$$

$$\left\{\begin{array}{l}\text{Where,}\\ S = \text{surface tension} = ?\\ h = \text{height of water in capillary} = 15\text{ cm}\\ r = \text{radius of capillary} = 0.015\text{ cm}\\ \theta = \text{angle of contact} = 0^\circ\\ g = 9.8\text{ ms}^{-2}\end{array}\right.$$

$\therefore$ S = 0.11 Nm^{-1}

29. A liquid does not wet the sides of a solid, if the angle of contact is

(1) Obtuse (2) 90° (3) Acute (4) Zero

Sol. Answer (1)

Solid will not get wet if the liquid has high surface tension (example mercury) and liquids with high surface tension have obtuse angle of contact.

30. Two drops of equal radius coalesce to form a bigger drop. What is ratio of surface energy of bigger drop to a smaller one?

(1) $2^{1/2} : 1$ (2) 1 : 1 (3) $2^{2/3} : 1$ (4) None of these

Sol. Answer (3)

Surface energy = surface tension × surface area

Let the radius of smaller drops be r

And that of bigger drop be R

Then ratio of surface energies = ratio of surface area [$\because$ Surface tension is same for both]

$= 4\pi R^2 : 4\pi r^2$

$= R^2 : r^2$ ...(1)

$\because$ 2 smaller drops are forming 1 big drop so

$$2\times\frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3$$

So, $2^{1/3}r = R$ ...(2)

$\Rightarrow$ Using 1 and 2 we can say that ratio of surface energies = $2^{2/3}r^2 : r^2 = 2^{2/3} : 1$

31. The excess pressure inside a spherical drop of water is frour times that of another drop. Then their respective mass ratio is

(1) 1 : 16 (2) 8 : 1 (3) 1 : 4 (4) 1 : 64

Sol. Answer (4)

Excess pressure $= \dfrac{2T}{r}$ {Where, r = radius of drop

$$\Delta P \propto \frac{1}{r}$$

$$\frac{\Delta P_1}{\Delta P_2} = \frac{r_2}{r_1} = \frac{4}{1} \qquad \left[\because \ \frac{\Delta P_1}{\Delta P_2} = \frac{1}{4}\right]$$

$$V \propto r^3$$

$$\frac{V_1}{V_2} = \left(\frac{r_1}{r_2}\right)^3 = \left(\frac{1}{4}\right)^3 = \frac{1}{64}$$

$\therefore$ $M = V \times \rho$ then

$$\frac{M_1}{M_2} = \frac{V_1}{V_2} = \frac{1}{64}$$

SECTION - D

Assertion - Reason Type Questions

1. A : Hydraulic lift is based on Pascal's Law.

R : Hydrostatic pressure is a scalar quantity

Sol. Answer (2)

A : is true

R : is true

But reason is not the correct explanation. Correct explanation is, change in pressure is transferred, undiminished from one point to the other.

2. A : The apparent weight of a body floating on the surface of a liquid is zero.

R : The net force on a body floating on the surface of a liquid is zero.

Sol. Answer (1)

A : is true

R : is true

And reason is also the correct explanation.

3. A : It is better to wash cloths in hot water than cold water.

R : On increasing temperature surface tension of water decreases.

Sol. Answer (1)

A : is true

R : is true and correct explanation.

4. A : The impurities added to water may increase or decrease surface tension.

R : The change in surface tension depends on the nature of impurities.

Sol. Answer (1)

A is true, R is true and correct explanation.

5. A : On increasing temperature the angle of contact generally decreases.

R : With rise in temperature, the surface tension of liquid increases.

Sol. Answer (4)

A : is false : Angle of contact increases with increase in temperature.

R : is false : Surface tension decreases with rise in temperature.

6. A : If air blows over the roof of a house, the force on the roof is upwards.

R : When air blows over the roof, the pressure over it from out side decreases.

Sol. Answer (1)

A is true, R is true and correct explanation.

7. A : When rain drops fall through air some distance, they attain a constant velocity.

R : The viscous drag of air just balances the weight of rain drops.

Sol. Answer (1)

A : is true

R : is true and correct explanation.

8. A : Bernoulli's theorem holds good only for non-viscous and incompressible liquid.

R : Bernoulli's theorem is based on the conservation of energy.

Sol. Answer (2)

A : is true

R : is true

Correct explanation of 'A' is Bernoulli's equation does not take into account the elastic energy of the fluids.

9. A : At high altitudes (mountains), it is very difficult to stop bleeding from a cut in the body.

R : At high altitude the atmospheric pressure is less than the blood pressure inside the body.

Sol. Answer (1)

A : is true

R : is true and correct explanation.

10. A : When liquid drops merge into each other to form a large drop, energy is released.

R : When liquid drops merge to form large drop surface tension decreases.

Sol. Answer (3)

A : is true

R : is false, because when large drop is formed, surface area gets reduced. Hence surface energy gets reduced due to reduction in surface area not the surface tension.

11. A : Excess pressure inside a soap bubble is $\frac{4T}{r}$ (symbols have their usual meanings).

R : The pressure difference across a curved surface of radius of curvature r is $\frac{2T}{r}$. There are two surfaces in a soap bubble.

Sol. Answer (1)

A : is true

R : is true and correct explanation.

12. A : Buoyant force is always vertically upward.

R : Buoyant force is always opposite to the direction of acceleration due to gravity.

Sol. Answer (4)

A : is wrong, Buoyant force is not always vertically upwards

R : is wrong, Buoyant force is always opposite to the direction of effective acceleration.

13. A : Equation of continuity is $A_1v_1\rho_1 = A_2v_2\rho_2$ (symbols have their usual meanings).

R : Equation of continuity is valid only for incompressible liquids.

Sol. Answer (3)

A : is true

R : is false,

14. A : Atomizer is based on the principle of Bernoulli's theorem.

R : Bernoulli's theorem is based on the conservation of energy.

Sol. Answer (2)

A : is true

R : is true, but not the correct explanation

Correct explanation is, decrease in pressure forces the water to move up the tube and get sprayed.

15. A : The spiders and insects can run on the surface of water.

R : Buoyant force balances the weight of insects.

Sol. Answer (3)

A : true

R : is false, surface tension balances the weight of insect.

❑ ❑ ❑

Chapter 11

Thermal Properties of Matter

Solutions

SECTION - A

Objective Type Questions

1. Temperature is a measure of

   (1) Hotness or coldness (2) Heat possessed by a body

   (3) Potential energy (4) Thermal energy

Sol. Answer (1)

Temperature is the measure of hotness and coldness.

2. The readings of a bath on Celsius and Fahrenheit thermometers are in the ratio 2 : 5. The temperature of the bath is

   (1) –26.66°C (2) 40°C (3) 45.71°C (4) 26.66°C

Sol. Answer (3)

$$\frac{T_C}{100} = \frac{T_F - 32}{180} \qquad \left\{\begin{array}{l}\text{where} \\ T_C \longrightarrow \text{temperature in Celcius} \\ T_F \longrightarrow \text{temperature in Fahrenheit}\end{array}\right\}$$

$T_C : T_F$ given as 2 : 5

Let $T_C = 2x$

$T_F = 5x$

$$\frac{2x}{10} = \frac{5x - 32}{18}$$

$$x = \frac{160}{7}$$

So, $2x = \frac{320}{7} \sim 45.7°\text{C}$

3. The pressure of a gas filled in the bulb of a constant volume gas thermometer at temperatures 0°C and 100°C are 27.50 cm and 37.50 cm of Hg respectively. At an unknown temperature the pressure is 32.45 cm of Hg. Unknown temperature is

   (1) 30°C (2) 39°C (3) 49.5°C (4) 29.6°C

Sol. Answer (3)

$$\frac{P-P_0}{P_{100}-P_0}=\frac{x-x_0}{x_{100}-x_0}=\frac{T-T_0}{T_{100}-T_0}$$

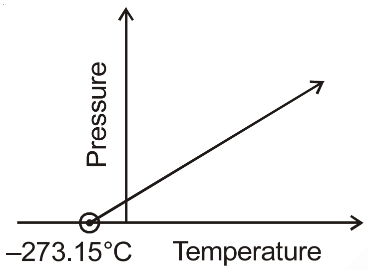
$$\frac{32.45-27.50}{37.50-27.50}=\frac{T-O}{100-0}$$

$T = 49.5°C$

4. A graph is plotted by taking pressure along *y*-axis and centigrade temperature along *x*-axis for an ideal gas at constant volume. *x* intercept of the graph is

(1) –273.15ºC (2) –273.15 K (3) –273ºC (4) –273 K

Sol. Answer (1)



5. A hole is drilled in a copper sheet. The diameter of hole is 4.24 cm at 27.0°C. Diameter of the hole when it is heated to 35°C is

(1) Less than 4.24 cm (2) Equal to 4.24 cm

(3) More than 4.24 cm (4) Data insufficient

Sol. Answer (3)

Thermal expansion in this case can be imagined as a photographic enlargement, hence the diameter of hole will also increase.

6. The density of water is maximum at

(1) 39.2°F (2) 4°F (3) 0°C (4) 273 K

Sol. Answer (1)

Density of water is maximum at 4°C or 39.2°F.

7. On heating a uniform metallic cylinder length increases by 3%. The area of cross-section of its base will increase by

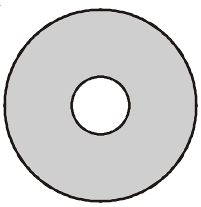
(1) 1.5% (2) 3% (3) 9% (4) 6%

Sol. Answer (4)

$\beta = 2\alpha$

∴ Area of crossection increases by 2 × 3 = 6%

8. A circular metallic disc of radius R has a small circular cavity of radius r as shown in figure. On heating the system



(1) R increases and r decreases
(2) R decreases and r increases
(3) Both R and r increases
(4) Both R and r decreases

Sol. Answer (3)

Both R and r will increase, superficial expansion is always outwards.

9. If in winter season the surface temperature of lake is 1°C, the temperature at the bottom of lake will be

(1) 1°C
(2) 0°C
(3) 4°C
(4) All values less than 1°C are possible

Sol. Answer (3)

Temperature of the surface is the lowest and it should increase as we go down to the bottom.

Temperature > 1°C

10. A uniform copper rod of length 50 cm and diameter 3.0 mm is kept on a frictionless horizontal surface at 20°C. The coefficient of linear expansion of copper is 2.0×10^{-5} K^{-1} and Young's modulus is 1.2×10^{11} N/m^2. The copper rod is heated to 100°C, then the tension developed in the copper rod is

(1) 12×10^3 N
(2) 36×10^3 N
(3) 18×10^3 N
(4) Zero

Sol. Answer (4)

Since the rod is not bounded, No compressive stress

hence no tensions

11. A seconds pendulum clock has a steel wire. The clock shows correct time at 25°C. How much time does the clock lose or gain, in one week, when the temperature is increased to 35°C?

($\alpha_{\text{steel}} = 1.2 \times 10^{-5}$ / °C)

(1) 321.5 s
(2) 3.828 s
(3) 82.35 s
(4) 36.28 s

Sol. Answer (4)

$$\frac{\Delta T}{T} = \frac{1}{2}\alpha\,\theta$$

$$= \frac{1}{2} \times 1.2 \times 10^{-5} \times 10$$

$$\frac{\Delta T}{T} = 6.0 \times 10^{-5}$$

Hence time lost in 1 week = $6.0 \times 10^{-5} \times T$

$= 6.0 \times 10^{-5} \times 7 \times 24 \times 3600$

$= 36.28$ s

12. The apparent coefficient of expansion of a liquid when heated in a brass vessel is X and when heated in a tin vessel is Y. If α is the coefficient of linear expansion for brass, the coefficient of linear expansion of tin is

(1) $\frac{X+Y+3\alpha}{3}$ (2) $\frac{X+3\alpha-Y}{3}$ (3) $\frac{X+Y-2\alpha}{3}$ (4) $\frac{(X+Y-2\alpha)}{2}$

Sol. Answer (2)

Coefficient of expansion of liquid = [Apparent coefficient of expansion + Coefficient of expansion of vessel]

Let coefficient of expansion of liquid be = x

Then

$$x = X + 3\,\alpha_{brass}$$

$$x = Y + 3\,\alpha_{tin}$$

$$X + 3\,\alpha_{brass} = Y + 3\,\alpha_{tin}$$

$$\alpha_{tin} = \frac{3\alpha_{brass} - Y + X}{3} = \frac{3\alpha - Y + X}{3}$$

13. The coefficient of volume expansion of glycerin is 49×10^{-5} K^{-1}. The fractional change in the density on a 30°C rise in temperature is

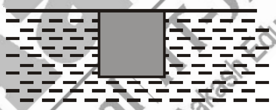
(1) 1.47×10^{-2} (2) 1.47×10^{-3} (3) 1.47×10^{-1} (4) 1.47×10^{-4}

Sol. Answer (1)

$$\rho_2 = \rho_1(1 - \gamma\Delta T)$$

$$\frac{-\rho_2+\rho_1}{\rho_1} = 49\times10^{-5}\times30 \Rightarrow \frac{\Delta\rho}{\rho_1} = 1.47\times10^{-2} \qquad [\because\ \Delta\rho = \rho_1 - \rho_2]$$

14. A solid cube is first floating in a liquid. The coefficient of linear expansion of cube is α and the coefficient of volume expansion of liquid is γ. On increasing the temperature of (liquid + cube) system, the cube will sink if



(1) $\gamma = 3\alpha$ (2) $\gamma > 3\alpha$ (3) $\gamma < 3\alpha$ (4) $\gamma = 2\alpha$

Sol. Answer (2)

Cube will sink if expansion in liquid upon heating is more than that of cube

or $3\,\alpha < \gamma$

15. A steel tape is calibrated at 20°C. On a cold day when the temperature is –15°C, percentage error in the tape will be [$\alpha_{steel} = 1.2 \times 10^{-5}$ °C^{-1}]

(1) –0.035% (2) –0.042% (3) 0.012% (4) –0.018%

Sol. Answer (2)

$$\%\text{ error} = \frac{\Delta L}{L}\times100$$

$$= \frac{L\,\alpha\,\Delta T}{L}\times100$$

$$= 1.2\times10^{-5}\times(-35)\times100 = -0.042\%$$

16. In engines water is used as coolant, because

(1) It's good conductor of heat energy (2) It has low density

(3) It has high specific heat (4) It's bad conductor of heat energy

Sol. Answer (3)

Because it absorbs and gives off heat readily or it has high specific heat.

17. Which of the following material is used to make calorimeter?

(1) Glass (2) Ebonite (3) Metal (4) Superconductor

Sol. Answer (3)

Metal is used (copper)

18. The thermal capacity of 100 g of aluminum (specific heat = 0.2 cal/g°C) is

(1) 0.002 cal/°C (2) 20 cal/°C (3) 200 cal/°C (4) 100 cal/°C

Sol. Answer (2)

Thermal capacity = m.C

= 100 × 0.2 = 20 cal/°C

19. Select correct statement related to heat

(1) Heat is possessed by a body

(2) Hot water contains more heat as compared to cold water

(3) Heat is a energy which flows due to temperature difference

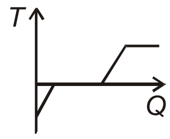
(4) All of these

Sol. Answer (3)

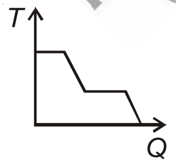
Heat is a energy which flows due to temperatures difference.

20. A block of ice at –12°C is slowly heated and converted into steam at 100°C. Which of the following curves best represents the event?

(1)



(2)



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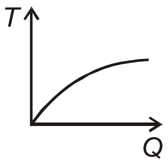
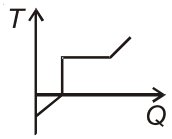
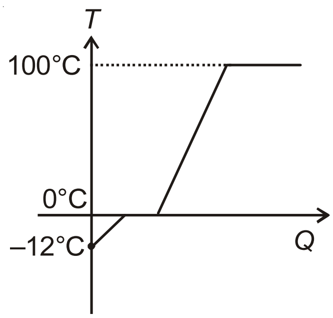


(4)



Sol. Answer (1)



21. The water equivalent of 20 g of aluminium (specific heat 0.2 cal g^{-1} $°C^{-1}$), is

(1) 40 g (2) 4 g (3) 8 g (4) 160 g

Sol. Answer (2)

$0.2 \times 20 = 4$ [Thermal Capacity]

Water equivalent numerically equal to thermal capacity

So $W = 4$ g

22. 100 g of ice (latent heat 80 cal g^{-1}, at 0°C) is mixed with 100 g of water (specific heat 1 cal g^{-1} $°C^{-1}$) at 80°C. The final temperature of the mixture will be

(1) 0°C (2) 40°C (3) 80°C (4) < 0°C

Sol. Answer (1)

100 g ice 0°C + 100 g water 80°C

$Q_{\text{required}} = mL$ if $\Delta T = 80$ [Q_f becomes = 0°]

$= 100 \times 80$ $Q_{\text{available}} = mC\Delta T$

$= 8000$ cal $= 100 \times 1 \times 80 = 8000$ cal

[Required to melt whole ice]

Since $Q_{\text{required}} = Q_{\text{available}}$

$\therefore$ Whole system will be water at equillibrium and temperature would be 0°C

23. 200 g of ice at –20°C is mixed with 500 g of water at 20°C in an insulating vessel. Final mass of water in vessel is (specific heat of ice = 0.5 cal $g^{-1}°C^{-1}$)

(1) 700 g (2) 600 g (3) 400 g (4) 200 g

Sol. Answer (2)

Maximum heat supplied by water

$\Delta Q_1 = 500 \times 1 \times (20 - 0)$

$= 10,000$ cal

Heat required to raise the temperature of ice upto 0°C

$\Delta Q_2 = 200 \times 0.5 \times 20$

$= 2000$ cal

$\Delta Q_1 - \Delta Q_2 = 8000$ cal

Melts the ice

$8000 = m \times 80$

$m = 100$ g

So, mass of water is 500 + 100 = 600 g.

24. Which of the following material is most suitable for cooking utensil?

(1) Low conductivity and low specific heat (2) High conductivity and low specific heat

(3) Low conductivity and high specific heat (4) High conductivity and high specific heat

Sol. Answer (2)

For cooking high conductivity and low specific heat because we do not want to waste heat energy in heating up the vessel it self also we want the vessel to absorb as much as heat is available.

25. Which of the following factors affect the thermal conductivity of a rod?

(1) Area of cross-section (2) Length of rod

(3) Material of rod (4) All of these

Sol. Answer (3)

Thermal conductivity is material property.

26. What is the dimensional formula for thermal resistance?

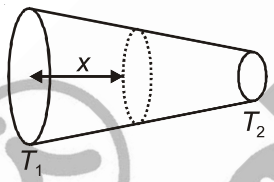
(1) $[M^{-1} L^{-2} T^{-1} K]$ (2) $[ML^{2} T^{-2} K^{-1}]$ (3) $[ML^{-3} T^{2} K^{-1}]$ (4) $[M^{-1} L^{-2} T^{3} K]$

Sol. Answer (4)

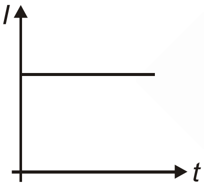
$$R = \frac{L}{KA}$$

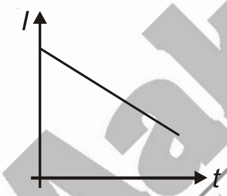
$[R] = [M^{-1} L^{-2} T^{3} K]$

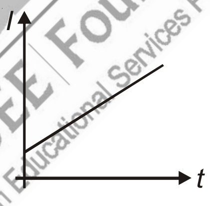
27. Two ends of a rod of non uniform area of cross-section are maintained at temperature T_1 and T_2 ($T_1 > T_2$) as shown in the figure

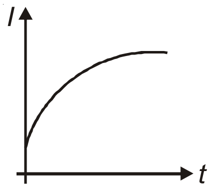


If I is heat current through the cross-section of conductor at distance x from its left face, then the variation of I with x is best represented by

(1) 

(2) 

(3) 

(4) 

Sol. Answer (1)

In steady state rate of heat transfer is constant so heat current through any cross-section remains same with time.

28. Four rods of same material with different radii r and length l are used to connect two reservoirs of heat at different temperatures. Which one will conduct maximum heat?

(1) $r = 1$ cm, $l = 1$ m (2) $r = 2$ cm, $l = 2$ m

(3) $r = 1$ cm, $l = 1/2$ m (4) $r = 2$ cm, $l = 1/2$ m

Sol. Answer (4)

$$H = \frac{K\pi r^2}{L}(T_2 - T_1)$$

$$H \propto r^2 \text{ and } H \propto \frac{1}{L}$$

So the rod with maximum $\frac{r^2}{L}$ ratio will conduct maximum heat.

29. Two walls of thickness d_1 and d_2, thermal conductivities K_1 and K_2 are in contact. In the steady state if the temperatures at the outer surfaces are T_1 and T_2, the temperature at the common wall will be

(1) $\frac{K_1T_1 + K_2T_2}{d_1 + d_2}$
(2) $\frac{K_1T_1d_2 + K_2T_2d_1}{K_1d_2 + K_2d_1}$
(3) $\frac{(K_1d_1 + K_2d_2)T_1T_2}{T_1 + T_2}$
(4) $\frac{K_1d_1T_1 + K_2d_2T_2}{K_1d_1 + K_2d_2}$

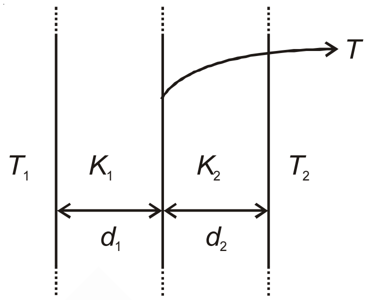
Sol. Answer (2)

Heat flow across both the walls will be same.

$$\frac{K_1A}{d_1}(T - T_1) = \frac{K_2A}{d_2}(T_2 - T)$$

$$K_1Td_2 - K_1T_1d_2 = K_2T_2d_1 - K_2Td_1$$

$$T = \frac{K_1T_1d_2 + K_2T_2d_1}{K_1d_2 + K_2d_1}$$



30. A cylinder of radius R made of a material of thermal conductivity K_1 is surrounded by a cylindrical shell of inner radius R and outer radius $2R$ made of a material of thermal conductivity K_2. The two ends of the combined system are maintained at two different temperatures. There is no loss of heat across the cylindrical surface and the system is in steady state. The effective thermal conductivity of the system is

(1) $K_1 + K_2$
(2) $\frac{K_1 + 3K_2}{4}$
(3) $\frac{K_1K_2}{K_1 + K_2}$
(4) $\frac{3K_1 + K_2}{4}$

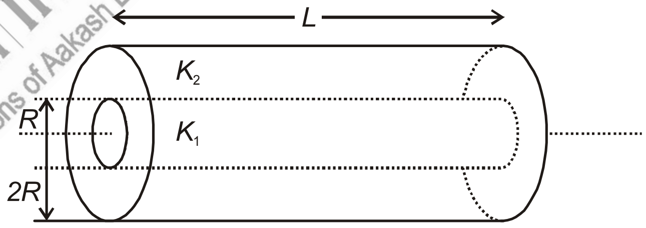
Sol. Answer (2)

$R = \frac{L}{KA}$ [R is thermal resistance]

These two cylinders are like two resistances in a parallel connection.

$$\therefore \quad \frac{1}{R_{\text{eff}}} = \frac{1}{R_1} + \frac{1}{R_2}$$

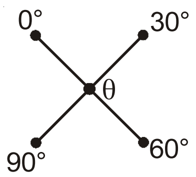
$$\frac{K_{eff} \times \pi(2R)^2}{L} = \frac{K_1 \times \pi R^2}{L} + \frac{K_2 \times \pi(4R^2 - R^2)}{L}$$



Solving for K_{eff} we get

$$K = \frac{K_1 + 3K_2}{4}$$

31. Four rods of same material and having the same cross section and length have been joined, as shown. The temperature of the junction of four rods will be



(1) 20°C
(2) 30°C
(3) 45°C
(4) 60°C

Sol. Answer (3)

Incoming heat = outgoing heat

$(90° - \theta) + (60° - \theta) = \theta - 30° + \theta - 0°$

$180° = 4\theta$

$45°C = \theta$

32. Why it is more hotter for same distance over the top of a candle than it in the side of its flame?

(1) Conduction of heat in air is upward

(2) Heat is maximum radiated in upward direction

(3) Radiation and conduction both contribute in transferring heat upwards

(4) Convection takes more heat in upward direction

Sol. Answer (4)

On the sides heating is only due to Radiation but over the top heating is due to Radiation as well as convection.

33. In gravity free space heat transfer is not possible by

(1) Conduction (2) Convection (3) Radiation (4) Both (1) & (3)

Sol. Answer (2)

For heat transfer through convention presence of gravity is a must requirement.

34. Which factor does not affect convection?

(1) Temperature difference (2) The rate of movement of carrying medium

(3) The volumetric specific heat of carrying medium (4) The thermal conductivity of carrying medium

Sol. Answer (4)

The thermal conductivity of carrying medium does not affects convection process.

35. A polished plate with rough black spot is heated to a high temperature and then taken to a dark room, then

(1) Spot will appear brighter than the plate (2) Spot will appear darker than the plate

(3) Both will appear equally brighter (4) Both will not be visible

Sol. Answer (1)

Rough black spot will act like a black body so radiations absorbed as well as emitted by the spot would be more than the other parts of the plate.

36. Select the incorrect statement

(1) A body radiates at all temperatures except 0 K

(2) A good reflector is a bad radiator

(3) A colder body can radiate heat to the hotter surroundings

(4) A body does not radiate when its temperature is below 0ºC

Sol. Answer (4)

0°C is 273 K so a body will radiate.

37. “A good absorber is a good emitter” is explained by

(1) Stefan’s law (2) Wien’s law

(3) Newton’s law of cooling (4) Kirchhoff’s law

Sol. Answer (4)

Kirchhoff's Law states that "A good absorber is a good emitter".

38. The rate of radiation of energy from a hot object is maximum, if its surface is

(1) White and smooth (2) Black and rough (3) Black and smooth (4) White and rough

Sol. Answer (2)

Black and rough surfaces absorb maximum amount of radiation and than radiate the same amount of radiations.

39. Two balls of same material and same surface finish have their diameters in the ratio 1 : 2. They are heated to the same temperature and are left in a room to cool by radiation, then the initial rate of loss of heat

(1) Will be same for the balls

(2) For larger ball is half that of other ball

(3) For larger ball is twice that of other ball

(4) For larger ball is four times that of the other ball

Sol. Answer (4)

By Stefan-Boltzmann's law

$$H = \sigma eA\left(T^4 - T_0^4\right)$$

$$H \propto A \propto r^2$$

$\therefore$ *f* or larger ball is $(2)^2$ that of the smaller ball.

40. A black body, which is at a high temperature *T* K, thermal radiation emitted at the rate of *E* W/m^2. If the temperature falls to *T*/4 K*,* the thermal radiation emitted in W/m^2 will be

(1) *E* (2) *E*/4 (3) *E*/64 (4) *E*/256

Sol. Answer (4)

Radiation $\propto T^4$

$$\frac{E_1}{E_2} = \frac{T_1^4}{T_2^4}$$

$$\frac{E}{E_2} = \frac{T^4 \times (4)^4}{T^4}$$

$$\Rightarrow \quad E_2 = \frac{E}{256}$$

41. A sphere, a cube and a thin circular plate, all made of the same mass and finish are heated to a temperature of 200°C. Which of these objects will cool slowest, when left in air at room temperature?

(1) The sphere (2) The cube

(3) The circular plate (4) All will cool at same rate

Sol. Answer (1)

Objects with more surface area cool faster [Stefan Boltzmann law].

42. A body cools down from 80°C to 60°C in 10 minutes when the temperature of surroundings is 30°C. The temperature of the body after next 10 minutes will be

(1) 30°C (2) 48°C (3) 50°C (4) 52°C

Sol. Answer (2)

Apply newton's law of cooling

$$\ln\left(\frac{T_1-T_0}{T_2-T_0}\right)=Kt$$

$$\ln\left(\frac{80-30}{60-30}\right)=K\times 10 \qquad \ldots(1)$$

Let temperature of body after next 10 minutes = T

So,

$$\ln\left(\frac{60-30}{T-30}\right)=K\times 10 \qquad \ldots(2)$$

Using equation 1 and 2

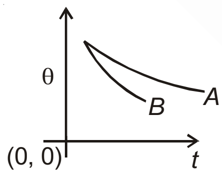
$$\ln\frac{5}{3}=\ln\frac{30}{T-30}$$

$$30\times 3=5T-5\times 30$$

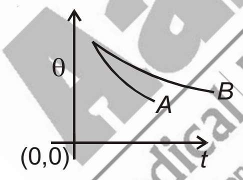
$$\Rightarrow \quad T=48°\text{C}$$

43. Two bodies A and B of same mass, area and surface finish with specific heats S_A and S_B ($S_A > S_B$) are allowed to cool for given temperature range. Temperature varies with time as

(1)



(2)



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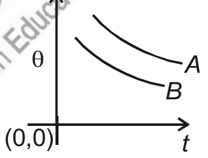

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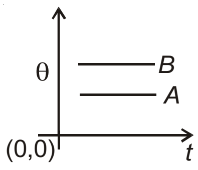
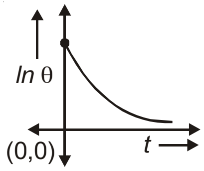


Sol. Answer (1)

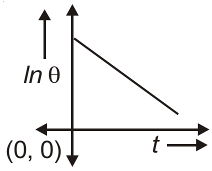
Body with more specific heat takes time to cool if initial temperature is same.

44. Instantaneous temperature difference between cooling body and the surroundings obeying Newton's law of cooling is θ. Which of the following represents the variation of *ln* θ with time *t*?

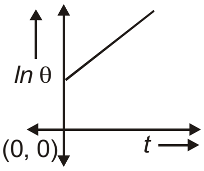
(1)



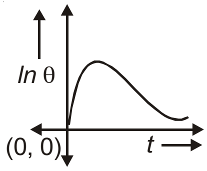
(2)



(3)



(4)



Sol. Answer (2)

$$\ln\left(\frac{T_f-T_0}{T-T_0}\right)=Kt$$

If θ is the instantaneous temperature than

$$\ln\left(\frac{\theta_i-\theta_0}{\theta-\theta_0}\right)=Kt$$

$$\left\{\begin{matrix}\theta_i \longrightarrow \text{initial temperature} \\ \theta_0 \longrightarrow \text{temperature of surrounding}\end{matrix}\right\}$$

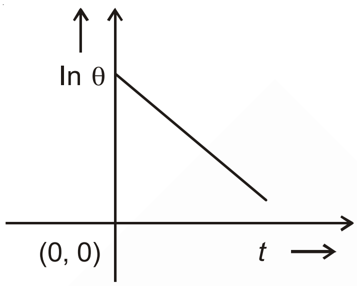
$\ln(\theta_i-\theta_0)-\ln(\theta-\theta_0)=KT$

$\ln(\theta-\theta_0)=-Kt+\ln(\theta_i-\theta_0)$

Comparing to

$y = mx + C$

We get a negative slope, so graph will be a straight line with decreasing slope.



45. Two metal spheres have radii r and $2r$ and they emit thermal radiation with maximum intensities at wavelengths λ and 2λ respectively. The respective ratio of the radiant energy emitted by them per second will be

(1) 4 : 1 (2) 1 : 4 (3) 16 : 1 (4) 8 : 1

Sol. Answer (1)

$$T\propto\frac{1}{\lambda}$$ [wien's displacement law]

So, $\frac{T_1}{T_2}=\frac{\lambda_2}{\lambda_1}=\frac{2\lambda}{\lambda}=2$

and $H=eA\sigma T^4\Rightarrow H\propto AT^4$

$$\frac{H_1}{H_2}=\frac{4\pi r^2}{4\pi(2r)^2}\times\frac{T_1^4}{T_2^4}=\frac{1}{4}\times(2)^4=4$$

$\therefore\quad H_1 : H_2 :: 4 : 1$

46. If temperature of sun is decreased by 1 % then the value of solar constant will change by

(1) 2% (2) –4% (3) –2% (4) 4%

Sol. Answer (2)

Solar constant $\propto T^4$

$$\left[\because S=\left[\frac{R}{r}\right]^2\sigma T^4\right]$$

$$\frac{\Delta S}{S}=\frac{4\Delta T}{T}$$

and $\frac{\Delta T}{T}=-1\%$ [given]

So $\frac{\Delta S}{S}=-4\%$

47. The value of solar constant is

(1) 2 kcal m^{-2} minute^{-1} (2) 20 kcal m^{-2} minute^{-1}

(3) 2 kWm^{-2} (4) 200 Wm^{-2}

Sol. Answer (2)

Value of solar constant $= \left[\frac{R}{r}\right]^2 \sigma T^4$

Where,

R = Radius of sun

r = Distance of earth from sun

σ = Stefan's constant

T = Temperature of sun

$\frac{R}{r} = 4.65 \times 10^{-3}$ radians

$\sigma = 5.67 \times 10^{-8}$ Wm^{-2}K^{-4}

$T = 5800$ K

So substituting values we get

$S = (4.65 \times 10^{-3})^2 \times 5.67 \times 10^{-8} \times (5800)^4$

$\simeq 1360$ Wm^{-2}

~ 21 Kcal m^{-2} min^{-1}

SECTION - B

Objective Type Questions

1. A uniform thermometre scale is at steady state with its 0 cm mark at 20°C and 100 cm mark at 100°C. Temperature of the 60 cm mark is

(1) 48°C (2) 68°C (3) 52°C (4) 58°C

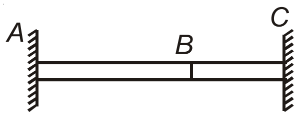
Sol. Answer (2)

$$\frac{T-20}{100-20} = \frac{60-0}{100-0}$$

$$\frac{T-20}{80} = \frac{60}{100}$$

$T = 48 + 20 = 68°C$

2. Two uniform rods AB and BC have Young's modulii 1.2×10^{11} N/m² and 1.5×10^{11} N/m² respectively. If coefficient of linear expansion of AB is 1.5×10^{-5}/°C and both have equal area of cross section, then coefficient of linear expansion of BC, for which there is no shift of the junction at all temperatures, is



(1) 1.5×10^{-5}/°C (2) 1.2×10^{-5}/°C (3) 0.6×10^{-5}/°C (4) 0.75×10^{-5}/°C

Sol. Answer (2)

$Y_{AB} = 1.2 \times 10^{11}$ N/m^2, $Y_{BC} = 1.5 \times 10^{11}$ N/m^2

No shift of the junction at all

$$\therefore \quad \alpha\angle\Delta\theta = \frac{FL}{AY}$$

$$\Rightarrow \quad \alpha \propto \frac{1}{Y}$$

So, $\frac{\alpha_1}{\alpha_2} = \frac{Y_2}{Y_1}$

Substituting values

$$\frac{1.5\times10^{-5}}{\alpha_2} = \frac{1.5\times10^{11}}{1.2\times10^{11}}$$

$\alpha_2 = 1.2 \times 10^{-5}$/°C

3. Coefficient of linear expansion of a vessel completely filled with Hg is 1×10^{-5}/°C. If there is no overflow of Hg on heating the vessel, then coefficient of cubical expansion of Hg is

(1) 4×10^{-5}/°C (2) $> 3 \times 10^{-5}$/°C (3) $\leq 3 \times 10^{-5}$/°C (4) Data is insufficient

Sol. Answer (3)

Expansion in Hg volume ≤ expansion in container.

$\Rightarrow$ Volume coefficient of Hg ≤ 3 × Linear coefficient of expansion of vessel

$\leq 3 \times 1 \times 10^{-5}$/°C

$\gamma_{Hg} \leq 3 \times 10^{-5}$/°C

4. A metallic tape gives correct value at 25ºC. A piece of wood is being measured by this metallic tape at 10ºC. The reading is 30 cm on the tape, the real length of wooden piece must be

(1) 30 cm (2) > 30 cm

(3) < 30 cm (4) Data is not sufficient

Sol. Answer (3)

At lesser temperature tape will decrease in length so the reading 30 cm on the tape is lesser than 30 cm in real.

5. In a thermostat two metal strips are used, which have different

(1) Length (2) Area of cross-section

(3) Mass (4) Coefficient of linear expansion

Sol. Answer (4)

Coefficient of linear expansion should be different.

6. The coefficient of linear expansion of a crystalline substance in one direction is 2×10^{-4}/°C and in every direction perpendicular to it is 3×10^{-4}/°C. The coefficient of cubical expansion of crystal is equal to

(1) 5×10^{-4}/°C (2) 4×10^{-4}/°C (3) 8×10^{-4}/°C (4) 7×10^{-4}/°C

Sol. Answer (3)

$\alpha_1 + \alpha_2 + \alpha_3 = \alpha$

$2 \times 10^{-4} + 3 \times 10^{-4} + 3 \times 10^{-4} = \alpha$

$\Rightarrow 8 \times 10^{-4}$/°C $= \alpha$

7. If C_p and C_v denote the specific heats (per unit mass) of an ideal gas of molecular weight M, where R is the molar gas constant

(1) $C_p - C_v = R/M^2$ (2) $C_p - C_v = R$ (3) $C_p - C_v = R/M$ (4) $C_p - C_v = MR$

Sol. Answer (3)

$$C_p - C_v = \frac{R}{M}$$

because C_p and C_v are given per unit mass.

8. The molar specific heat at constant pressure of an ideal gas is (7/2)R. The ratio of specific heat at constant pressure to that at constant volume is

(1) $\frac{9}{7}$ (2) $\frac{7}{5}$ (3) $\frac{8}{7}$ (4) $\frac{5}{7}$

Sol. Answer (2)

$$C_p = \frac{7}{2}R$$

$$C_v = C_p - R$$

$$= \frac{5}{2}R$$

$$\therefore \quad \frac{C_p}{C_v} = \frac{7}{5}$$

9. A bullet of mass 10 g moving with a speed of 20 m/s hits an ice block of mass 990 g kept on a frictionless floor and gets stuck in it. How much ice will melt if 50% of the lost KE goes to ice? (initial temperature of the ice block and bullet = 0°C)

(1) 0.001 g (2) 0.002 g (3) 0.003 g (4) 0.004 g

Sol. Answer (3)

50% of lost KE goes to melt ice

$$\Rightarrow \quad \frac{1}{2}\times\frac{1}{2}\times\frac{10\times20\times20}{1000} = 1\text{ J}$$

$$\text{Amount of ice that melts } = \frac{1}{80\times4.2} = 0.003\text{ g}$$

10. 50 g ice at 0°C is dropped into a calorimeter containing 100 g water at 30°C. If thermal capacity of calorimeter is zero then amount of ice left in the mixture at equilibrium is

(1) 12.5 g (2) 25 g (3) 20 g (4) 10 g

Sol. Answer (1)

Heat required to bring 100 g of water from 30°C to 0°C will be

$Q = 100 \times 1 \times 30 = 3000$ cal

$$\therefore \quad \text{Amount of ice that get melted} = \frac{3000}{80} = 37.5\text{ g}$$

So amount left = 12.5 g

11. Heat is being supplied at a constant rate to the sphere of ice which is melting at the rate of 0.1 gm/s. It melts completely in 100 s. The rate of rise of temperature thereafter will be

(1) 0.4°C/s (2) 2.1°C/s (3) 3.2°C/s (4) 0.8°C/s

Sol. Answer (4)

$$\frac{dQ}{dt}=\frac{dm}{dt}\times L \qquad [\because Q=mL]$$

$$\frac{dQ}{dt}=0.1\times 80=8\text{ cal/gs}$$

also, $Q = ms\Delta t$

So $\frac{dQ}{dt}=ms\frac{dT}{dt}$

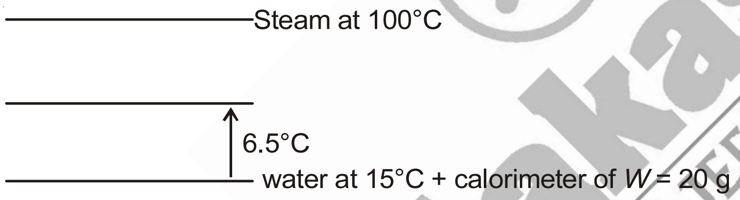
$$8=10\times 1\times\frac{dT}{dt} \qquad [\because \text{ It melts in 100 s so total mass of sphere} = 0.1 \times 100 = 10\text{ g}]$$

$$8°\text{C/s}=\frac{dT}{dt}$$

12. In a calorimeter of water equivalent 20 g, water of mass 1.1 kg is taken at 288 K temperature. If steam at temperature 373 K is passed through it and temperature of water increases by 6.5°C then the mass of steam condensed is

(1) 17.5 g (2) 11.7 g (3) 15.7 g (4) 18.2 g

Sol. Answer (2)



Let mass of steam that gets condenced while the temperature of water is raised by 6.5°C = x g

So, heat released by steam = 540x cal + x × 1 × 78.5 [$Q = mL + ms\Delta T$]

This heat goes to the water + calorimeter system

Q required by water = 1100 × 1 × 6.5 = 7150 cal

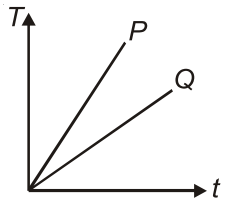
Q required by calorimeter = 20 × 1 × 6.5 = 130 cal

$Q_{\text{released}} = Q_{\text{required}}$

$78.5x + 540x = 7150 + 130$

$x \simeq 11.7$ g

13. Heat energy at constant rate is given to two substances P and Q. If variation of temperature (T) of substances with time (t) is as shown in figure, then select the correct statement.



(1) Specific heat of P is greater than Q (2) Specific heat of Q is greater than P

(3) Both have same specific heat (4) Data is insufficient to predict it

Sol. Answer (2)

$\frac{dT}{dt}$ (slope) less means more specific heat.

14. If the radius of a star is *R* and it acts as a black body, what would be the temperature of the star, in which the rate of energy production is *Q*? (σ stands for Stefan's constant.)

(1) $\left(\frac{4\pi R^2 Q}{\sigma}\right)^{1/4}$ (2) $\left(\frac{Q}{4\pi R^2\sigma}\right)^{1/4}$ (3) $\frac{Q}{4\pi R^2\sigma}$ (4) $\left(\frac{Q}{4\pi R^2\sigma}\right)^{-1/2}$

Sol. Answer (2)

$H = \sigma\,(4\,\pi\,R^2)T^4$ $[H = \sigma\, eAT^4]$ for black body $e = 1$

$$\Rightarrow \quad T = \left[\frac{Q}{\sigma 4\pi r^2}\right]^{1/4}$$

15. Gravitational force is required for

(1) Stirring of liquid (2) Convection (3) Conduction (4) Radiation

Sol. Answer (2)

Gravity is required for convection.

16. Which of the following processes is reversible?

(1) Transfer of heat by conduction (2) Transfer of heat by radiation

(3) Isothermal compression (4) Electrical heating of a nichrome wire

Sol. Answer (3)

In isothermal compression

Work done = *Q* (heat supplied)

∴ Isothermal compression is reversible

17. Solar constant (*S*) depends upon the temperature of the Sun (*T*) as

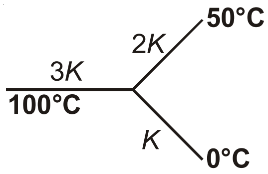
(1) $S \propto T$ (2) $S \propto T^2$ (3) $S \propto T^3$ (4) $S \propto T^4$

Sol. Answer (4)

$$S = \left[\frac{R}{r}\right]^2 \sigma T^4$$

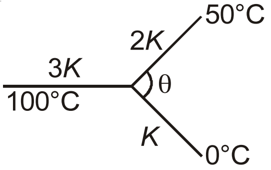
$S \propto T^4$

18. Three rods of same dimensions have thermal conductivities 3*K*, 2*K* and *K*. They are arranged as shown, with their ends at 100°C, 50°C and 0°C. The temperature of their junction is



(1) 75°C (2) $\frac{200}{3}$ °C (3) 40°C (4) $\frac{100}{3}$ °C

Sol. Answer (2)



$3K(100 - \theta) + 2K(50 - \theta) = K\theta$

$300K - 3K\theta + 100K - 2K\theta = K\theta$

$400 = 6\theta$

$$\frac{400}{6} = \theta$$

$$\frac{200}{3} = \theta$$

19. If wavelength of maximum intensity of radiation emitted by Sun and Moon are 0.5×10^{-6} m and 10^{-4} m respectively, then the ratio of their temperature is

(1) $\frac{1}{10}$ (2) $\frac{1}{50}$ (3) 100 (4) 200

Sol. Answer (4)

$\lambda_m T_1$ = Constant [Wien's law]

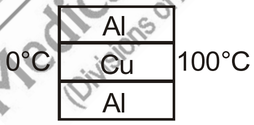
$\Rightarrow \lambda_1 T_1 = \lambda_2 T_2$

$0.5 \times 10^{-6} \times T_1 = 10^{-4} \times T_2$

$$\frac{T_1}{T_2} = 200$$

20. The three rods shown in figure have identical dimensions. Heat flows from the hot end at a rate of 40 W in the arrangement (a). Find the rates of heat flow when the rods are joined as in arrangement (b). (Assume K_{Al} = 200 W/m °C and K_{Cu} = 400 W/m °C)

(a)



(b)

(1) 75 W (2) 200 W (3) 400 W (4) 4 W

Sol. Answer (3)

(a)

∵ The rods have identical dimensions.

Let their area of crossection be = A

and length be = L

So each rod would have heat resistance of

$$R = \frac{L}{KA}$$

$R_{eff} = R_1 + R_2 + R_3$

$$= \frac{L}{K_{Al}A} + \frac{L}{K_{Cu}A} + \frac{L}{K_{Al}A}$$

$$R_{eff} = \frac{L}{A} \times \frac{5}{400} \qquad [\because K_{Al} = 200,\ K_{Cu} = 400]$$

$$H_1 = \frac{\Delta T}{R_{eff}} = \frac{100}{\frac{L}{A} \times \frac{5}{400}} \qquad \ldots(1)$$

(b) When rods are connected in parallel

$$\frac{1}{R_{eff}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

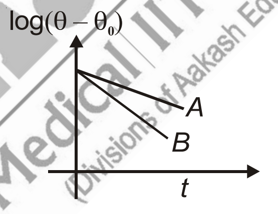
$$R_{eff} = \frac{L}{A} \times 800$$

$$H_2 = \frac{100}{\frac{L}{A} \times 800} \qquad \ldots(2)$$

Dividng (2) by (1)

$$\frac{40}{H_2} = \frac{400}{800 \times 5} \Rightarrow H_2 = 400\ \text{W}$$

21. Two bodies A and B of equal masses, area and emissivity cooling under Newton's law of cooling from same temperature are represented by the graph. If θ is the instantaneous temperature of the body and θ_0 is the temperature of surroundings, then relationship between their specific heats is



(1) $S_A = S_B$ (2) $S_A > S_B$ (3) $S_A < S_B$ (4) None of these

Sol. Answer (2)

Body loosing its temperature soon means low specific heat

$\Rightarrow S_A > S_B$

22. Two spheres of same material and radius r and $2r$ are heated to same temperature and are kept in identical surroundings, ratio of their rate of loss of heat is

(1) 1 : 2 (2) 1 : 4 (3) 1 : 6 (4) 1 : 8

Sol. Answer (2)

Heat loss $\propto$ Area $\propto$ (Radius)^2

$$\text{So } \frac{H_1}{H_2} = \left[\frac{r_1}{r_2}\right]^2 = \left[\frac{r}{2r}\right]^2 = \frac{1}{4}$$

23. Assume that Solar constant is 1.4 kW/m^2, radius of sun is 7 × 10^5 km and the distance of earth from centre of sun is 1.5 × 10^8 km. Stefan's constant is 5.67 × 10^{-8} Wm^{-2} K^{-4}, find the approximate temperature of sun

(1) 5800 K (2) 16000 K (3) 15500 K (4) 8000 K

Sol. Answer (1)

$$S = \left[\frac{R}{r}\right]^2 \sigma T^4$$

$$1.4\times10^3 = \left[\frac{7\times10^5}{1.5\times10^8}\right]^2 \times 5.67\times10^{-8}\times T^4$$

T = 5800 K

24. If a graph is plotted by taking spectral emissive power along y-axis and wavelength along x-axis then the area below the graph above wavelength axis is

(1) Emissivity (2) Total intensity of radiation

(3) Diffusivity (4) Solar constant

Sol. Answer (2)

$$\int_0^\infty e_\lambda \, d\lambda = \text{ area under the graph of } e_\lambda \text{ and } \lambda$$

also it gives total radiated average power per unit surface area which is called total intensity of radiation.

25. A spherical black body with radius 12 cm radiates 450 W power at 500 K. If the radius is halved and temperature is doubled, the power radiated in watt would be

(1) 225 (2) 450 (3) 900 (4) 1800

Sol. Answer (4)

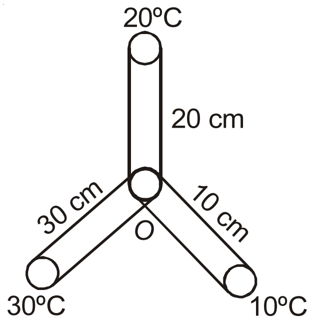
Power radiated ∝ r^2 T^4

$$\frac{P_1}{P_2} = \left[\frac{r_1}{r_2}\right]^2 \left[\frac{T_1}{T_2}\right]^4$$

$$\frac{450}{P_2} = \left[\frac{r}{r/2}\right]^2 \left[\frac{T}{2T}\right]^4 = 1$$

$\Rightarrow$ P_2 = 1800 W

26. Three rods of same material, same area of cross-section but different lengths 10 cm, 20 cm and 30 cm are connected at a point as shown. What is temperature of junction O?



(1) 19.2°C (2) 16.4°C (3) 11.5°C (4) 22°C

Sol. Answer (2)

Let temperature of junction be = θ

Heat flowing to junction = heat out flowing

$$\frac{KA}{30}(30-\theta)=\frac{KA}{20}(\theta-20)+\frac{KA}{10}(\theta-10)$$

$$\frac{(30-\theta)}{3}=\frac{(\theta-20)}{2}+\frac{(\theta-10)}{1}$$

$$\frac{(30-\theta)}{3}=\frac{\theta-20+2\theta-20}{2}$$

$60 - 2\theta = 9\theta - 120$

$$\frac{180}{11}=\theta$$

$16.36°\text{C} = \theta$

27. If transmission power of a surface is $\frac{1}{9}$, reflective power is $\frac{1}{6}$, then what is its absorptive power?

(1) $\frac{18}{13}$ (2) $\frac{13}{18}$ (3) $\frac{3}{15}$ (4) $\frac{15}{3}$

Sol. Answer (2)

$t + r + a = 1$

$a = 1 - (t + r)$

$$=1-\left(\frac{1}{9}+\frac{1}{6}\right)$$

$$a=\frac{13}{18}$$

28. A solid cylinder of length L and radius r is heat upto same temperature as that of a cube of edge length a. If both have same material, volume and allowed to cool under similar conditions, then ratio of amount of radiations radiated will be (Neglect radiation emitted from flat surfaces of the cylinder)

(1) $\frac{a}{3r}$ (2) $\frac{2a}{rL}$ (3) $\frac{a^2}{rL}$ (4) $\frac{\pi a^2}{2rL}$

Sol. Answer (1)

$\because$ Both have same volume

$\therefore$ $a^3 = \pi r^2 L$ …(1)

Amount of radiation $\propto$ Surface area [$\because$ Temperature, material are same for both]

$$\frac{\text{Radiation cylinder}}{\text{Radiation cube}}=\frac{2\pi rL}{6a^2}=\frac{2\pi rL\,.\,a}{6a^3}$$

using equation (1)

We get

$$\frac{R_{\text{cylinder}}}{R_{\text{cube}}}=\frac{a}{3r}$$

29. A very thin metallic shell of radius r is heated to temperature T and then allowed to cool. The rate of cooling of shell is proportional to

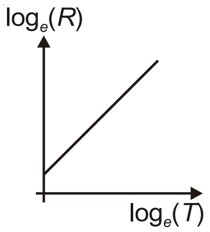
(1) rT (2) $\frac{1}{r}$ (3) r^2 (4) r^0

Sol. Answer (4)

Rate of cooling depends on temperature of body, surrounding temperature, not on radius.

30. If an object at absolute temperature (T) radiates energy at rate R, then select correct graph showing the variation of $\log_e R$ with $\log_e(T)$.

(1)



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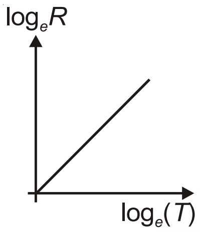

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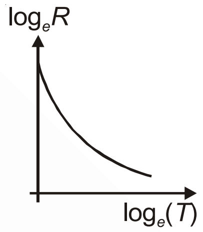

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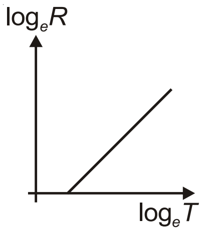

Sol. Answer (1)

$R = eA\sigma T^4$

$\log_e R = eA\sigma \times 4 \log_e T$

directly proportional.

31. Two diagonally opposite corners of a square made of a four thin rods of same material, same dimensions are at temperature 40°C and 10°C. If only heat conduction takes place, then the temperature difference between other two corners will be

(1) 0°C (2) 10°C (3) 25°C (4) 15°C

Sol. Answer (1)

Arrangement is like resistances in wheat stone bridge

$\therefore$ No temperature difference between two outer corners.

32. Bottom of a lake is at 0°C and atmospheric temperature is –20°C. If 1 cm ice is formed on the surface in 24 h, then time taken to form next 1 cm of ice is

(1) 24 h (2) 72 h (3) 48 h (4) 96 h

Sol. Answer (2)

Time intervals to change thickness from 0 to x from x to $2x$ are in ratio of 1 : 3 : 5 : 7 ……

$\therefore \quad t_1 : t_2 = 1 : 3$

$\qquad = 24 : 24 \times 3$

$\Rightarrow \quad t_2 = 72$ hours

33. The power received at distance d from a small metallic sphere of radius $r(<<d)$ and at absolute temperature T is P. If temperature is doubled and distance reduced to half of initial value, then the power received at that point will be

(1) $4p$ (2) $8p$ (3) $32p$ (4) $64p$

Sol. Answer (4)

$$\text{Solar constant} \propto \frac{T^4}{r^2}$$

Solar constant equivalent to power received so

$$\frac{P_1}{P_2} = \frac{T_1^4}{r_1^2} \times \frac{r_2^2}{T_2^4}$$

$$\frac{P}{P_2} = \frac{T^4}{r^2} \times \frac{(r/2)^2}{(2T)^4}$$

$P_2 = 64p$

SECTION - C

Previous Years Questions

1. On a new scale of temperature (which is linear) and called the W scale, the freezing and boiling points of water are 39°W and 239°W respectively. What will be the temperature on the new scale, corresponding to a temperature of 39°C on the Celsius scale?

(1) 139°W (2) 78°W (3) 117°W (4) 200°W

Sol. Answer (3)

$$\frac{39-0}{100-0} = \frac{T-39}{239-39}$$

117°W = T

2. The coefficients of linear expansion of brass and steel are α_1 and α_2 respectively. When we take a brass rod of length l_1 and steel rod of length l_2 at 0°C, then difference in their lengths $(l_2 - l_1)$ will remain the same at all temperatures, if

(1) $\alpha_1^2 l_1 = \alpha_2^2 l_2$ (2) $\alpha_1 l_2 = \alpha_2 l_1$ (3) $\alpha_1 l_1 = \alpha_2 l_2$ (4) $\alpha_1 l_2^2 = \alpha_2 l_1^2$

Sol. Answer (3)

Let the temperature difference be = t

$l_1' = l_1 + l_1\alpha_1 t$

$l_2' = l_2 + l_2\alpha_2 t$ {Where l_2' and l_2 are increased lengths}

$l_2' - l_1' = l_2 - l_1$ {$\because$ difference of length is same at all temperature}

$l_2 + l_2\alpha_2 t - l_1 - l_1\alpha_1 t = l_2 - l_1$

$l_2\alpha_2 = l_1\alpha_1$

3. The density of water at 20°C is 998 kg/m³ and at 40°C 992 kg/m³. The coefficient of volume expansion of water is

(1) 10^{-4}/°C (2) 3×10^{-4}/°C (3) 2×10^{-4}/°C (4) 6×10^{-4}/°C

Sol. Answer (2)

$\rho_2 = \rho_1 (1 - \gamma\Delta T)$

$992 = 998 (1 - \gamma \times 20)$

$\gamma \simeq 3 \times 10^{-4}$/°C

4. Liquid oxygen at 50 K is heated to 300 K at constant pressure of 1 atm. The rate of heating is constant. Which one of the following graphs represents the variation of temperature with time?

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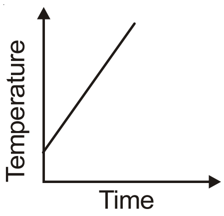

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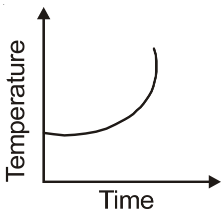

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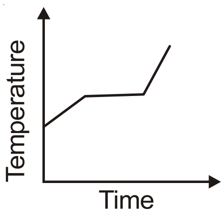

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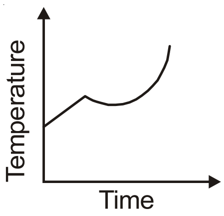
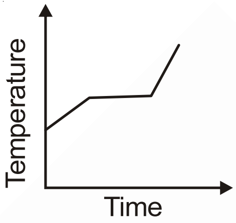


Sol. Answer (3)

Liquid oxygen when heated will observe a rise in temperature as well as change in state one time which can be represented as



5. A slab of stone of area 0.36 m^2 and thickness 0.1 m is exposed on the lower surface to steam at 100°C. A block of ice at 0°C rests on the upper surface of the slab. In one hour 4.8 kg of ice is melted. The thermal conductivity of slab is (Given latent heat of fusion of ice = 3.36×10^5 J kg^{-1})

(1) 1.24 J/m/s/°C (2) 1.29 J/m/s/°C (3) 2.05 J/m/s/°C (4) 1.02 J/m/s/°C

Sol. Answer (1)

In 1 hour, 4.8 kg ice melts

$\Rightarrow$ Heat supplied = $3.36 \times 10^5 \times 4.8$ J {$Q = Lm$}

Heat supplied per second $= \frac{KA}{L} \times \Delta T$

$$\frac{3.36 \times 10^5 \times 4.8}{1 \times 3600} = \frac{K \times 0.36}{0.1} \times 100$$

K = 1.24 J/m/s/°C

6. When 1 kg of ice at 0°C melts to water at 0° C, the resulting change in its entropy, taking latent heat of ice to be 80 cal/°C is

(1) 293 cal/K (2) 273 cal/K (3) 8×10^4 cal/K (4) 80 cal/K

Sol. Answer (1)

Change in entropy $\Delta S = \frac{\text{Heat absorbed}}{\text{Temperature at that instant}}$

$\Delta S = \frac{Q}{T}$ [$Q = mL_1$]

$$\Delta S = \frac{1000 \times 80}{273}$$

ΔS = 293 cal/K

7. If 1 g of steam at 100°C steam is mixed with 1 g of ice at 0°C, then resultant temperature of the mixture is

(1) 100°C (2) 230°C (3) 270°C (4) 50°C

Sol. Answer (1)

Heat required to convert phase of ice = 80 cal

Heat required to bring water at 0°C to water at 100°C = 100 cal

Total heat required = 180 cal

Heat available = 540 cal [L_u of 1 g steam]

∴ Final mixture will have steam + water

and when steam is present in mixture temperature has to be 100°C

8. Heat is flowing through two cylindrical rods of the same material. The diameters of the rods are in the ratio 1 : 2 and the lengths in the ratio 2 : 1. If the temperature difference between the ends is same, then ratio of the rate of flow of heat through them will be

(1) 2 : 1 (2) 8 : 1 (3) 1 : 1 (4) 1 : 8

Sol. Answer (4)

$$H \propto \frac{d^2}{L} \qquad \left[H = \frac{KA}{L}(\Delta T)\right]$$

So $\dfrac{H_1}{H_2} = \left[\dfrac{d_1}{d_2}\right]^2\left[\dfrac{L_2}{L_1}\right]$

$$= \left[\frac{1}{2}\right]^2 \times \frac{1}{2} = \frac{1}{8}$$

$$\frac{H_1}{H_2} = \frac{1}{8}$$

9. A cylindrical rod has temperatures T_1 and T_2 at its ends. The rate of flow of heat is Q (cal/s). If all the linear dimensions are doubled keeping temperatures constant, then rate of flow of heat Q_2 will be

(1) $4Q_1$ (2) $2Q_1$ (3) $\dfrac{Q_1}{4}$ (4) $\dfrac{Q_1}{2}$

Sol. Answer (2)

$$Q_1 = \frac{KA}{L}(T_2 - T_1) = \frac{K \cdot \pi r^2}{L}(T_2 - T_1)$$

and $Q_2 = \dfrac{K \cdot \pi(2r^2)}{(2L)}(T_2 - T_1) = \dfrac{2K \cdot \pi r^2}{L}(T_2 - T_1) = 2Q_1$

10. Two metal rods 1 and 2 of same lengths have same temperature difference between their ends. Their thermal conductivities are K_1 and K_2 and cross sectional areas A_1 and A_2, respectively. If the rate of heat conduction in 1 is four times that in 2, then

(1) $K_1A_1 = K_2A_2$ (2) $K_1A_1 = 4K_2A_2$ (3) $K_1A_1 = 2K_2A_2$ (4) $4K_1A_1 = K_2A_2$

Sol. Answer (2)

$\because$ ΔT is same for both the rods and lengths are also same

$\Rightarrow \dfrac{H}{KA} = \text{constant}$

So $\dfrac{H_1}{K_1A_1} = \dfrac{H_2}{K_2A_2}$

$\dfrac{H_1}{H_2} = \dfrac{K_1A_1}{K_2A_2}$ $\left[\because \dfrac{H_1}{H_2} = 4\right]$

$\Rightarrow 4K_2A_2 = K_1A_1$

11. Consider two rods of same lengths and different specific heats (S_1, S_2), conductivities (K_1, K_2) and area of cross-sections (A_1, A_2) and both having temperatures T_1, and T_2 at their ends. If rate of flow of heat due to conduction is equal, then

(1) $K_1A_1 = K_2A_2$ (2) $\dfrac{K_1A_1}{S_1} = \dfrac{K_2A_2}{S_2}$ (3) $K_2A_1 = K_1A_2$ (4) $\dfrac{K_2A_1}{S_2} = \dfrac{K_1A_2}{S_1}$

Sol. Answer (1)

$$\frac{K_1A_1}{L}(T_2 - T_1) = \frac{K_2A_2}{L}(T_2 - T_1)$$

$\Rightarrow K_1A_1 = K_2A_2$

12. Unit of Stefan's constant is

(1) watt-m^2-K^4 (2) watt-m^2/K^4 (3) watt/m^2-K (4) watt/m^{2}K^4

Sol. Answer (4)

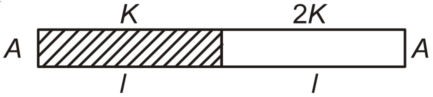
Unit of Stefan's constant is watt/m^{2}K^4

13. Consider a compound slab consisting of two pieces of same length and different materials having equal thicknesses and thermal conductivities K and 2 K, respectively. The equivalent thermal conductivity of the slab is

(1) 2/3 K (2) $\sqrt{2}$ K (3) 3K (4) 4/3 K

Sol. Answer (4)

Connected series way so,



$R = R_1 + R_2$ [For series]

$$\frac{2l}{K'A} = \frac{l}{KA} + \frac{l}{2KA}$$

$\Rightarrow K' = 4/3\ K.$

14. Which of the following rods, (given radius r and length l) each made of the same material and whose ends are maintained at the same temperature will conduct most heat?

(1) $r = r_0$, $l = l_0$ (2) $r = 2r_0$, $l = l_0$ (3) $r = r_0$, $l = 2l_0$ (4) $r = 2r_0$, $l = 2l_0$

Sol. Answer (2)

Rod with more $\dfrac{A}{L}$ ratio or $\dfrac{r^2}{L}$ ratio will conduct more heat $\left\{\because H \propto \dfrac{A}{L}\right\}$

15. A cylindrical metallic rod in thermal contact with two reservoirs of heat at its two ends conducts an amount of heat Q in time t. The metallic rod is melted and the material is formed into a rod of half the radius of the original rod. What is the amount of heat conducted by the new rod, when placed in thermal contact with the two reservoirs in time t?

(1) $\frac{Q}{2}$ (2) $\frac{Q}{4}$ (3) $\frac{Q}{16}$ (4) $2Q$

Sol. Answer (3)

Original volume $\propto r^2h$

New volume also same as the original volume

But new radius = $r/2$

Let new height be = h'

So $r^2h = \left(\frac{r}{2}\right)^2 h'$

$4h = h'$

$Q \propto \frac{KR^2}{L}$

$Q_2 \propto \frac{KR^2}{4\times4\times L} = \frac{Q}{16}$

16. Gravitational force is required for

(1) Stirring of liquid (2) Convection (3) Conduction (4) Radiation

Sol. Answer (2)

Gravity is the necessary requirement for convection.

17. A black body is at a temperature of 500 K. It emits energy at a rate which is proportional to

(1) $(500)^3$ (2) $(500)^4$ (3) 500 (4) $(500)^2$

Sol. Answer (2)

$E \propto T^4$

So, $E \propto (500)^4$

18. Which of the following is closest to an ideal black body?

(1) Black lamp

(2) Cavity maintained at constant temperature

(3) Platinum black

(4) A lamp of charcoal heated to high temperature

Sol. Answer (2)

Cavity maintained at constant temperature is closest to black body.

19. A black body is at 727°C. It emits energy at a rate which is proportional to

(1) $(1000)^4$ (2) $(1000)^2$ (3) $(727)^4$ (4) $(727)^2$

Sol. Answer (1)

$E \propto T^4$

So $E \propto (727 + 273)^4$

$\propto (1000)^4$

20. For a black body at temperature 727°C, its rate of energy loss is 20 watt and temperature of surrounding is 227°C. If temperature of black body is changed to 1227°C then its rate of energy loss will be

(1) 304 W (2) $\frac{320}{3}$ W (3) 240 W (4) 120 W

Sol. Answer (2)

According to Stefan - Boltzmann's Law

$$\frac{dH}{dt} \propto T^4 - T_0^4$$

$$\frac{20}{x} = \frac{1000^4 - 5^4}{1500^4 - 5^4}$$

$$\Rightarrow \quad x = \frac{320}{3}\text{ W}$$

21. A black body at 227°C radiates heat at the rate of 7 cals/cm^{2}s. At a temperature of 727°C, the rate of heat radiated in the same units will be

(1) 80 (2) 60 (3) 50 (4) 112

Sol. Answer (4)

Radiation $\propto T^4$

$$\text{So } \frac{R_1}{R_2} = \left(\frac{T_1}{T_2}\right)^4$$

$$\frac{7}{x} = \left(\frac{500}{1000}\right)^4$$

x = 112 cal/cm^{2}s

22. A beaker full of hot water is kept in a room. If it cools from 80°C to 75°C in t_1 minutes, from 75°C to 70°C in t_2 minutes and from 70°C to 65°C in t_3 minutes, then

(1) $t_1 < t_2 < t_3$ (2) $t_1 > t_2 > t_3$ (3) $t_1 = t_2 = t_3$ (4) $t_1 < t_2 = t_3$

Sol. Answer (1)

$$80°\text{C} \xrightarrow[t_1]{} 75°\text{C} \xrightarrow[t_2]{} 70°\text{C} \xrightarrow[t_3]{} 65°\text{C}$$

According to newton's law of cooling

$$\ln \frac{T_1 - T_0}{T_2 - T_0} = kt$$

Where T_0 is temperature of surroundings and T_1 and T_2 are initial and final temperature so more difference between T_1, T_2 and T_0 less is the time taken to reach T_2 from T_1

$\Rightarrow \quad t_3 > t_2 > t_1$

23. A black body at 1227°C emits radiations with maximum intensity at a wavelength of 5000 Å. If the temperature of the body is increased by 1000°C, the maximum intensity will be observed at

(1) 3000 Å (2) 4000 Å (3) 5000 Å (4) 6000 Å

Sol. Answer (1)

Wien's law $\left[\lambda \propto \frac{1}{T}\right]$

$$\Rightarrow \frac{T_1}{T_2} = \frac{\lambda_2}{\lambda_1}$$

$$\frac{1500\text{ K}}{2500\text{ K}} = \frac{\lambda}{5000\,\text{Å}}$$

$$\Rightarrow 3000\text{ Å} = \lambda$$

24. The two ends of a rod of length *L* and a uniform cross-sectional area *A* are kept at two temperatures T_1 and T_2 ($T_1 > T_2$). The rate of heat transfer, $\frac{dQ}{dt}$, through the rod in a steady state is given by

(1) $\frac{dQ}{dt} = \frac{kA(T_1 - T_2)}{L}$ (2) $\frac{dQ}{dt} = \frac{kL(T_1 - T_2)}{A}$

(3) $\frac{dQ}{dt} = \frac{k(T_1 - T_2)}{LA}$ (4) $\frac{dQ}{dt} = kLA(T_1 - T_2)$

Sol. Answer (1)

$$H = \frac{dQ}{dt} = \frac{kA(T_1 - T_2)}{L}$$

25. A piece of iron is heated in a flame. It first becomes dull red then becomes reddish yellow and finally turns to white hot. The correct explanation for the above observation is possible by using

(1) Wien's displacement Law (2) Kirchhoff's Law

(3) Newton's Law of cooling (4) Stefan's Law

Sol. Answer (1)

According to Wien's displacement Law, if temperature rises than λ decreases.

Which explains change of colour.

26. The Wien's displacement law expresses the relation between

(1) Wavelength corresponding to maximum intensity and temperature

(2) Radiation energy and wavelength

(3) Temperature and wavelength

(4) Colour of light and temperature

Sol. Answer (1)

$\lambda_{\text{Maximum}} \cdot$ Temperature = *b*(constant)

27. We consider the radiation emitted by the human body. Which one of the following statements is correct?

    (1) The radiation emitted is in the infra-red region

    (2) The radiation is emitted only during the day

    (3) The radiation is emitted during the summers and absorbed during the winters

    (4) The radiation emitted lies in the ultraviolet region and hence is not visible

Sol. Answer (1)

Wavelength lies in infra-red region as temperature of human body is very low.

28. If λ_m denotes the wavelength at which the radiative emission from a black body at a temperature T K is maximum, then

    (1) $\lambda_m \propto T^4$ (2) λ_m is independent of T (3) $\lambda_m \propto T$ (4) $\lambda_m \propto T^{-1}$

Sol. Answer (4)

Wien's displacement Law

$$\lambda_m \cdot T = b$$

So $\lambda_m \propto \frac{1}{T}$

29. If the radius of a star is R and it acts as a black body, what would be the temperature of the star, in which the rate of energy production is Q?

    (1) $\left(\frac{4\pi R^2 Q}{\sigma}\right)^{1/4}$ (2) $\left(\frac{Q}{4\pi R^2\sigma}\right)^{1/4}$ (3) $\frac{Q}{4\pi R^2\sigma}$ (4) $\left(\frac{Q}{4\pi R^2\sigma}\right)^{-1/2}$

    (σ stands for Stefan's constant.)

Sol. Answer (2)

$$Q = e\sigma AT^4$$

For black body $e = 1$

$$\Rightarrow \quad T = \left(\frac{Q}{4\pi R^2\sigma}\right)^{1/4}$$

30. Assumings the sun to have a spherical outer surface of radius r, radiating like a black body at temperature t°C, the power received by a unit surface, (normal to the incident rays) at a distance R from the centre of the sun is (where σ is the Stefan's constant.)

    (1) $\frac{r^2\sigma(t+273)^4}{4\pi R^2}$ (2) $\frac{16\pi^2 r^2\sigma t^4}{R^2}$ (3) $\frac{r^2\sigma(t+273)^4}{R^2}$ (4) $\frac{4\pi r^2\sigma t^4}{R^2}$

Sol. Answer (3)

$$P = \frac{Q}{4\pi R^2}, \quad Q = \sigma 4\pi r^2(t + 273)^4$$

$$\Rightarrow \quad P = \frac{r^2\sigma(t+273)^4}{R^2}$$

31. A black body has wavelength corresponding to maximum intensity λ_m at 2000 K. Its corresponding wavelength at 3000 K will be

(1) $\frac{3}{2}\lambda_m$ (2) $\frac{2}{3}\lambda_m$ (3) $\frac{16}{81}\lambda_m$ (4) $\frac{81}{16}\lambda_m$

Sol. Answer (2)

$\lambda \propto \frac{1}{T}$ [Wien's Law]

So $\frac{\lambda_1}{\lambda_2} = \frac{T_2}{T_1}$

$$\frac{\lambda_m}{\lambda} = \frac{3000}{2000}$$

$$\frac{2}{3}\lambda_m = \lambda$$

32. The radiant energy from the sun, incident normally at the surface of earth is 20 kcal/m² min. What would have been the radiant energy, incident normally on the earth, if the sun had a temperature, twice of the present one?

(1) 320 kcal/m² min (2) 40 kcal/m² min (3) 160 kcal/m² min (4) 80 kcal/m² min

Sol. Answer (1)

$E \propto T^4$

$$\frac{20}{E} = \left(\frac{T}{2T}\right)^4$$

E = 320 kcal/m² minute

33. The total radiant energy per unit area, normal to the direction of incidence, received at a distance R from the centre of a star of radius r, whose outer surface radiates as a black body at a temperature T K is given by (where σ is stefan's constant)

(1) $\frac{4\pi\sigma r^2T^4}{R^2}$ (2) $\frac{\sigma r^2T^4}{R^2}$ (3) $\frac{\sigma r^2T^4}{4\pi r^2}$ (4) $\frac{\sigma r^4T^4}{r^4}$

Sol. Answer (2)

$$P = \frac{Q}{4\pi R^2},\ Q = \sigma\cdot 4\pi r^2\cdot T^4$$

$$\Rightarrow\ P = \frac{\sigma r^2T^4}{R^2}$$

SECTION - D

Assertion - Reason Type Questions

1. A : Density of water is maximum at 4°C.

   R : Water has both positive and negative temperature coefficients of volumetric expansions depending on the temperature range.

Sol. Answer (2)

A : is true

R : is true

But the correct explanation is that due to structural changes in moleculer of water we observe this anomalous behaviour.

2. A : A solid and a hollow sphere of same diameter and same material when heated for the same temperature rise, will expand by the same amount.

   R : The change in volume is independent of the original mass but depends on original volume.

Sol. Answer (1)

A : is true

R : is true and correct explanation of Assertion.

3. A : Fahrenheit is the smallest unit for measuring temperature.

   R : Fahrenheit was the first temperature scale used for measuring temperature.

Sol. Answer (2)

A : is true

R : is true

But correct explanation is Fahrenheit has 180 divisions where as other scales have 100 divisions.

4. A : Material used for making cooking utensils is the one having high specific heat and high conductivity.

   R : Low conductivity means high specific heat.

Sol. Answer (4)

A : is false, material used for making cooking utensils is the one having low specific heat and high conductivity.

R : is false.

5. A : The value of the absorptive power and the emissivity has the same value for a single body at a particular temperature.

   R : Value of absorptive power is 1 for a black body.

Sol. Answer (2)

A : is true

R : is true

But the correct reason is black body radiate as much as it absorbs.

6. A : The reflectance of a black body is zero.

R : Black body absorbs all radiations incident on it.

Sol. Answer (1)

A : is true

R : is true and correct explanation.

7. A : Evaporation of water is fast on the surface of moon as compared to earth.

R : On the surface of moon temperature is much greater than the surface of earth.

Sol. Answer (3)

A : is true

R : is false, temperature of surface of moon is much less than that of earth's surface.

8. A : The internal energy of a solid substance increases during melting.

R : Latent heat is required to melt a solid substance.

Sol. Answer (1)

A : is true

R : is true and correct explanation.

9. A : Transmission cables are not tightly fixed on the poles.

R : During winters the length of cables decreases due to decrease in temperature, which can damage poles.

Sol. Answer (1)

A : True

R : True and correct explanation.

10. A : The thermal conductivity of a body depends on its material and dimensions.

R : Thermal conductivity is proportional to length and inversely proportional to area cross-section of body.

Sol. Answer (4)

A : False, Thermal conductivity depends only on material

R : False, Thermal conductivity is constant for a given material

11. A : Eskimos make double wall houses of ice blocks.

R : The air trapped between double walls prevents the conduction of heat energy from inside the house to outside it.

Sol. Answer (1)

A : True

R : True and correct explanation

12. A : The rate of growth of ice on the surface of a lake decreases with increase in thickness of ice layer.

R : Ice is poor conductor of heat energy.

Sol. Answer (1)

A : True

R : True and correct explanation.

13. A : Natural convection is not possible in an orbiting satellite.

R : Natural convection is not possible in gravity free space.

Sol. Answer (1)

A : True

R : True and correct explanation.

❑ ❑ ❑

Chapter 12

Thermodynamics

Solutions

SECTION - A

Objective Type Questions

1. In thermodynamics the Zeroth law is related to

(1) Work done (2) Thermal equilibrium (3) Entropy (4) Diffusion

Sol. Answer (2)

Zeroth law related to thermal equilibrium.

2. For a cyclic process

(1) $\Delta U = 0$ (2) $\Delta Q = 0$ (3) $W = 0$ (4) Both (1) & (3)

Sol. Answer (1)

Since initial and final points are at same, temperature so $\Delta U = 0$

3. Select the incorrect relation. (Where symbols have their usual meanings)

(1) $C_P = \dfrac{\gamma R}{\gamma - 1}$ (2) $C_P - C_V = R$ (3) $\Delta U = \dfrac{P_f V_f - P_i V_i}{1-\gamma}$ (4) $C_V = \dfrac{R}{\gamma - 1}$

Sol. Answer (3)

$\Delta U = \dfrac{P_f V_f - P_i V_i}{\gamma - 1}$ is the correct relation.

4. Internal energy of a non-ideal gas depends on

(1) Temperature (2) Pressure (3) Volume (4) All of these

Sol. Answer (4)

Depends on Temperature, Pressure, Volume.

5. For an adiabatic expansion of an ideal gas the fractional change in its pressure is equal to

(1) $-\gamma\dfrac{V}{dV}$ (2) $-\dfrac{dV}{\gamma V}$ (3) $\dfrac{dV}{V}$ (4) $-\gamma\dfrac{dV}{V}$

Sol. Answer (4)

$\because$ PV^{γ} = constant So, $P \propto V^{-\gamma}$

Then, $\dfrac{\Delta P}{P} = -\gamma\left(\dfrac{dV}{V}\right)$

6. Which of the following laws of thermodynamics defines internal energy?

(1) Zeroth law (2) Second law (3) First law (4) Third law

Sol. Answer (3)

Internal energy is defined in first law

$\because \quad \Delta Q = \Delta U + \Delta W$

So, $\Delta U = \Delta Q - \Delta W$

7. Select the correct statement for work, heat and change in internal energy.

(1) Heat supplied and work done depend on initial and final states

(2) Change in internal energy depends on the initial and final states only

(3) Heat and work depend on the path between the two points

(4) All of these

Sol. Answer (4)

All statements are correct.

8. Morning breakfast gives 5000 cal to a 60 kg person. The efficiency of person is 30%. The height upto which the person can climb up by using energy obtained from breakfast is

(1) 5 m (2) 10.5 m (3) 15 m (4) 16.5 m

Sol. Answer (2)

$\because \quad W = \eta JQ \quad$ So, $mgh = \eta JQ$

$$h = \frac{\eta JQ}{mgh} = \frac{\left(\frac{30}{100}\right)\times 4.2\times 5000}{60\times 10} = 10.5 \text{ m}$$

9. Select the incorrect statement about the specific heats of a gaseous system.

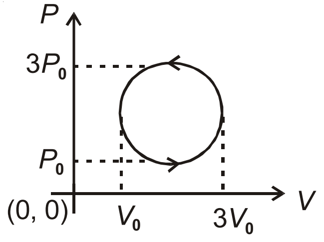
(1) Specific heat at no exchange condition, $C_A = 0$ (2) Specific heat at constant temperature, $C_T = \infty$

(3) Specific heat at constant pressure, $C_P = \frac{\gamma R}{\gamma - 1}$ (4) Specific heat at constant volume, $C_V = \frac{R}{\gamma}$

Sol. Answer (4)

The correct value of $C_V = \frac{R}{\gamma - 1}$

10. Work done in the cyclic process shown in figure is



(1) $4P_0V_0$ (2) $-4P_0V_0$ (3) $-\frac{22}{7}P_0V_0$ (4) $-13P_0V_0$

Sol. Answer (3)

Cyclic process is anticlockwise then

Work done = –(Area of P-V graph)

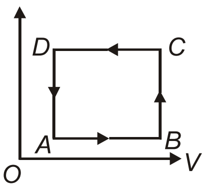
$$W = -\pi R_1 R_2$$

$$= -\pi\left(\frac{3P_0 - P_0}{2}\right)\times\left(\frac{3V_0 - V_0}{2}\right)$$

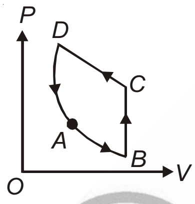
$$= \frac{-22}{7}P_0V_0$$

11. In following figures (a) to (d), variation of volume by change of pressure is shown in figure. The gas is taken along the path $ABCDA$. Change in internal energy of the gas will be

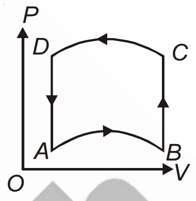
(a)



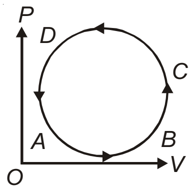
(b)



(c)



(d)



(1) Positive in all cases from (a) to (d)

(2) Positive in cases (a), (b) and (c) but zero in case (d)

(3) Negative in cases (a), (b) and (c) but zero in case (d)

(4) Zero in all the four cases

Sol. Answer (4)

ΔU = 0 in all cases because cyclic process.

12. In a thermodynamic process pressure of a fixed mass of a gas is changed in such a manner that the gas releases 20 J of heat when 8 J of work was done on the gas. If the initial internal energy of the gas was 30 J, then the final internal energy will be

(1) 2 J (2) 18 J (3) 42 J (4) 58 J

Sol. Answer (2)

We know by 1st Law of Thermodynamics

$$\Delta Q = \Delta U + \Delta W$$

$$-20\text{ J} = \Delta U - 8\text{ J}$$

$$\because \quad \Delta U = U_{\text{final}} - U_{\text{initial}}$$

$$\Delta U = -12\text{ J}$$

So, $U_{\text{final}} = U_{\text{initial}} + \Delta U$

$$= 30 + (-12) = 18\text{ J}$$

13. A perfect gas goes from state A to state B by absorbing 8×10^5 joule and doing 6.5×10^5 joule of external work. If it is taken from same initial state A to final state B in another process in which it absorbs 10^5 J of heat, then in the second process work done

(1) On gas is 10^5 J

(2) On gas is 0.5×10^5 J

(3) By gas is 10^5 J

(4) By gas is 0.5×10^5 J

Sol. Answer (2)

$$\Delta Q = \Delta U + \Delta W$$

$$8 \times 10^5 = \Delta U + 6.5 \times 10^5$$

$$1.5 \times 10^5 \text{ J} = \Delta U$$

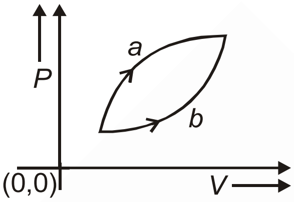
Again using $\Delta Q = \Delta U + W$ for the second case ΔU will stay the same.

Now, $10^5 = 1.5 \times 10^5 + \Delta W$

$$-0.5 \times 10^5 = \Delta W$$

negative sign indicates work is being done on the gas.

14. Figure shows two processes *a* and *b* for a given sample of gas. If ΔQ_1, ΔQ_2 are the amount of heat absorbed by the system in the two cases; and ΔU_1, ΔU_2 are changes in internal energy respectively, then



(1) $\Delta Q_1 = \Delta Q_2$; $\Delta U_1 = \Delta U_2$
(2) $\Delta Q_1 > \Delta Q_2$; $\Delta U_1 > \Delta U_2$
(3) $\Delta Q_1 < \Delta Q_2$; $\Delta U_1 < \Delta U_2$
(4) $\Delta Q_1 > \Delta Q_2$; $\Delta U_1 = \Delta U_2$

Sol. Answer (4)

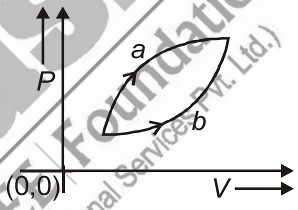
$\because$ Initial and final states are same.

$\therefore$ $\Delta U_1 = \Delta U_2$

Area under '*a*' > area under '*b*' *i.e.*, $\Delta W_1 > \Delta W_2$

$\therefore$ Heat absorbed by *a* > heat absorbed by *b*

$\Delta Q_1 > \Delta Q_2$



15. A gas undergoes a change at constant temperature. Which of the following quantities remain fixed?

(1) Pressure
(2) Entropy
(3) Heat exchanged with the system
(4) All the above may change

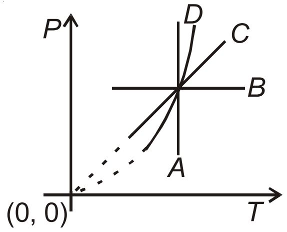
Sol. Answer (4)

When temperature change = 0 then,

$P_1V_1 = P_2V_2$ = constant

Rest may change.

16. Following figure shows *P*-*T* graph for four processes *A*, *B*, *C* and *D*. Select the correct alternative.



(1) *A* – Isobaric process
(2) *B* – Adiabatic process
(3) *C* – Isochoric process
(4) *D* – Isothermal process

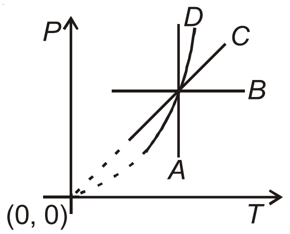
Sol. Answer (3)

(A) Temperature is constant – isothermal

(B) Pressure is constant – Isobaric

(C) Pressure ∝ Temperature – Isochoric process

(D) $P^{1-\gamma}T^{\gamma}$ = constant – Adiabatic process



17. An ideal gas with adiabatic exponent γ is heated at constant pressure. It absorbs Q amount of heat. Fraction of heat absorbed in increasing the temperature is

(1) γ (2) $\frac{1}{\gamma}$ (3) $1-\frac{1}{\gamma}$ (4) 2γ

Sol. Answer (2)

Heat absorbed in increasing temperature = $\Delta U = \Delta Q - \Delta W = nC_V\Delta T$

$$\text{Fraction of heat absorbed} = \frac{\text{Heat absorbed}}{\text{Total heat}}$$

$$= \frac{nC_V\Delta T}{nC_P\Delta T}$$

$$= \frac{C_V}{C_P} = \frac{1}{\gamma}$$

18. A certain amount of an ideal monatomic gas needs 20 J of heat energy to raise its temperature by 10°C at constant pressure. The heat needed for the same temperature rise at constant volume will be

(1) 30 J (2) 12 J (3) 200 J (4) 215.3 J

Sol. Answer (2)

$\Delta Q = nC_P\Delta T$

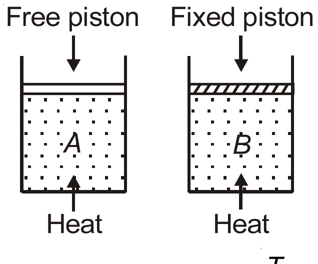
$20 = nC_P \times 10$ ...(1)

$\Delta U = nC_V\Delta T$

$\Delta U = n\frac{C_P}{\gamma}\Delta T$ $\{\because\ \gamma_{mono} = 5/3\}$

$\Delta U = 12$ J

19. Two cylinders contain same amount of ideal monatomic gas. Same amount of heat is given to two cylinders. If temperature rise in cylinder A is T_0 then temperature rise in cylinder B will be



(1) $\frac{4}{3}T_0$ (2) $2T_0$ (3) $\frac{T_0}{2}$ (4) $\frac{5}{3}T_0$

Sol. Answer (4)

Cylinder *A*	Cylinder *B*
Free piston *i.e.*, at constant pressure	Fixed piston *i.e.*, at constant volume

$\Delta Q = \Delta U$

$nC_P\Delta T = nC_V\Delta T'$

$C_PT_0 = C_V(\Delta T)'$

$$\Delta T' = \frac{C_P}{C_V}T_0 = \gamma T_0 = \frac{5}{3}T_0$$

20. A sample of an ideal gas undergoes an isothermal expansion. If *dQ*, *dU* and *dW* represent the amount of heat supplied, the change in internal energy and the work done respectively, then

(1) dQ = +ve, dU = +ve, dW = +ve (2) dQ = +ve, dU = 0, dW = +ve

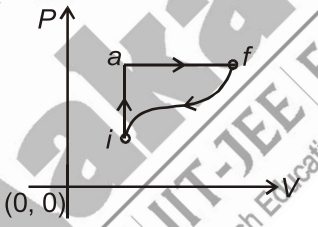
(3) dQ = +ve, dU = +ve, dW = 0 (4) dQ = –ve, dU = –ve, dW = –ve

Sol. Answer (2)

dQ = positive, *dU* = zero, *dW* = positive

$\because$ $dQ = dU + dW$

21. In the diagram shown Q_{iaf} = 80 cal and W_{iaf} = 50 cal. If W = –30 cal for the curved path *fi,* value of *Q* for path *fi,* will be



(1) 60 cal (2) 30 cal (3) –30 cal (4) –60 cal

Sol. Answer (4)

From process *iaf*

Find ΔU first, $\Delta Q = \Delta W + \Delta U$

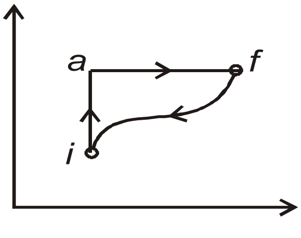
$80 = 50 + \Delta U$

$30 \text{ cal} = \Delta U$

Use this ΔU for process if

$\Delta Q = \Delta W + \Delta U$

$\Delta Q = -30 + (-30) = -60$ cal



22. A mass of dry air at N.T.P. is compressed to $\frac{1}{32}$th of its original volume suddenly. If γ = 1.4, the final pressure would be

(1) 32 atm (2) 128 atm (3) $\frac{1}{32}$ atm (4) 150 atm

Sol. Answer (2)

Process carried out suddenly so process is adiabatic.

$$\Rightarrow \quad PV^{\gamma} = K$$

$$P_1V_1^{\gamma} = P_2V_2^{\gamma}$$

$$P_2 = P_1\left(\frac{V_1}{V_2}\right)^{\gamma}$$

$$P_2 = (1\,\text{atm})\left(\frac{V_1}{V_1/32}\right)^{7/5}$$

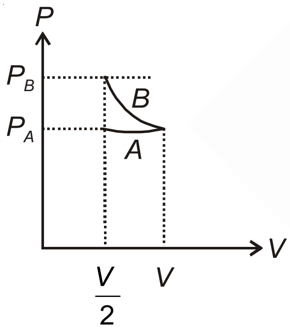
$$P_2 = 1\text{ atm} \times (2^5)^{7/5}$$

$$= 128\text{ atm}$$

23. Two samples A and B of a gas initially at the same temperature and pressure, are compressed from volume V to $\frac{V}{2}$ (A isothermally and B adiabatically). The final pressure

(1) $P_A > P_B$ (2) $P_A = P_B$ (3) $P_A < P_B$ (4) $P_A = 2P_B$

Sol. Answer (3)



i.e., $P_A < P_B$

24. The adiabatic elasticity of a diatomic gas at NTP is

(1) Zero (2) 1×10^5 N/m^2 (3) 1.4×10^5 N/m^2 (4) 2.75×10^5 N/m^2

Sol. Answer (3)

$$\text{Adiabatic elasticity} = \gamma P = \frac{7}{5}\times 1.01\times 10^5$$

$$= 1.414\times 10^5\text{ N/m}^2$$

25. For an isometric process

(1) $\Delta W = -\Delta U$ (2) $\Delta Q = \Delta U$ (3) $\Delta Q = \Delta W$ (4) $\Delta Q = -\Delta U$

Sol. Answer (2)

For an isometric process, (*i.e.*, isochoric) workdone = zero

So $\Delta Q = \Delta U$

26. A mixture of gases at NTP for which $\gamma = 1.5$ is suddenly compressed to $\frac{1}{9}$th of its original volume. The final temperature of mixture is

(1) 300°C (2) 546°C (3) 420°C (4) 872°C

Sol. Answer (2)

$TV^{\gamma-1}$ = constant

$T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$

$$T_2 = T_1\left(\frac{V_1}{V_2}\right)^{\gamma-1}$$

$$T_2 = (273\text{ K})\left[\frac{V_1}{V/9}\right]^{1.5-1}$$

T_2 = (273 K) × 3

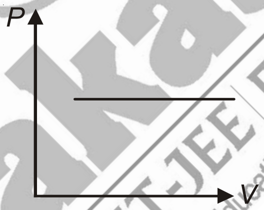
= 819 K

= 546°C

27. In which process P-V diagram is a straight line parallel to the volume axis?

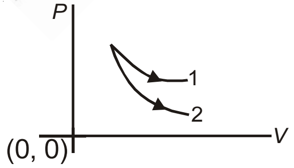
(1) Isochoric (2) Isobaric (3) Isothermal (4) Adiabatic

Sol. Answer (2)



Process having a constant pressure, so isobaric process.

28. The P-V plots for two gases during adiabatic processes are shown in the figure. The graphs 1 and 2 should correspond respectively to



(1) O_2 and He (2) He and O_2 (3) O_2 and CO (4) N_2 and O_2

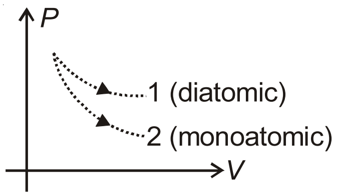
Sol. Answer (1)

PV^{γ} = constant [equation of graphs]

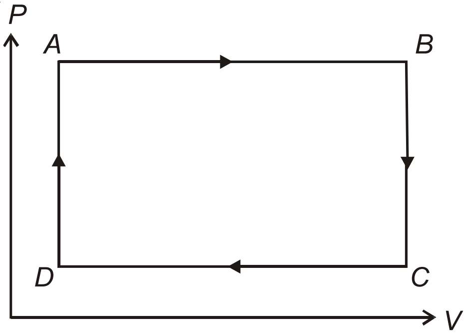
So for more γ less the rate of change or slope of graph and γ is less for diatomic.

So graph 1 for O_2

Graph 2 for He.



29. The pressure and volume of a gas are changed as shown in the *P*-*V* diagram in this figure. The temperature of the gas will



(1) Increase as it goes from *A* to *B*

(2) Increase as it goes from *B* to *C*

(3) Remain constant during these changes

(4) Decrease as it goes from *D* to *A*

Sol. Answer (1)

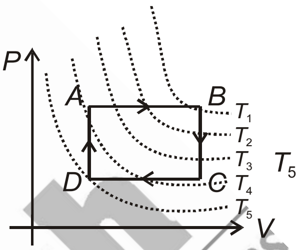
In the process $A \rightarrow B$

Pressure is constant.

$PV = nRT$

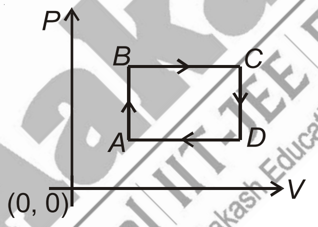
So $V \propto T$

and volume is increasing so temperature also increases.

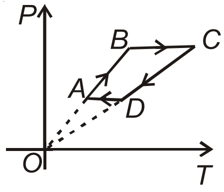


$T_5 > T_4 > T_3 > T_2 > T_1$

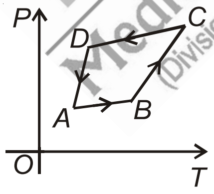
30. The figure shows *P*-*V* diagram of a thermodynamic cycle. Which corresponding curve is correct?



(1)



(2)



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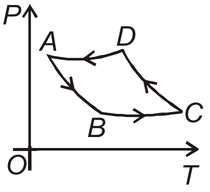
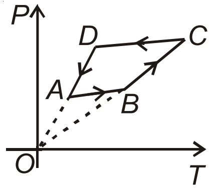


(4)

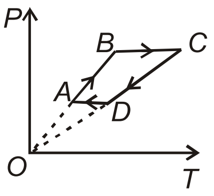


Sol. Answer (1)

$A \rightarrow B$ V = constant

$\because$ $PV = RT$

$$P = \frac{R}{V}T$$



Compare with $y = mx$

P-*T* graph is a straight line which must passes from origin

$A \rightarrow B$ volume constant, P-increasing, T-increasing.

$B \rightarrow C$ pressure constant, volume - increasing, temperature - increasing

$B \rightarrow C$ P = constant, origin P-T graph is a straightline parallel to v-axis

$C \rightarrow D$ V = constant then

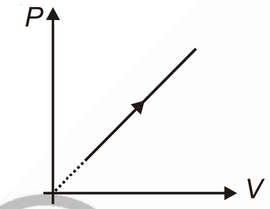
$$P = \frac{R}{V}T$$

P-T graph is straight line must passes from origin

$D \rightarrow A$ P = constant

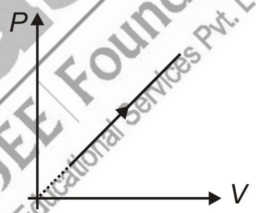
P-T graph is a straightline parallel to T-axis.

31. During the thermodynamic process shown in figure for an ideal gas



(1) $\Delta T = 0$ (2) $\Delta Q = 0$ (3) $W < 0$ (4) $\Delta U > 0$

Sol. Answer (4)



For a straight P-V graph line $P \propto V$

If pressure increases, volume increases then T also increases $[PV \propto T]$

So $\Delta T \neq 0$

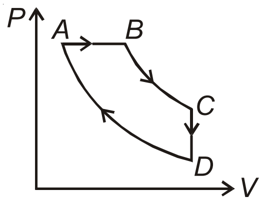
Volume increasing so work is positive, $W > 0$

and temperature also increasing so $\Delta Q > 0$

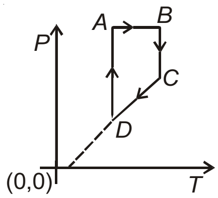
$\because \quad \Delta Q = \Delta U + \Delta W$

So $\Delta U > 0$

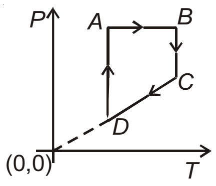
32. For P-V diagram of a thermodynamic cycle as shown in figure, process BC and DA are isothermal. Which of the corresponding graphs is correct?



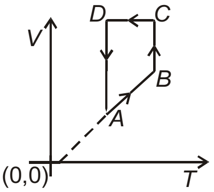
(1)



(2)



(3)



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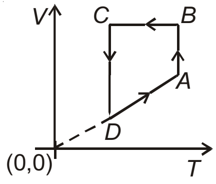


Sol. Answer (2)

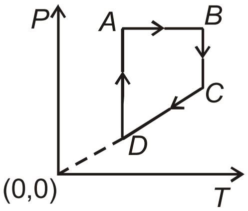
From $A \longrightarrow B$, volume increasing, pressure constant

$B \longrightarrow C$, Pressure $\propto \dfrac{1}{\text{Volume}} \Rightarrow$ Temperature constant

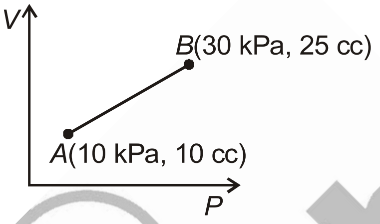
Same for $D \longrightarrow A$

$C \longrightarrow D$ pressure decreasing, volume constant

So $P \propto T$



33. Work done for the process shown in the figure is



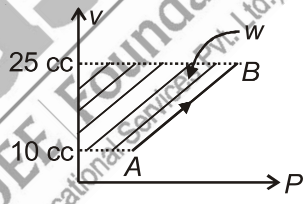
(1) 1 J (2) 1.5 J (3) 4.5 J (4) 0.3 J

Sol. Answer (4)

Area under graph and V axis = work done

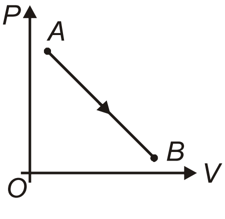
$$= \frac{1}{2} \times (30 + 10) \times 10^3 \times (25 - 10) \times 10^{-6}$$

= 0.3 J

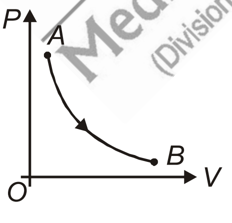


34. During which of the following thermodynamic process represented by PV diagram the heat energy absorbed by system may be equal to area under PV graph?

(1)



(2)



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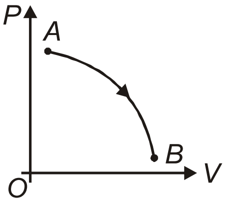
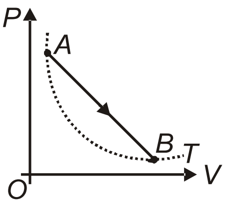
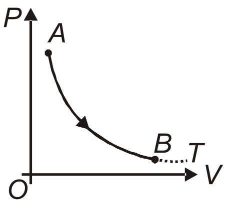
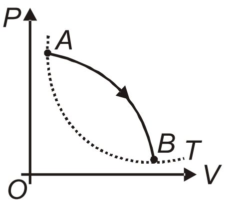


(4) All of these

Sol. Answer (4)







$\because$ T is constant in all cases.

35. The specific heat of a gas in a polytropic process is given by

(1) $\frac{R}{\gamma-1}+\frac{R}{N-1}$ (2) $\frac{R}{1-\gamma}+\frac{R}{1-N}$ (3) $\frac{R}{\gamma-1}-\frac{R}{N-1}$ (4) $\frac{R}{1-\gamma}-\frac{R}{1-N}$

Sol. Answer (3)

$$\because \quad C = C_V+\frac{R}{1-N} = \frac{R}{\gamma-1}-\frac{R}{N-1}$$

36. For a certain process, pressure of diatomic gas varies according to the relation $P = aV^2$, where a is constant. What is the molar heat capacity of the gas for this process?

(1) $\frac{17R}{6}$ (2) $\frac{6R}{17}$ (3) $\frac{13R}{6}$ (4) $\frac{16R}{7}$

Sol. Answer (1)

$P = aV^2$

$PV^{-2} = a$ Compare with PV^N = constant then $N = -2$

Polytropic process

$$\because \quad C = C_V+\frac{R}{1-N}$$

$$=\frac{R}{\gamma-1}+\frac{R}{1-N} \qquad \left\{\gamma \text{ of diatomic} = \frac{7}{5}\right\}$$

$$=\frac{R}{\left(\frac{7}{5}-1\right)}+\frac{R}{1-(-2)}$$

$$=\frac{5R}{2}+\frac{R}{1+2}=\frac{17R}{6}$$

37. In a thermodynamic process two moles of a monatomic ideal gas obeys $P \propto V^{-2}$. If temperature of the gas increases from 300 K to 400 K, then find work done by the gas (where R = universal gas constant).

(1) 200 R (2) –200 R (3) –100 R (4) –400 R

Sol. Answer (2)

$P \propto V^{-2}$

PV^2 = constant Compare with PV^N = constant then $N = 2$

$$W = \mu\left(\frac{R}{1-N}\right)\Delta T$$

$$W = \frac{\mu R}{1-N}(T_2-T_1)$$

$$=\frac{2\times R(400-300)}{(1-2)}$$

$= -200\ R$

38. Entropy of a system decreases

(1) When heat is supplied to a system at constant temperature

(2) When heat is taken out from the system at constant temperature

(3) At equilibrium

(4) In any spontaneous process

Sol. Answer (2)

Entropy of a system decreases when heat is taken out of the system at constant temperature.

39. If during an adiabatic process the pressure of mixture of gases is found to be proportional to square of its absolute temperature. The ratio of C_P/C_V for mixture of gases is

(1) 2 (2) 1.5 (3) 1.67 (4) 2.1

Sol. Answer (1)

$P \propto T^2$

PT^{-2} = constant compare with $PT\left(\frac{\gamma}{1-\gamma}\right) = \text{constant}$

$$\frac{C_P}{C_V} = \gamma = 2$$

40. If the efficiency of a carnot engine is η, then the coefficient of performance of a heat pump working between the same temperatures will be

(1) $1 - \eta$ (2) $\frac{1-\eta}{\eta}$ (3) $\frac{1}{\eta}$ (4) $1 + \frac{1}{\eta}$

Sol. Answer (3)

$$\text{Coefficient of performance of heat pump} = \frac{1}{\text{efficiency of Carnot engine}} = \frac{1}{\eta}$$

41. In a Carnot engine, when heat is absorbed from the source, temperature of source

(1) Increases (2) Decreases

(3) Remains constant (4) Cannot say

Sol. Answer (3)

Even when heat is taken out temperature stays the same. *i.e.*, heat capacity of surface is infinite.

42. A Carnot engine working between 300 K and 600 K has a work output of 800 J per cycle. The amount of heat energy supplied to engine from the source in each cycle is

(1) 800 J (2) 1600 J (3) 3200 J (4) 6400 J

Sol. Answer (2)

W = 800 J

$$\frac{W}{Q} = 1 - \frac{T_2}{T_1}$$

$$\frac{800}{Q} = 1 - \frac{300}{600}$$

1600 J = Q

43. An ideal heat engine operates on Carnot cycle between 227°C and 127°C. It absorbs 6×10^4 cal at the higher temperature. The amount of heat converted into work equals to

(1) 4.8×10^4 cal (2) 3.5×10^4 cal (3) 1.6×10^4 cal (4) 1.2×10^4 cal

Sol. Answer (4)

$$\frac{W}{6\times10^4}=1-\frac{400}{500}$$

$W = 1.2 \times 10^4$ cal

44. The maximum possible efficiency of a heat engine is

(1) 100%

(2) $\frac{T_1}{T_2}$

(3) $\frac{T_1}{T_2}+1$

(4) Dependent upon the temperature of source (T_1) and sink (T_2) and is equal to $\left(1-\frac{T_2}{T_1}\right)$

Sol. Answer (4)

$$\eta=1-\frac{T_2}{T_1}$$

So it depends on source and sink temperature.

45. A frictionless heat engine can be 100% efficient only if its exhaust temperature is

(1) Equal to its input temperature (2) Less than its input temperature

(3) 0 K (4) 0°C

Sol. Answer (3)

$$\because \quad \eta=1-\frac{T_2}{T_1}$$

If exhaust temperature zero kelvin then $\eta = 100\%$.

46. A reversible engine and an irreversible engine are working between the same temperatures. The efficiency of the

(1) Two engines are same (2) Reversible engine is greater

(3) Irreversible engine is greater (4) Two engines cannot be compared

Sol. Answer (2)

Efficiency of reversible engine is greater, because there is no loss of heat.

47. Which of the following can be coefficient of performance of refrigerator?

(1) 1 (2) 0.5 (3) 9 (4) All of these

Sol. Answer (4)

$$\beta=\frac{1-\eta}{\eta}$$

$$\beta=\frac{1}{\eta}-1$$

η is less than 1 so $\dfrac{1}{\eta} > 1$

$\Rightarrow \quad \dfrac{1}{\eta} - 1 > 0$

$\Rightarrow \quad \beta > 0$

48. The temperature inside and outside a refrigerator are 273 K and 300 K respectively. Assuming that the refrigerator cycle is reversible, for every joule of work done, the heat delivered to the surrounding will be nearly

(1) 11 J (2) 22 J (3) 33 J (4) 50 J

Sol. Answer (1)

$$\eta = 1 - \frac{T_2}{T_1}\,;\ \eta = 1 - \frac{273}{300} = \frac{9}{100}$$

$$\beta = \frac{1-\eta}{\eta} = \frac{100}{9} - 1 = \frac{91}{9} \sim 11\,\text{J}$$

$$\beta = \frac{Q}{W}$$

For W = 1 J

$Q = \beta$

Q = 11 J

49. By opening the door of a refrigerator placed inside a room you

(1) Can cool the room to certain degree

(2) Can cool it to the temperature inside the refrigerator

(3) Ultimately warm the room slightly

(4) Can neither cool nor warm the room

Sol. Answer (3)

Ultimately warm the room because work is being done by the refrigerator.

50. A Carnot engine whose sink is at 300 K has an efficiency of 40%. By how much should the temperature of source be increased to as to increase its efficiency by 50% of original efficiency?

(1) 150 K (2) 250 K (3) 300 K (4) 450 K

Sol. Answer (2)

$$\frac{40}{100} = 1 - \frac{300}{T_1}$$

$T_1 = 500$ K

50% increase in efficiency

$$\frac{150}{100} \times 0.4 = 0.6$$

new efficiency = 0.6 = $\dfrac{60}{100}$

$$\frac{60}{100} = 1 - \frac{300}{T_1}$$

$T_1 = 750$ K

Difference between 2 Temperatures = 250 K

SECTION - B

Objective Type Questions

1. A container is filled with 20 moles of an ideal diatomic gas at absolute temperature T. When heat is supplied to gas temperature remains constant but 8 moles dissociate into atoms. Heat energy given to gas is

(1) $4RT$ (2) $6RT$ (3) $3RT$ (4) $5RT$

Sol. Answer (1)

Heat supplied = $\Delta U = U_{\text{final}} - U_{\text{initial}}$

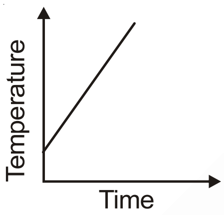
$$U_{\text{initial}} = \frac{5}{2}\times 20\times RT, U_{\text{final}} = \frac{5}{2}\times(20-8)RT + \frac{3}{2}\times(2\times 8)RT$$

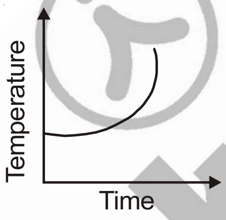
$$\Delta U = \frac{1}{2}\times 8\times RT$$

$= 4RT$

$\Rightarrow$ Heat energy given is $4RT$.

2. Liquid oxygen at 50 K is heated to 300 K at constant pressure of 1 atm. The rate of heating is constant. Which one of the following graphs represents the variation of temperature with time?

(1)


(2)


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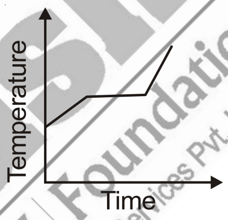

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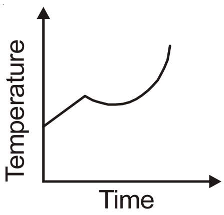
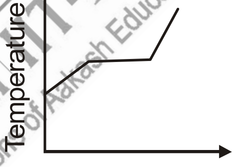


Sol. Answer (3)

Liquid oxygen when heated will observe a rise in temperature as well as change in state one time, which can be represented as



3. For an isobaric process, the ratio of ΔQ (amount of heat supplied) to the ΔW (work done by the gas) is $\left(\gamma = \frac{C_P}{C_V}\right)$

(1) γ (2) $\gamma - 1$ (3) $\frac{\gamma}{\gamma+1}$ (4) $\frac{\gamma}{\gamma-1}$

Sol. Answer (4)

For isobaric process $\Delta Q = nC_P\Delta T$ and $\Delta W = nR\Delta T$

$$\text{So, } \frac{\Delta Q}{\Delta W} = \frac{C_P}{R} = \frac{C_P}{C_P - C_V} = \frac{1}{1-\frac{C_V}{C_P}} = \frac{\gamma}{\gamma-1} \qquad \left[\because \frac{C_P}{C_V} = \gamma\right]$$

4. 3 moles of an ideal gas are contained within a cylinder by a frictionless piston and are initially at temperature T. The pressure of the gas remains constant while it is heated and its volume doubles. If R is molar gas constant, the work done by the gas in increasing its volume is

(1) $\frac{3}{2}RT\ln 2$ (2) $3RT \ln 2$ (3) $\frac{3}{2}RT$ (4) $3RT$

Sol. Answer (4)

$$W = P\Delta V$$
$$= PV$$
$$= nRT$$
$$= 3RT$$

5. Two moles of a gas at temperature T and volume V are heated to twice its volume at constant pressure. If $\frac{C_p}{C_v} = \gamma$ then increase in internal energy of the gas is

(1) $\frac{RT}{\gamma - 1}$ (2) $\frac{2RT}{\gamma - 1}$ (3) $\frac{2RT}{3(\gamma - 1)}$ (4) $\frac{2T}{\gamma - 1}$

Sol. Answer (2)

$$\Delta Q = \Delta U + \Delta W$$
$$\Delta Q - \Delta W = \Delta U$$
$$\frac{\gamma}{\gamma - 1}\Delta W - \Delta W = \Delta U$$
$$\Delta U = \Delta W\left(\frac{1}{\gamma - 1}\right) = \frac{(P.\Delta V)}{\gamma - 1} = \frac{nRT}{\gamma - 1} = \frac{2RT}{\gamma - 1}$$

6. A triatomic, diatomic and monatomic gas is supplied same amount of heat at constant pressure, then

(1) Fractional energy used to change internal energy is maximum in monatomic gas

(2) Fractional energy used to change internal energy is maximum in diatomic gas

(3) Fractional energy used to change internal energy is maximum in triatomic gases

(4) Fractional energy used to change internal energy is same in all the three gases

Sol. Answer (3)

$$\frac{\Delta U}{\Delta Q} = \frac{nC_V\Delta T}{nC_P\Delta T} = \frac{C_V}{C_P} = \frac{1}{\gamma}$$
$$\left(\frac{\Delta U}{\Delta Q}\right)_{\text{mono}} = \frac{1}{\gamma_{\text{mono}}} = \frac{3}{5}$$
$$\left(\frac{\Delta U}{\Delta Q}\right)_{\text{dia}} = \frac{1}{\gamma_{\text{dia}}} = \frac{5}{7}$$
$$\left(\frac{\Delta U}{\Delta Q}\right)_{\text{tria}} = \frac{1}{\gamma_{\text{tria}}} = \frac{3}{4}$$

Fractional energy used to change internal energy is maximum in Triatomic gas.

7. 105 calories of heat is required to raise the temperature of 3 moles of an ideal gas at constant pressure from 30°C to 35°C. The amount of heat required in calories to raise the temperature of the gas through the range (60°C to 65°C) at constant volume is $\left(\gamma = \frac{C_p}{C_v} = 1.4\right)$

(1) 50 cal (2) 75 cal (3) 70 cal (4) 90 cal

Sol. Answer (2)

At constant pressure heat absorbed = $\Delta Q = nC_P\Delta T$ …(1)

At constant volume heat absorbed = $\Delta U = nC_V\Delta T$ …(2)

Dividing (1) by (2),

$$\frac{\Delta Q}{\Delta U} = \frac{C_P}{C_V} = \gamma = 1.4 \Rightarrow \frac{105}{\Delta U} = 1.4$$

$\therefore \quad \Delta U_V = 75$ cal

8. To an ideal triatomic gas 800 cal heat energy is given at constant pressure. If vibrational mode is neglected, then energy used by gas in work done against surroundings is

(1) 200 cal (2) 300 cal (3) 400 cal (4) 60 cal

Sol. Answer (1)

Heat at constant pressure

$\Delta Q = nC_P\Delta T$

Heat for doing work

$\Delta W = nR\Delta T$

Then $\frac{\Delta W}{\Delta Q} = \frac{nR\Delta T}{nC_P\Delta T}$

$$\frac{\Delta W}{800} = \left(\frac{\gamma - 1}{\gamma}\right)$$

$$\frac{\Delta W}{800} = 1 - \frac{1}{\gamma}$$

$$\frac{\Delta W}{800} = 1 - \frac{3}{4}$$

$\Delta W = 200$ cal

9. A closed cylindrical vessel contains *N* moles of an ideal diatomic gas at a temperature *T*. On supplying heat, temperature remains same, but *n* moles get dissociated into atoms. The heat supplied is

(1) $\frac{5}{2}(N-n)RT$ (2) $\frac{5}{2}nRT$ (3) $\frac{1}{2}nRT$ (4) $\frac{3}{2}nRT$

Sol. Answer (3)

Heat supplied = $\Delta U = U_{\text{final}} - U_{\text{initial}}$

Total internal energy initially = $\frac{5}{2}NRT$ [Only diatomic gas is present]

Total internal energy when

'n' moles get dissociated $= \frac{5}{2}(N-n)RT + \frac{3}{2}(2n)RT$ [diatomic and monoatomic both are present]

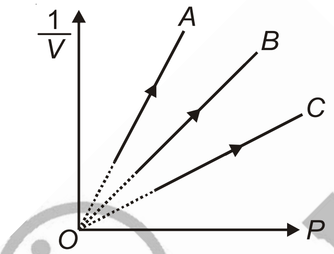
$$\Delta U = \left\{\frac{5}{2}(N-n)RT + \frac{3}{2}(2n)RT\right\} - \frac{5}{2}NRT$$

Solving this we get

$$\Delta U = \frac{1}{2}nRT$$

$\therefore$ Heat supplied is $\frac{1}{2}nRT$.

10. Figure shows the isotherms of a fixed mass of an ideal gas at three temperatures T_A, T_B and T_C, then

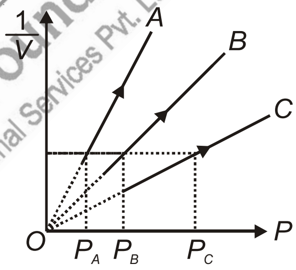


(1) $T_A > T_B > T_C$ (2) $T_A < T_B < T_C$ (3) $T_B < T_A < T_C$ (4) $T_A = T_B = T_C$

Sol. Answer (2)

$\because$ $PV = RT$

$$\frac{RT}{V} = P$$



$\because$ For constant $\frac{1}{V}$ So, $P \propto T$

$\because$ $P_C > P_B > P_A$ then

$T_C > T_B > T_A$

11. An ideal monatomic gas at 300 K expands adiabatically to 8 times its volume. What is the final temperature?

(1) 75 K (2) 300 K (3) 560 K (4) 340 K

Sol. Answer (1)

Adiabatic expansion

γ for monoatomic gas $= \frac{5}{3}$

$$T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$$

$$T_2 = T_1\left(\frac{V_1}{V_2}\right)^{\gamma-1}$$

$$= 300\left(\frac{V_1}{8V_1}\right)^{5/3} = \frac{300}{4} = 75 \text{ K}$$

12. Slope of isotherm for a gas (having $\gamma = \frac{5}{3}$) is 3×10^5 N/m^2. If the same gas is undergoing adiabatic change then adiabatic elasticity at that instant is

(1) 3×10^5 N/m^2 (2) 5×10^5 N/m^2 (3) 6×10^5 N/m^2 (4) 10×10^5 N/m^2

Sol. Answer (2)

Adiabatic elasticity = γP

$$= \frac{5}{3} \times 3 \times 10^5 = 5 \times 10^5 \text{ N/m}^2$$

13. A gas may expand either adiabatically or isothermally. A number of P–V curves are drawn for the two processes over different range of pressure and volume. It will be found that

(1) An adiabatic curve and an isothermal curve may intersect

(2) Two adiabatic curves do not intersect

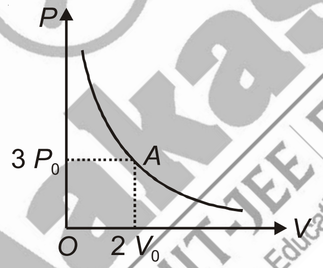
(3) Two isothermal curves do not intersect

(4) All of these

Sol. Answer (4)

Slope for isothermal and adiabatic are not same so they will intersect.

14. The variation of pressure P with volume V for an ideal monatomic gas during an adiabatic process is shown in figure. At point A the magnitude of rate of change of pressure with volume is



(1) $\frac{3\,P_0}{5\,V_0}$ (2) $\frac{5\,P_0}{3\,V_0}$ (3) $\frac{3\,P_0}{2\,V_0}$ (4) $\frac{5\,P_0}{2\,V_0}$

Sol. Answer (4)

PV^{γ} = constant

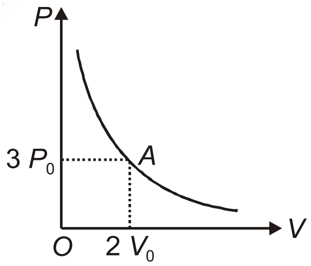
$P \propto V^{-\gamma}$

$$\frac{dP}{P} = -\gamma \frac{dV}{V}$$

$$\frac{dP}{dV} = \gamma \frac{P}{V}$$

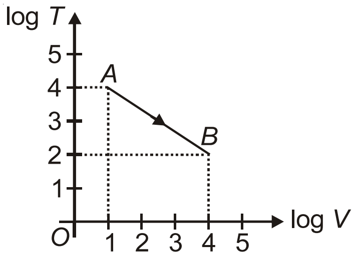
$$= \frac{5}{3} \times \frac{3\,P_0}{2\,V_0}$$

$$= \frac{5\,P_0}{2\,V_0}$$



Then $\left(\frac{dP}{dV}\right) = \frac{5P_0}{2V_0}$

15. Figure shows, the adiabatic curve on a log T and log V scale performed on ideal gas. The gas is



(1) Monatomic (2) Diatomic

(3) Polyatomic (4) Mixture of monatomic and diatomic

Sol. Answer (1)

$TV^{\gamma-1} = K$

$\log T + (\gamma - 1)\log V = 0$

$\log T = -(\gamma - 1)\log V$

$y = -(\gamma - 1)\,x$

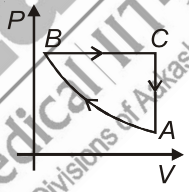
$\frac{y}{x} = -(\gamma - 1) =$ slope $= \frac{2-4}{4-1}$

$\Rightarrow\ -(\gamma - 1) = -\frac{2}{3}$

$\gamma = \frac{5}{3}$

$\therefore$ Monoatomic.

16. A cyclic process on an ideal monatomic gas is shown in figure. The correct statement is



(1) Work done by gas in process AB is more than that in the process BC

(2) Net heat energy has been supplied to the system

(3) Temperature of the gas is maximum at state B

(4) In process CA, heat energy is absorbed by system

Sol. Answer (2)

It is a cyclic system $\Rightarrow \Delta U = 0$

and work done is (+)ive, so heat is supplied to system.

17. A diatomic gas undergoes a process represented by $PV^{1.3}$ = constant. Choose the incorrect statement

(1) The gas expands by absorbing heat from the surroundings

(2) The gas cools down during expansion

(3) The work done by surroundings during expansion of the gas is negative

(4) None of these

Sol. Answer (4)

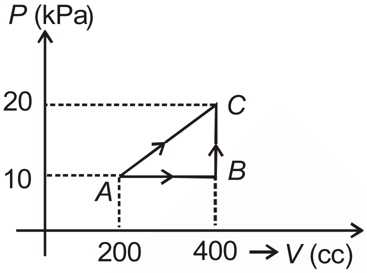
$PV^{1.3} = K$

$W = \dfrac{P_2V_2 - P_1V_1}{1-N}$ $\qquad\because N > 1$, so W is negative.

Heat supplied by surrounding heat goes to do work.

$\therefore$ Down when expands.

18. If a gas is taken from A to C through B then heat absorbed by the gas is 8 J. Heat absorbed by the gas in taking it from A to C directly is



(1) 8 J
(2) 9 J
(3) 11 J
(4) 12 J

Sol. Answer (2)

When taken through ABC [ΔU + work = heat absorbed]

Heat absorbed = area under graph + ΔU = 8

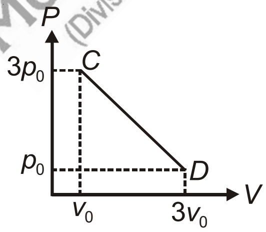
$$\Delta U = 8 - \frac{10\times 200}{1000} = 6$$

when taken directly to C

$W + \Delta U = Q$

$$\left[\frac{10\times 200}{1000} + \frac{1}{2}\times\frac{2000}{1000}\right] + 6 = Q \Rightarrow Q = 9\text{ J}$$

19. The process CD is shown in the diagram. As system is taken from C to D, what happens to the temperature of the system?



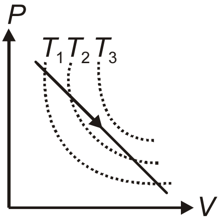
(1) Temperature first decreases and then increases
(2) Temperature first increases and then decreases
(3) Temperature decreases continuously
(4) Temperature increases continuously

Sol. Answer (2)

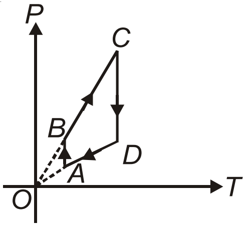
$T_3 > T_2 > T_1$

So from $C \rightarrow D$

Temperature first increases then decreases.



20. A P-T graph is shown for a cyclic process. Select correct statement regarding this



(1) During process CD, work done by gas is negative

(2) During process AB, work done by the gas is positive

(3) During process BC internal energy of system increases

(4) During process BC internal energy of the system decreases

Sol. Answer (3)

In process BC (isochoric process) where ΔT is (+)ive.

So $\Delta U = nC_V\Delta T$

$\because$ ΔT is positive $\Rightarrow U$ increases

21. A hydrogen cylinder is designed to withstand an internal pressure of 100 atm. At 27°C, hydrogen is pumped into the cylinder which exerts a pressure of 20 atm. At what temperature does the danger of explosion first sets in?

(1) 500 K (2) 1500 K (3) 1000 K (4) 2000 K

Sol. Answer (2)

Constant volume process

$PV = nRT$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$\frac{20}{300} = \frac{100}{T_2}$$

$T_2 = 1500$ K

22. An ideal gas of volume V and pressure P expands isothermally to volume 16 V and then compressed adiabatically to volume V. The final pressure of gas is [$\gamma = 1.5$]

(1) P (2) $3P$ (3) $4P$ (4) $6P$

Sol. Answer (3)

Isothermal expansion

$P_1V_1 = P_2V_2$

$PV = 16\ V \times P'$

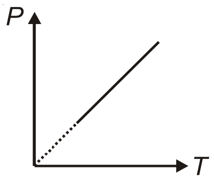
$$\frac{P}{16} = P'$$

$P_1V_1^{\gamma} = P_2V_2^{\gamma}$ [adiabatic compression]

$P'(16\ V)^{1.5} = P''\ (V)^{1.5}$

$$\frac{P}{16} \times 16^{1.5} = P'' = 4P$$

23. The pressure P of an ideal diatomic gas varies with its absolute temperature T as shown in figure. The molar heat capacity of gas during this process is [R is gas constant]



(1) 1.7 R (2) 3.25 R (3) 2.5 R (4) 4.2 R

Sol. Answer (3)

C_V of diatomic $= \frac{5}{2}R$

24. An ideal gas expands according to the law P^2V = constant. The internal energy of the gas

(1) Increases continuously (2) Decreases continuously

(3) Remain constant (4) First increases and then decreases

Sol. Answer (1)

$P^2V = K$

or $PV^{-2} = K$

$N = -2$

$C = C_V + \frac{R}{1-N}$ = positive quantity

$C > 0$

$W > 0$ [gas is expanding]

$\because$ $PV^{-2} = K$ so TV^{-3} = constant

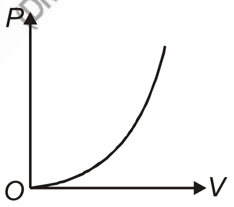
$\Rightarrow$ T will increases if V increases.

$\Rightarrow$ $\Delta T > 0$

So $\Delta U = \eta C \Delta T > 0$

It will increase continuously.

25. The variation of pressure P with volume V for an ideal diatomic gas is parabolic as shown in the figure. The molar specific heat of the gas during this process is



(1) $\frac{9R}{5}$ (2) $\frac{17R}{6}$ (3) $\frac{3R}{4}$ (4) $\frac{8R}{5}$

Sol. Answer (2)

$P = aV^{-2}$ So, PV^2 = constant then $N = 2$

$C = \frac{R}{\gamma - 1} - \frac{R}{1-N}$ $\because \gamma = 1.4$

$C = \frac{17R}{6}$

26. Neon gas of a given mass expands isothermally to double volume. What should be the further fractional decrease in pressure, so that the gas when adiabatically compressed from that state, reaches the original state?

(1) $1 - 2^{-2/3}$ (2) $1 - 3^{1/3}$ (3) $2^{1/3}$ (4) $3^{2/3}$

Sol. Answer (1)

$P_1V_1 = P_2V_2$ [for isothermal]

$PV = P' \times 2V$

$\frac{P}{2} = P'$

$P_1V_1^{\gamma} = P_2V_2^{\gamma}$ [for adiabatic]

$\frac{P}{2} \times (2V)^{5/3} = P_2 (V)^{5/3}$ [γ for neon = 5/3]

$P = P_2 . (2)^{-2/3}$

Fractional decrease $= \frac{P_2 - P}{P_2} = \frac{P_2 - P_2 .(2)^{-2/3}}{P_2} = 1 - 2^{-2/3}$

27. When 1 kg of ice at 0°C melts to water at 0° C, the resulting change in its entropy, taking latent heat of ice to be 80 cal/°C is

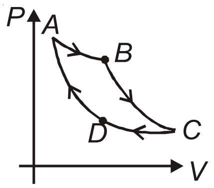
(1) 293 cal/K (2) 273 cal/K (3) 8×10^4 cal/K (4) 80 cal/K

Sol. Answer (1)

$\because$ Entropy $= \left(\frac{Q}{\Delta T}\right) = \left(\frac{ml_f}{\Delta T}\right)$

$\Delta y = \frac{1000 \times 80}{273} = 293$ cal/K

28. Carnot cycle is plotted in P-V graph. Which portion represents an isothermal expansion?



(1) AB (2) BC (3) CD (4) DA

Sol. Answer (1)

AB is isothermal expansion. BC is adiabatic expansion

CD is isothermal compression

ΔA = adiabatic compression.

29. Efficiency of a heat engine working between a given source and sink is 0.5. Coefficient of performance of the refrigerator working between the same source and the sink will be

(1) 1 (2) 0.5 (3) 1.5 (4) 2

Sol. Answer (1)

$$\eta = \frac{1}{1+\beta}$$

$$0.5 = \frac{1}{1+\beta}$$

$\beta = 1$

30. A heat engine rejects 600 cal to the sink at 27°C. Amount of work done by the engine will be

(Temperature of source is 227°C & $J = 4.2$ J/cal)

(1) 1680 J (2) 840 J (3) 2520 J (4) None of these

Sol. Answer (1)

$$1 - \frac{T_2}{T_1} = \frac{W}{Q_1}$$

$$1 - \frac{300}{500} = \frac{W}{Q_1}$$

$$\frac{W}{Q_1} = \frac{2}{5}$$

$$Q_1 = \frac{5W}{2}$$

$\because \; W = Q_1 - Q_2$

Then $Q_2 = Q_1 - W$

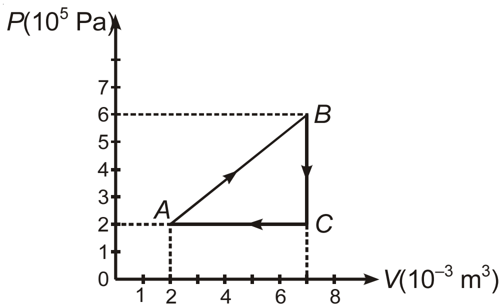
$$Q_2 = \frac{5W}{2} - W = \frac{3W}{2}$$

Then $W = \frac{2Q_2}{3} = \frac{2\times 600}{3}$ = 400 cal = 400 × 4.2 J = 1680 J

SECTION - C

Previous Years Questions

1. A gas is taken through the cycle $A \rightarrow B \rightarrow C \rightarrow A$, as shown. What is the net work done by the gas?



(1) 1000 J (2) Zero (3) –2000 J (4) 2000 J

Sol. Answer (1)

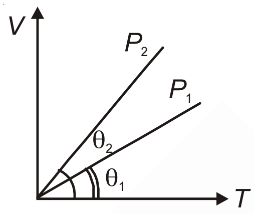
$\because$ Cyclic curve is clockwise *i.e.*, W = +ve

W = area enclosed

$$= \frac{1}{2} \times 5 \times 10^{-3} \times 4 \times 10^{5}$$

= 1000 J

2. In the given (V-T) diagram, what is the relation between pressures P_1 and P_2?



(1) $P_2 > P_1$ (2) $P_2 < P_1$ (3) Cannot be predicted (4) $P_2 = P_1$

Sol. Answer (2)

$\because \quad PV = RT$

$$\frac{V}{T} = \frac{R}{P} = \tan\theta \qquad \left\{\begin{array}{c}\because \text{ Slope of } V\text{-}T \text{ graph}\\ m = \tan\theta = \dfrac{V}{T}\end{array}\right\}$$

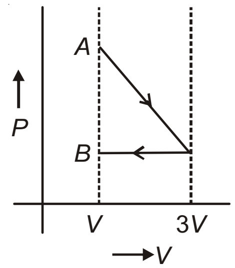
i.e., $P = \dfrac{1}{\tan\theta}$

$\theta_2 > \theta_1$ so $\tan\theta_2 > \tan\theta_1$

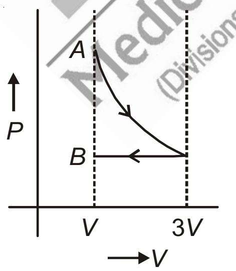
$\Rightarrow \quad P_2 < P_1$ then $P_2 < P_1$

3. One mole of an ideal gas goes from an initial state A to final state B via two processes: It first undergoes isothermal expansion from volume V to $3V$ and then its volume is reduced from $3V$ to V at constant pressure. The correct P-V diagram representing the two processes is

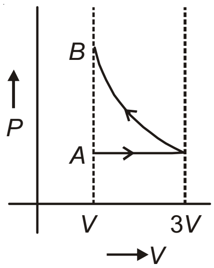
(1)



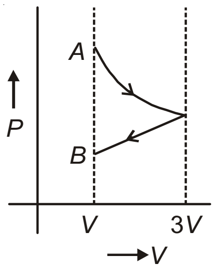
(2)



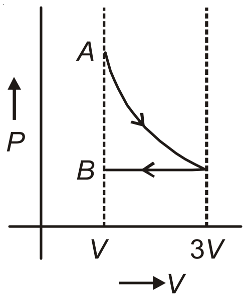
(3)



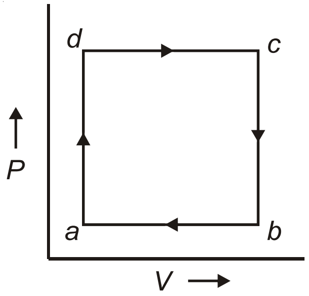
(4)



Sol. Answer (2)



4. A system is taken from state *a* to state *c* by two paths *adc* and *abc* as shown in the figure. The internal energy at *a* is U_a = 10 J. Along the path *adc* the amount of heat absorbed δQ_1 = 50 J and the work obtained δW_1 = 20 J whereas along the path *abc* the heat absorbed δQ_2 = 36 J. The amount of work along the path *abc* is



(1) 6 J (2) 10 J (3) 12 J (4) 36 J

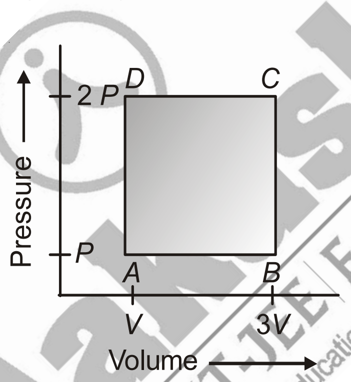
Sol. Answer (1)

$dQ_{1\ adc} = 50 = dU_{adc} + 20 \Rightarrow dU_{adc} = 30 = dU_{abc}$

$dQ_{abc} = 36 = 30 + dW_{abc}$

$\Rightarrow\ dW_{abc} = 6$ J

5. A thermodynamic system is taken through the cycle *ABCD* as shown in figure. Heat rejected by the gas during the cycle is

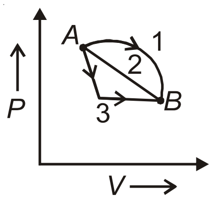


(1) $\frac{1}{2}PV$ (2) PV (3) $2\ PV$ (4) $4\ PV$

Sol. Answer (3)

Heat rejected = workdone by surrounding = area of *PV* graph = $P \times 2V = 2PV$

6. An ideal gas goes from state *A* to state *B* via three different processes as indicated in the *P*-*V* diagram



If Q_1, Q_2, Q_3 indicate the heat absorbed by the gas along the three processes and ΔU_1, ΔU_2, ΔU_3 indicate the change in internal energy along the three processes respectively, then

(1) $Q_1 > Q_2 > Q_3$ and $\Delta U_1 = \Delta U_2 = \Delta U_3$ (2) $Q_3 > Q_2 > Q_1$ and $\Delta U_1 = \Delta U_2 = \Delta U_3$

(3) $Q_1 = Q_2 = Q_3$ and $\Delta U_1 > \Delta U_2 > \Delta U_3$ (4) $Q_3 > Q_2 > Q_1$ and $\Delta U_1 > \Delta U_2 > \Delta U_3$

Sol. Answer (1)

$Q_1 > Q_2 > Q_3$ and $\Delta U_1 = \Delta U_2 = \Delta U_3$

7. During an isothermal expansion, a confined ideal gas does –150 J of work against its surrounding. This implies that

(1) 150 J of heat has been added to the gas

(2) 150 J of heat has been removed from the gas

(3) 300 J of heat has been added to the gas

(4) No heat is transferred because the process is isothermal

Sol. Answer (2)

It implies 150 J heat has been removed from the gas.

8. During an adiabatic process, the pressure of a gas is found to be proportional to the cube of its temperature. The ratio of $\frac{C_p}{C_v}$ for the gas is

(1) 2 (2) $\frac{5}{3}$ (3) $\frac{3}{2}$ (4) $\frac{4}{3}$

Sol. Answer (3)

$P \propto T^3$

PT^{-3} = constant

Compare with $PT^{\left(\frac{\gamma}{1-\gamma}\right)} = \text{constant}$

Then, $\frac{\gamma}{1-\gamma} = -3$

$\gamma = \frac{3}{2}$

9. A mass of diatomic gas (γ = 1.4) at a pressure of 2 atmospheres is compressed adiabatically so that its temperature rises from 27°C to 927°C. The pressure of the gas in the final state is

(1) 256 atm (2) 8 atm (3) 28 atm (4) 68.7 atm

Sol. Answer (1)

$P^{1-\gamma}T^{\gamma} = C$ then, $PT^{\left(\frac{\gamma}{1-\gamma}\right)} = \text{constant}$

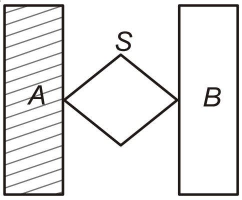
$$\frac{P_2}{P_1} = \left(\frac{T_1}{T_2}\right)^{\gamma/1-\gamma}$$

$$\frac{P_2}{2} = \left(\frac{300}{1200}\right)^{1.4/1-1.4}$$

$$\frac{P_2}{2} = \left(\frac{1}{4}\right)^{-7/2}$$

$P_2 = 2^6 = 256$ atm

10. Consider two insulated chambers (A, B) of same volume connected by a closed knob, S. 1 mole of perfect gas is confined in chamber A. What is the change in entropy of gas when knob S is opened? R = 8.31 J mol^{-1}K^{-1}.



(1) 1.46 J/K (2) 3.46 J/K (3) 5.46 J/K (4) 7.46 J/K

Sol. Answer (3)

$$\Delta S = 2.303\ nR\log_e \frac{V_2}{V_1}$$

If initially volume is taken as V, then final volume = ZV, as volume of both chambers is given to be same.

$$\Rightarrow \quad \Delta S = 2.303 \times 1 \times 8.31 \times \log_e \frac{2V}{V}$$

$$\Delta S \cong 5.46 \text{ J/K}$$

11. A Carnot engine has efficiency 25%. It operates between reservoirs of constant temperatures with temperature difference of 80°C. What is the temperature of the low-temperature reservoir?

(1) –25°C (2) 25°C (3) –33°C (4) 33°C

Sol. Answer (3)

$$\eta = 1 - \frac{T_L}{T_H}$$

$$\frac{1}{4} = 1 - \frac{T_L}{T_H}$$

$$T_H = \frac{4}{3}T_L$$

also $T_H - T_L = 80$

$\Rightarrow$ $T_L = 240$ K = –33°C

12. If Q, E and W denote respectively the heat added, change in internal energy and the work done in a closed cycle process, then

(1) Q = 0 (2) W = 0 (3) Q = W = 0 (4) E = 0

Sol. Answer (4)

E = change in U

and in cyclic process $\Delta U = 0$

$\Rightarrow$ $E = 0$

13. In an adiabatic change, the pressure and temperature of a monatomic gas are related as $P \propto T^c$, where c equals

(1) $\frac{3}{5}$ (2) $\frac{5}{3}$ (3) $\frac{2}{5}$ (4) $\frac{5}{2}$

Sol. Answer (4)

$$P \propto T^C \Rightarrow PT^{-C} = K$$

And compare with $PT^{\left(\frac{\gamma}{1-\gamma}\right)} = \text{constant}$ [condition from adiabatic process]

Then, $-C = \dfrac{\gamma}{1-\gamma}$

$$C = -\frac{5/3}{1-5/3} = -\frac{5/3}{-2/3} = \frac{5}{2}$$

14. An ideal Carnot engine, whose efficiency is 40%, receives heat at 500 K. If its efficiency is 50%, then the intake temperature for the same exhaust temperature is

(1) 800 K (2) 900 K (3) 600 K (4) 700 K

Sol. Answer (3)

$$\eta = 1 - \frac{T_2}{T_1}$$

$$\frac{40}{100} = 1 - \frac{T_2}{500}$$

$T_2 = 300$ K

If $\eta = 50\%$

$$\frac{50}{100} = 1 - \frac{300}{T_1}$$

$\Rightarrow T_1 = 600$ K

15. A monatomic gas initially at 18°C is compressed adiabatically to one eighth of its original volume. The temperature after compression will be

(1) 1164 K (2) 144 K (3) 18 K (4) 887.4 K

Sol. Answer (1)

$\because TV^{\gamma-1} = \text{constant}$

$$T_1\left(\frac{V_1}{V_2}\right)^{\gamma-1} = T_2$$

$291 \times (8)^{2/3} = T_2$

$T_2 = 291 \times 4 = 1164$ K

16. An ideal gas, undergoing adiabatic change, has which of the following pressure temperature relationship?

(1) $P^{\gamma}T^{1-\gamma}$ = constant (2) $P^{1-\gamma}T^{\gamma}$ = constant (3) $P^{\gamma-1}T^{\gamma}$ = constant (4) $P^{\gamma}T^{\gamma-1}$ = constant

Sol. Answer (2)

$$PV^{\gamma} = \text{constant}$$

$$P\left(\frac{T}{P}\right)^{\gamma} = \text{constant} \qquad \left\{\begin{aligned} \because\ PV &= RT \\ V &= \left(\frac{RT}{P}\right) \end{aligned}\right\}$$

$$P^{1-\gamma}.T^{\gamma} = \text{constant}$$

17. A sample of gas expands from volume V_1 to V_2. The amount of work done by the gas is greatest, when the expansion is

(1) Adiabatic (2) Equal in all cases (3) Isothermal (4) Isobaric

Sol. Answer (4)

Work done is maximum in isobaric process

$W = P.\Delta V = P(V_2 - V_1) = nR(T_2 - T_1)$

18. The efficiency of a Carnot engine operating with reservoir temperature of 100°C and – 23°C will be

(1) $\frac{373+250}{373}$ (2) $\frac{373-250}{373}$ (3) $\frac{100+23}{100}$ (4) $\frac{100-23}{100}$

Sol. Answer (2)

$$\eta = 1 - \frac{T_2}{T_1} \qquad \begin{bmatrix} \text{Where} \\ T_2 - \text{sink temperature} \\ T_1 - \text{reservoir temperature} \end{bmatrix}$$

$$\eta = \frac{373-250}{373}$$

19. We consider a thermodynamic system. If ΔU represents the increase in its internal energy and W the work done by the system, which of the following statements is true?

(1) $\Delta U = -W$ in an isothermal process (2) $\Delta U = W$ in an isothermal process

(3) $\Delta U = -W$ in an adiabatic process (4) $\Delta U = W$ in an adiabatic process

Sol. Answer (3)

As Q = zero for adiabatic process

So $\Delta U = -W$ for adiabatic process

20. If the ratio of specific heat of a gas at constant pressure to that at constant volume is γ, the change in internal energy of a mass of gas, when the volume changes from V to $2V$ at constant pressure P, is

(1) $\frac{PV}{(\gamma-1)}$ (2) PV (3) $\frac{R}{(\gamma-1)}$ (4) $\frac{\gamma PV}{(\gamma-1)}$

Sol. Answer (1)

$$\Delta U = nC_V\Delta T = n\left(\frac{R}{\gamma-1}\right)\Delta T = \frac{nR(T_2-T_1)}{\gamma-1} = \frac{nRT_2 - nRT_1}{\gamma-1}$$

$$= \frac{P(2V-V)}{\gamma-1} = \frac{PV}{\gamma-1}$$

21. An ideal gas at 27°C is compressed adiabatically to 8/27 of its original volume. The rise in temperature is (Take γ = 5/3)

(1) 275 K (2) 375 K (3) 475 K (4) 175 K

Sol. Answer (2)

$\because \quad TV^{\gamma-1}$ = constant

$$T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$$

$$T_1 \times \left[\frac{V_1}{V_2}\right]^{\gamma-1} = T_2$$

$$300 \times \left[\frac{27}{8}\right]^{5/3-1} = T_2$$

$$300 \times \left[\frac{3}{2}\right]^{2} = T_2$$

$$300 \times \frac{9}{4} = T_2$$

675 K = T_2

$\therefore \quad \Delta T = 675 - 300 = 375$ K

22. Two Carnot engines *A* and *B* are operated in series. The engine *A* receives heat from the source at temperature T_1 and rejects the heat to the sink at temperature *T*. The second engine *B* receives the heat at temperature *T* and rejects to its sink at temperature T_2. For what value of *T* the efficiencies of the two engines are equal?

(1) $\frac{T_1 + T_2}{2}$ (2) $\frac{T_1 - T_2}{2}$ (3) T_1T_2 (4) $\sqrt{T_1T_2}$

Sol. Answer (4)

$\eta_A = \eta_B$

$$\left(\frac{T_L}{T_H}\right)_A = \left(\frac{T_L}{T_H}\right)_B$$

$$\frac{T}{T_1} = \frac{T_2}{T}$$

$$T^2 = T_1T_2 \Rightarrow T = \sqrt{T_1T_2}$$

23. The (W/Q) of a Carnot engine is 1/6. Now the temperature of sink is reduced by 62°C, then this ratio becomes twice, therefore the initial temperature of the sink and source are respectively

(1) 33°C, 67°C (2) 37°C, 99°C (3) 67°C, 33°C (4) 97K, 37K

Sol. Answer (2)

$$\frac{1}{6} = 1 - \frac{T_L}{T_H} \text{ ...(1)}$$

$$2 \times \left(\frac{1}{6}\right) = 1 - \left(\frac{T_L - 62}{T_H}\right)$$

$$\frac{1}{3} = 1 - \frac{(T_2 - 62)}{T_H}$$

$$\frac{1}{3} = 1 - \frac{5}{6} + \frac{62}{T_H}$$

T_H = 372°K = 99°C

T_L = 37°C

24. A scientist says that the efficiency of his heat engine which works at source temperature 127°C and sink temperature 27°C is 26%, then

(1) It is impossible
(2) It is possible but less probable
(3) It is quite probable
(4) Data are incomplete

Sol. Answer (1)

$$\eta = 1 - \frac{T_L}{T_H} = 1 - \frac{300}{400} = 25\%$$

25. The efficiency of Carnot engine is 50% and temperature of sink is 500 K. If temperature of source is kept constant and its efficiency raised to 60%, then the required temperature of sink will be

(1) 100 K
(2) 600 K
(3) 400 K
(4) 500 K

Sol. Answer (3)

$$\frac{1}{2} = 1 - \frac{500}{T_H} \quad \Bigg| \quad \frac{6}{10} = 1 - \frac{T_L}{10^3}$$

$$T_H = 10^3 \quad \Big| \quad T_L = 4 \times 10^2 = 400\text{ K}$$

26. An ideal gas heat engine operates in a Carnot cycle between 227°C and 127°C. It absorbs 6 kcal at the higher temperature. The amount of heat (in kcal) converted into work is equal to

(1) 4.8
(2) 3.5
(3) 1.6
(4) 1.2

Sol. Answer (4)

$$\frac{W}{Q_1} = 1 - \frac{T_L}{T_H}$$

$$\frac{W}{6} = 1 - \frac{400}{500} = 1.2\text{ J}$$

27. One mole of an ideal gas at an initial temperature of T K does $6R$ joules of work adiabatically. If the ratio of specific heats of this gas at constant pressure and at constant volume is 5/3, the final temperature of gas will be

(1) $(T + 2.4)$ K
(2) $(T - 2.4)$ K
(3) $(T + 4)$ K
(4) $(T - 4)$ K

Sol. Answer (4)

$$W = \frac{-nR(T_2 - T_1)}{\gamma - 1} = -dU \qquad \left[\gamma = \frac{5}{3}\right]$$

$$\Rightarrow \quad T_{\text{final}} = (T - 4)\text{ K}$$

28. Which of the following processes is reversible?

(1) Transfer of heat by conduction
(2) Transfer of heat by radiation
(3) Isothermal compression
(4) Electrical heating of a nichrome wire

Sol. Answer (3)

Isothermal compression takes place slowly at constant pressure, also ΔU is zero so it is a reversible process.

29. A Carnot engine whose sink is at 300 K has an efficiency of 40%. By how much should the temperature of source be increased so as to increase its efficiency by 50% of original efficiency?

(1) 380 K (2) 275 K (3) 325 K (4) 250 K

Sol. Answer (4)

$\eta = 1 - \frac{T_2}{T_1}$ Where T_2 = Sink Temperature

T_1 = Source Temperature

Temperature of sink is given to be 300 K.

$\eta = 0.4$

So $0.4 = 1 - \frac{300}{T_1}$

$\Rightarrow T_1 = 500$ K

Now, η is increased by 50%.

$\Rightarrow \eta' = \frac{150}{100} \times \eta = \frac{15}{10} \times 0.4 = 0.6$

To maintain same sink temperature new source temperature is

$0.6 = 1 - \frac{300}{T_1}$

$T_1 = 750$ K

$\therefore$ Increase in temperature = 750 – 500 = 250 K

30. An engine has an efficiency of 1/6. When the temperature of sink is reduced by 62°C, its efficiency is doubled. Temperatures of the source is

(1) 37°C (2) 62°C (3) 99°C (4) 124°C

Sol. Answer (3)

$$\frac{1}{3} = 1 - \frac{(T_L - 62)}{T_H}$$

$$\frac{1}{3} = 1 - \frac{5}{6} + \frac{62}{T_H} \qquad \left[\frac{T_L}{T_H} = \frac{5}{6}\right]$$

$T_H = 372°$ K = 99°C

$T_L = 37$°C

31. In thermodynamic processes which of the following statements is not true?

(1) In an adiabatic process PV^γ = constant

(2) In an adiabatic process the system is insulated from the surroundings

(3) In an isochoric process pressure remains constant

(4) In an isothermal process the temperature remains constant

Sol. Answer (3)

In isochoric processes volume remains constant.

32. The amount of heat energy required to raise the temperature of 1 g of Helium at NTP, from T_1 K to T_2 K is

(1) $\frac{3}{2}N_a k_B(T_2 - T_1)$ (2) $\frac{3}{4}N_a k_B(T_2 - T_1)$ (3) $\frac{3}{4}N_a k_B\left(\frac{T_2}{T_1}\right)$ (4) $\frac{3}{8}N_a k_B(T_2 - T_1)$

Sol. Answer (4)

$$Q = \eta \,.\, \frac{f}{2} R(dT)$$

$$= \frac{3}{8} N_a K_B (T_2 - T_1) = Q$$

33. The internal energy change in a system that has absorbed 2 kcals of heat and done 500 J of work is

(1) 7900 J (2) 8900 J (3) 6400 J (4) 5400 J

Sol. Answer (1)

$2 \times 4.2 \times 1000 = dU + 500$

$dU = 7900$ J

34. If ΔU and ΔW represent the increase in internal energy and work done by the system respectively in a thermodynamical process, which of the following is true?

(1) $\Delta U = -\Delta W$, in a isothermal process (2) $\Delta U = -\Delta W$, in a adiabatic process

(3) $\Delta U = \Delta W$, in a isothermal process (4) $\Delta U = \Delta W$, in a adiabatic process

Sol. Answer (2)

In adiabatic process $Q = 0$

So $\Delta U = -\Delta W$ $[\because \Delta Q = \Delta W + \Delta U]$

35. The molar specific heats of an ideal gas at constant pressure and volume are denoted by C_p and C_v respectively. If $\gamma = \frac{C_p}{C_v}$ and R is the universal gas constant, then C_v is equal to

(1) $\frac{R}{(\gamma - 1)}$ (2) $\frac{(\gamma - 1)}{R}$ (3) γR (4) $\frac{1+\gamma}{1-\gamma}$

Sol. Answer (1)

$$\gamma = \frac{C_p}{C_v}$$

We know $C_p - C_v = R$

So $C_v = \frac{R}{\gamma - 1}$

36. Which of the following relations does not give the equation of an adiabatic process, where terms have their usual meaning?

(1) $P^{\gamma}.T^{1-\gamma}$ = constant (2) $P^{1-\gamma}T^{\gamma}$ = constant

(3) PV^{γ} = constant (4) $TV^{\gamma-1}$ = constant

Sol. Answer (1)

It is $P^{1-\gamma}T^{\gamma} = K$

37. If C_p and C_v denote the specific heats (per unit mass) of an ideal gas of molecular weight M, where R is the molar gas constant

(1) $C_p - C_v = R/M^2$ (2) $C_p - C_v = R$ (3) $C_p - C_v = R/M$ (4) $C_p - C_v = MR$

Sol. Answer (3)

$$C_p - C_v = \frac{R}{M}$$

Because C_p & C_v are given per unit mass

And $C_p - C_v = R$ is for 1 mole

So here we use R/M where M is molecular mass.

38. According to C.E. van der Waal, the interatomic potential varies with the average interatomic distance (R) as

(1) R^{-1} (2) R^{-2} (3) R^{-4} (4) R^{-6}

Sol. Answer (4)

According to van der Waal's formulae, interatomic potential is inversely proportion to R^6.

So, $U \propto R^{-6}$

39. In a vessel, the gas is at a pressure P. If the mass of all the molecules is halved and their speed is doubled, then the resultant pressure will be

(1) $4P$ (2) $2P$ (3) P (4) $P/2$

Sol. Answer (2)

$$P = \frac{1}{3}MnV^2$$

$$P' = \frac{1}{3}\times\frac{M}{2}n(2V)^2 = 2\times\frac{1}{3}MnV^2 = 2P$$

40. The mean free path of collision of gas molecules varies with its diameter (d) of the molecules as

(1) d^{-1} (2) d^{-2} (3) d^{-3} (4) d^{-4}

Sol. Answer (2)

$$\lambda \propto \frac{1}{d^2}$$

41. A monatomic gas at pressure P_1 and V_1 is compressed adiabatically to $\frac{1}{8}$th its original volume. What is the final pressure of the gas?

(1) $64\,P_1$ (2) P_1 (3) $16\,P_1$ (4) $32\,P_1$

Sol. Answer (4)

$\because$ PV^{γ} = constant

$$P_2 = P_1\left(\frac{V_1}{V_2}\right)^{\gamma} = P(8)^{5/3} = 32P_1$$

42. At 10°C the value of the density of a fixed mass of an ideal gas divided by its pressure is x. At 110°C this ratio is

(1) $\frac{283}{383}x$ (2) x (3) $\frac{383}{283}x$ (4) $\frac{10}{110}x$

Sol. Answer (1)

$$\frac{\rho}{P} = x \qquad \text{at } 10°\text{C}$$

$$\frac{M}{PV} = x$$

$$\frac{\text{Molecular mass} \times \text{number of moles}}{R \times T} = x$$

$$\Rightarrow \quad \frac{1}{T} \propto x$$

$$\frac{383}{283} = \frac{x}{x'}$$

$$x' = \frac{283}{383}x$$

43. At 0 K, which of the following properties of a gas will be zero?

(1) Volume (2) Density (3) Kinetic energy (4) Potential energy

Sol. Answer (3)

at 0 K $V_{\text{rms}} = 0$ so K.E. = 0

44. The value of critical temperature in terms of van der Waals' constants *a* and *b* is given by

(1) $T_C = \frac{8a}{27Rb}$ (2) $T_C = \frac{27a}{8Rb}$ (3) $T_C = \frac{a}{2Rb}$ (4) $T_C = \frac{a}{27Rb}$

Sol. Answer (1)

$$T_C = \frac{8a}{27Rb}$$

45. The degrees of freedom of a triatomic gas is

(Consider moderate temperature)

(1) 6 (2) 4 (3) 2 (4) 8

Sol. Answer (1)

Degree of freedom = 3 rotational + 3 translational + 0 vibrational [*T* is moderate] = 6

46. To find out degree of freedom, the expression is

(1) $f = \frac{2}{\gamma - 1}$ (2) $f = \frac{\gamma + 1}{2}$ (3) $f = \frac{2}{\gamma + 1}$ (4) $f = \frac{1}{\gamma + 1}$

Sol. Answer (1)

$$\because \quad C_V = \frac{fR}{2}$$

$$\text{Then, } f = \frac{2C_V}{R} = \frac{2C_V}{C_P - C_V} = \frac{2}{\frac{C_P}{C_V} - 1} = \frac{2}{\gamma - 1}$$

47. The equation of state for 5 g of oxygen at a pressure P and temperature T, when occupying a volume V, will be (where R is the gas constant)

(1) $PV = \frac{5}{32}RT$ (2) $PV = 5RT$ (3) $PV = \frac{5}{2}RT$ (4) $PV = \frac{5}{16}RT$

Sol. Answer (1)

$$\because \quad PV = nRT = \left(\frac{m}{M}\right)RT$$

$$PV = \frac{5}{32}RT$$

48. The molar specific heat at constant pressure of an ideal gas is (7/2)R. The ratio of specific heat at constant pressure to that at constant volume is

(1) $\frac{9}{7}$ (2) $\frac{7}{5}$ (3) $\frac{8}{7}$ (4) $\frac{5}{7}$

Sol. Answer (2)

$$C_P = \frac{7}{2}R = \frac{\gamma R}{\gamma - 1}$$

$$\Rightarrow \quad \gamma = \frac{7}{5}$$

SECTION - D

Assertion - Reason Type Questions

1. A : Work done by a gas in isothermal expansion is more than the work done by the gas in the same expansion adiabatically.

R : Temperature remains constant in isothermal expansion and not in adiabatic expansion.

Sol. Answer (2)

A : is true

R : is true, but not correct explanation

correct explanation is, in isothermal expansion.

$\because \quad \Delta T = 0$ so $\Delta U = 0$

$\Rightarrow \quad \Delta Q = \Delta W$

all the heat goes in doing work.

Whereas in adiabatic process

Heat goes to work as well as in increasing internal energy.

$\therefore \quad W_{\text{isothermal}} > W_{\text{adiabatic}}$

2. A : Efficiency of heat engine can never be 100%.

R : Second law of thermodynamics puts a limitation on the efficiency of a heat engine.

Sol. Answer (1)

A : is true

R : is true, and correct explanation

3. A : Heat absorbed in a cyclic process is zero.

R : Work done in a cyclic process is zero.

Sol. Answer (4)

A : is false, in cyclic process only $\Delta U = 0$, $\Delta Q = \Delta W$.

R : is false, work done is not zero only change in internal energy is zero.

4. A : Coefficient of performance of a refrigerator is always greater than 1.

R : Efficiency of heat engine is greater than 1.

Sol. Answer (4)

A : is false.

R : is false

Because efficiency of heat engine can never be equal to greater to 1.

$\eta \not\geq 1$

$\because$ all the heat cannot be converted to work.

and coefficient of performane of refrigerator

$$\beta = \frac{1-\eta}{\eta} = \frac{1}{\eta} - 1$$

$\because$ $\eta < 1$ so β may be less than 1.

5. A : Adiabatic expansion causes cooling.

R : In adiabatic expansion, internal energy is used up in doing work.

Sol. Answer (1)

A : is true

R : is true, and correct explanation

6. A : The specific heat of an ideal gas is zero in an adiabatic process.

R : Specific heat of a gas is process independent.

Sol. Answer (3)

A : is true

R : is false

Because specific heat depends on the process.

7. A : The change in internal energy does not depend on the path of process.

R : The internal energy of an ideal gas is independent of the configuration of its molecules.

Sol. Answer (2)

A : is true

R : is true, but not the correct explanation, because internal energy depends on the temperature of the gas.

8. A : Heat supplied to a gaseous system in an isothermal process is used to do work against surroundings.

R : During isothermal process there is no change in internal energy of the system.

Sol. Answer (1)

A : true

R : true and correct explanation

9. A : In nature all thermodynamic processes are irreversible.

R : During a thermodynamic process it is not possible to eliminate dissipative effects.

Sol. Answer (1)

A : is true

R : is true and correct explanation

10. A : During a cyclic process work done by the system is zero.

R : Heat supplied to a system in the cyclic process converts into internal energy of the system.

Sol. Answer (4)

A : is false, in cyclic process, work done is not zero, internal energy change is zero.

R : is false, heat supplied converts to work as initial state is equal to final state.

$\therefore$ No change in internal energy.

❑ ❑ ❑

Chapter 13

Kinetic Theory

Solutions

SECTION - A

Objective Type Questions

1. Select the appropriate property of an ideal gas

   (1) Its molecules are infinitesimally small

   (2) There are no forces of interaction between its molecules

   (3) It strictly obeys the ideal gas laws

   (4) All of these

Sol. Answer (4)

All of the statements are true for an ideal gas.

2. A real gas behaves as an ideal gas at

   (1) Very low pressure and high temperature (2) High pressure and low temperature

   (3) High pressure and high temperature (4) Low pressure and low temperature

Sol. Answer (1)

At very low pressure the force of interaction between particles may be considered negligible. Also at high temperature the force of inter molecular interaction decreases

3. A gas at a pressure P_0 is contained in a vessel. If the masses of all the molecules are halved and their velocities doubled, then the resulting pressure P will be

   (1) $4P_0$ (2) $2P_0$ (3) P_0 (4) $\frac{P_0}{2}$

Sol. Answer (4)

$$P_0 = \frac{1}{3} = \frac{mn}{v}\bar{v}^2$$

$$P' = \frac{1}{3} = \frac{mn}{2v}(2\bar{v})^2 = \frac{P_0}{2}$$

4. If E is the energy density in an ideal gas, then the pressure of the ideal gas is

(1) $P = \frac{2}{3}E$ (2) $P = \frac{3}{2}E$ (3) $P = \frac{5}{2}E$ (4) $P = \frac{2}{5}E$

Sol. Answer (1)

$$E = \frac{1}{2}m\bar{v}^2 \times \frac{n}{v}$$

$$P = \frac{1}{3}\frac{mN}{v}\bar{v}^2$$

$$P = \frac{2}{3}E$$

5. A sample of gas in a box is at pressure P_0 and temperature T_0. If number of molecules is doubled and total kinetic energy of the gas is kept constant, then final temperature and pressure will be

(1) T_0, P_0 (2) T_0, $2P_0$ (3) $\frac{T_0}{2}, 2P_0$ (4) $\frac{T_0}{2}, P_0$

Sol. Answer (4)

$$P_0 = \frac{1}{3}\frac{mN}{v}\cdot v_{\text{rms}}^2$$

If E_0 is initial KE of one molecule

$$nE_0 = E'\cdot 2n \Rightarrow E' = \frac{E}{2} \Rightarrow \left(\frac{1}{2}mv^2\right)\frac{1}{2} = \frac{1}{2}mv'^2 = v' = \frac{v}{\sqrt{2}}$$

Thus KE of every molecule becomes half. Hence temperature becomes $\frac{T_0}{2}$.

$$P' = \frac{1}{3}\frac{m2N}{v}\left(\frac{v}{\sqrt{2}}\right)^2 = P_0$$

Thus $T' = \frac{T_0}{2},\ P' = P_0$

6. By increasing temperature of a gas by 6°C its pressure increases by 0.4 %, at constant volume. Then initial temperature of gas is

(1) 1000 K (2) 1500 K (3) 2000 K (4) 750 K

Sol. Answer (2)

$$\frac{P_2}{P_1} = \frac{T_2}{T_1} \qquad T_1 = T$$

$$T_2 = T + 6$$

$$\frac{P_2}{P_1} - 1 = \frac{T_2}{T_1} - 1$$

$$\frac{P_2 - P_1}{P_1}\times 100 = \left(\frac{T+6}{T} - 1\right)100$$

$$0.4 = \frac{600}{T} \Rightarrow T = 1500\text{ K}$$

7. Boyle's law is obeyed by

(1) Real gas of constant mass and temperature

(2) Ideal gas of constant mass and temperature

(3) Both ideal and real gases at constant temperature and variable mass

(4) Both ideal and real gases of constant mass and variable temperature

Sol. Answer (2)

Boyle's law states that if m and T are constant.

$$V \propto \frac{1}{P}$$

and gas laws are only valid for ideal gases.

8. For an ideal gas the fractional change in its volume per degree rise in temperature at constant pressure is equal to [T is absolute temperature of gas]

(1) T^0 (2) T (3) T^{-1} (4) T^2

Sol. Answer (3)

$$PV = n\,RT \quad \text{... (1)}$$

$$P\,dv = n\,R\,dT \quad \text{... (2)}$$

Dividing (2) by (1)

$$\frac{dV}{V} = \frac{dT}{T}$$

Fractional change in volume per degree rise in temperature

$$\frac{\frac{dV}{V}}{dT} = \frac{1}{T}$$

9. The raise in the temperature of a given mass of an ideal gas at constant pressure and at temperature 27° to double its volume is

(1) 327°C (2) 54°C (3) 300°C (4) 600°C

Sol. Answer (1)

$$PV = n\,RT$$

Initial temperature $T_0 = 300$ K

$$V_0 \propto T_0$$

$$2V_0 \propto 2T_0$$

$$2T_0 = 600 \text{ K}$$

$$\therefore \quad \Delta T = 600 - 300 = 300 \text{ K}$$

10. The average velocity of gas molecules is

(1) Proportional to $\sqrt{T}$ (2) Proportional to T

(3) Zero (4) Not possible to determine

Sol. Answer (3)

$$\bar{v} = \sqrt{\frac{3RT}{M}}$$

$$\therefore \quad v \propto \sqrt{T}$$

11. Which of the following methods will enable the volume of ideal gas to be increased four times?

(1) Double the temperature and reduce the pressure to half

(2) Double the temperature and also double the pressure

(3) Reduce the temperature to half and double the pressure

(4) Reduce the temperature to half and reduce the pressure to half

Sol. Answer (1)

$$V_0 = k\frac{T_0}{P_0}$$

$$4V_0 = 4k\frac{T_0}{P_0}$$

$$= k\times\frac{2T_0}{P_0/2}$$

$\therefore$ Temperature is doubled and pressure halved.

12. A container has N molecules at absolute temperature T. If the number of molecules is doubled but kinetic energy in the box remain the same as before, the absolute temperature of the gas is

(1) T (2) $\frac{T}{2}$ (3) $3T$ (4) $4T$

Sol. Answer (2)

Initial energy of gas = Final energy

Let K.E. of each molecule initially be E_0.

$\therefore$ Total kinetic energy = $E_0 \times n$

Let final kinetic energy of each molecule be E_f.

$$E_0 \times n = E_f \times 2n$$

$$E_f = \frac{E_0}{2}$$

Since temperature is the average kinetic energy of molecules.

$$T_0 = KE_0 \qquad T_f = \frac{KE_0}{2}$$

$\therefore$ Temperature becomes $T_f = \frac{T_0}{2}$

13. During an experiment an ideal gas is found to obey an additional law VP^2 = constant. The gas is initially at temperature T and volume V, when it expands to volume $2V$, the resulting temperature is

(1) $\frac{T}{2}$ (2) $2T$ (3) $\sqrt{2}T$ (4) $\frac{T}{\sqrt{2}}$

Sol. Answer (3)

VP^2 = constant ... (i)

As $PV = RT \Rightarrow P = \frac{RT}{V}$. Thus from (i)

$$\frac{VR^2T^2}{V^2} = \text{constant} \Rightarrow \frac{T^2}{V} = \text{constant}$$

$$\frac{T_2^2}{2V} = \frac{T^2}{V} \Rightarrow T_2 = T\sqrt{2}$$

14. When pressure remaining constant, at what temperature will the r.m.s. speed of a gas molecules increase by 10% of the r.m.s. speed at NTP?

(1) 57.3 K (2) 57.3ºC (3) 557.3 K (4) –57.3ºC

Sol. Answer (2)

$$V = \sqrt{\frac{3RT}{M}} \text{ or } V = K\sqrt{T}$$

Let $\frac{V \times 110}{100} = K\sqrt{T_2}$

$$\frac{V}{1.1} \text{ V} = \sqrt{\frac{T}{T_2}}$$

T_2 = 1.21 T

Putting T = 273 K

T_2 = 57.33°C

15. Two thermally insulated vessels 1 and 2 are filled with air at temperatures (T_1, T_2), volume (V_1, V_2) and pressure (P_1, P_2) respectively. If the valve joining the two vessels is opened, the temperature inside the vessel at equilibrium will be

(1) $T_1 + T_2$ (2) $\frac{(T_1+T_2)}{2}$ (3) $\frac{T_1T_2(P_1V_1+P_2V_2)}{P_1V_1T_2+P_2V_2T_1}$ (4) $\frac{T_1T_2(P_1V_1+P_2V_2)}{P_1V_1T_1+P_2V_2T_2}$

Sol. Answer (3)

Total number of moles remain constant.

$$n_1 + n_2 = n_1' + n_2'$$

$$\frac{P_1V_1}{T_1} + \frac{P_2V_2}{T_2} = \frac{P_1V_1}{T} + \frac{P_2V_2}{T}$$

Solving, we get

$$T = \frac{P_1V_1 + P_2V_2}{\frac{P_1V_1}{T_1} + \frac{P_2V_2}{T_2}}$$

16. The average speed of gas molecules is v at pressure P. If by keeping temperature constant the pressure of gas is doubled, then average speed will become

(1) $\sqrt{2}\,v$ (2) v (3) $2v$ (4) $\frac{v}{\sqrt{2}}$

Sol. Answer (2)

$$v_{av} \propto \sqrt{T}$$

Since temperature is constant v_{av} is constant.

17. Four molecules of a gas have speeds 1, 2, 3 and 4 km/s. The value of the r.m.s. speed of the gas molecules is

(1) $\frac{1}{2}\sqrt{15}$ km/s (2) $\frac{1}{2}\sqrt{10}$ km/s (3) 2.5 km/s (4) $\sqrt{\frac{15}{2}}$ km/s

Sol. Answer (4)

$$\text{R.M.S. speed} = \sqrt{\frac{v_1^2+v_2^2+v_3^2...v_n^2}{n}}$$

$$\bar{v} = \sqrt{\frac{1^2+2^2+3^2+4^2}{4}}$$

$$\bar{v} = \sqrt{\frac{30}{4}}$$

$$\bar{v} = \sqrt{\frac{15}{2}}$$

18. The r.m.s. speed of the molecules of enclosed gas is V. What will be the r.m.s. speed if pressure is doubled keeping the temperature same?

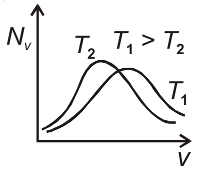
(1) $\frac{V}{2}$ (2) V (3) $2V$ (4) $4V$

Sol. Answer (2)

Temperature is a quantities which denotes a value which gives the average kinetic energy of molecules in a gas. This depends on velocities of gas molecules and vice-versa. If temperature does not change $V_{\text{r.m.s.}}$ will also not change.

19. The effect of temperature on Maxwell's speed distribution is correctly shown by

(1)



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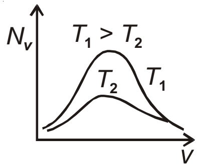

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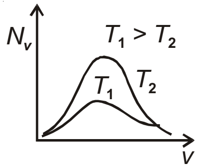

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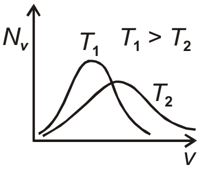


Sol. Answer (1)

The Maxwell's distribution curve heats at the most probable speed, which depends on temperature.

$$v_{\text{probable}} \propto \sqrt{T}$$

Hence $T_1 > T_2$ is correctly shown in option (1) as it shows with peaks of the curve at higher temperature, furthers along the *x*-axis.

20. Select the incorrect statement about Maxwell's speed distribution

(1) The distribution function depends only on the absolute temperature

(2) $V_{\text{rms}} > V_{\text{av}} > V_{\text{mp}}$

(3) The area under the distribution curve gives total number of molecules of the gas

(4) The distribution curve is symmetric about the most probable speed

Sol. Answer (4)

The Maxwell's speed distribution is asymmetric due to the fact that the lowest speed possible is zero. While the highest speed possible is infinity.

21. The ratio of number of collisions per second at the walls of containers by He and O_2 gas molecules kept at same volume and temperature, is (assume normal incidence on walls)

(1) 2 : 1 (2) 1 : 2 (3) $2\sqrt{2} : 1$ (4) $1 : 2\sqrt{2}$

Sol. Answer (3)

$$\left(\frac{n_{O_2}}{n_{\text{He}}}\right)^2 = \frac{M_{\text{He}}}{M_{O_2}}$$

$M_{\text{He}} = 4$ $M_{O_2} = 32$

$$\frac{n_{O_2}}{n_{\text{He}}} = \frac{1}{2\sqrt{2}}$$

$$\therefore \quad n_{\text{He}} : n_{O_2} = 2\sqrt{2} : 1$$

22. An ant is moving on a plane horizontal surface. The number of degrees of freedom of the ant will be

(1) 1 (2) 2 (3) 3 (4) 6

Sol. Answer (2)

The number of degrees of freedom of movement of ant is 2 as it can move only in two independent directions in the plane surface.

23. If a gas has '*f*' degree of freedom, the ratio of the specific heats of the gases $\frac{C_p}{C_v}$ is

(1) $\frac{1+f}{2}$ (2) $1+\frac{f}{2}$ (3) $1+\frac{1}{f}$ (4) $1+\frac{2}{f}$

Sol. Answer (4)

$$C_p = C_v + R$$

and $C_v = \frac{f}{2}R$

$$\frac{C_p}{C_v} = \frac{\frac{f}{2}R + R}{\frac{f}{2}}$$

$$\frac{C_p}{C_v} = \frac{f+2}{f}$$

$$\frac{C_p}{C_v} = \frac{2+f}{f}$$

$$\frac{C_p}{C_v} = 1+\frac{2}{f}$$

24. Molar specific heat at constant volume, for a non-linear triatomic gas is (vibration mode neglected)

(1) $3R$ (2) $4R$ (3) $2R$ (4) R

Sol. Answer (1)

Molar heat capacities for a gas is given by $C_v = \frac{f}{2}RT$

Where $f = 6$ in triatomic molecules

$$C_v = 3\ RT$$

25. A mixture of ideal gases has 2 moles of He, 4 moles of oxygen and 1 mole of ozone at absolute temperature T. The internal energy of mixture is

(1) 13 RT (2) 11 RT (3) 16 RT (4) 14 RT

Sol. Answer (3)

Degrees of freedom of He (f_{He}) = 3

Degrees of freedom of O_2 (f_{O_2}) = 5

Degrees of freedom of O_3 (f_{O_3}) = 6

$n_{\text{He}} = 2$, $n_{O_2} = 4$ $n_{O_3} = 1$

Energy of mixture = Sum of individual energies

$$= \left(n_{\text{He}}f_{\text{He}} + n_{O_2}f_{O_2} + n_{O_3}f_{O_3}\right)\frac{RT}{2}$$

$$= (2\times 3 + 4\times 5 + 1\times 6)\frac{RT}{2}$$

$$= (3 + 10 + 3)\ RT$$

$$= 16\ RT$$

26. E_0 and E_H respectively represents the average kinetic energy of a molecule of oxygen and hydrogen. If the two gases are at the same temperature, which of the following statement is true?

(1) $E_0 > E_H$ (2) $E_0 = E_H$ (3) $E_0 < E_H$ (4) Data insufficient

Sol. Answer (2)

Temperature is an approximate value which refers to average kinetic energy per molecule. If temperature of both is same, average energy will be same according to definition.

27. 14 g of CO at 27°C is mixed with 16 g of O_2 at 47°C. The temperature of mixture is (vibration mode neglected)

(1) –5°C (2) 32°C (3) 37°C (4) 27°C

Sol. Answer (3)

1 mole of CO and 1 mole of O_2 are mixed.

$$\text{Net internal energy} = \frac{f_1}{2}RT_{CO} + \frac{f_2}{2}RT_{O_2}$$

$$= \frac{5}{2}R\,300 + \frac{5}{2}R\,350$$

$$= \frac{5}{2}R(650)$$

$$= 5\,R(325)$$

$$= 1625\,R$$

$$1625 = \frac{5}{2}RT_{\text{final}} \times n_{\text{final}}$$

$$\frac{1625\times 2}{5} = T_{\text{final}} \times n_{\text{final}}$$

$$325 \times 2 = T_{\text{final}} \times 2$$

$$T_{\text{final}} = 325\text{ K}$$

$$T_{\text{final}} = 37°\text{C}$$

28. When one mole of monatomic gas is mixed with one mole of a diatomic gas, then the equivalent value of γ for the mixture will be (vibration mode neglected)

(1) 1.33 (2) 1.40 (3) 1.50 (4) 1.6

Sol. Answer (3)

Y for monatomic gas $= 1+\frac{2}{3} = \frac{5}{3} = \gamma_1$

$$\frac{n}{\gamma-1} = \frac{n_1}{\gamma_1-1} + \frac{n_2}{\gamma_2-1}$$

Y for diatomic gas $= 1+\frac{2}{5} = \frac{7}{5} = \gamma_2$

$$\frac{2}{\gamma-1} = \frac{1}{\frac{5}{3}-1} + \frac{1}{\frac{7}{5}-1}$$

Solving, we get $\gamma = 3/2$

29. A box of negligible mass containing 2 moles of an ideal gas of molar mass M and adiabatic exponent γ moves with constant speed v on a smooth horizontal surface. If the box suddenly stops, then change in temperature of gas will be

(1) $\frac{(\gamma-1)Mv^2}{4R}$
(2) $\frac{\gamma Mv^2}{2R}$
(3) $\frac{Mv^2}{2(\gamma-1)R}$
(4) $\frac{(\gamma-1)Mv^2}{2R}$

Sol. Answer (4)

Mass of gas in the box = 2 M

Initial kinetic energy = $\frac{1}{2}\times 2M\times v^2 = Mv^2$

$$Mv^2 = \frac{1}{2}nfR\Delta T$$

$$\therefore \quad \Delta T = \frac{2Mv^2}{nfR}$$

Substitution $f = \frac{2}{1-r}$ and $n = 2$

$$\Delta T = \frac{(\gamma-1)Mv^2}{2R}$$

30. On increasing number density for a gas in a vessel, mean free path of a gas

(1) Decreases
(2) Increases
(3) Remains same
(4) Becomes double

Sol. Answer (1)

Mean free path of a substance is the average distance a molecule may travel without collision.

If the number of molecules per unit volume increases it increases the frequency of collision and decreases the mean free path.

SECTION - B

Objective Type Questions

1. At room temperature the rms speed of the molecules of a certain diatomic gas is found to be 1920 m/s. The gas is

(1) H_2
(2) F_2
(3) Cl_2
(4) O_2

Sol. Answer (1)

$$V_{\text{r.m.s.}} = \sqrt{\frac{3RT}{M}}$$

$$1920 = \frac{\sqrt{3\times 8.314\times 300}}{M}$$

$$M = \frac{3\times 8.314\times 300}{1920}$$

$M = 0.00202$ kg

On molar weight = 2.02 g.

Hence it is hydrogen.

2. An ideal gas is enclosed in a container of volume V at a pressure P. It is being pumped out of the container by using a pump with stroke volume v. What is final pressure in container after n-stroke of the pump? (assume temperature remains same)

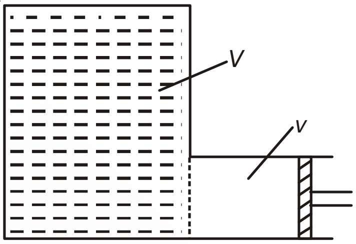
(1) $P\left(\frac{V}{V+v}\right)^n$ (2) $\frac{PV}{(V-v)^n}$ (3) $P\frac{V^n}{v^n}$ (4) $P\left(\frac{V}{V-v}\right)^n$

Sol. Answer (1)

After stroke PV = constant

$$PV = P_1(V + v)$$

$$P_1 = \frac{PV}{(V+v)}$$



Similarly after 2nd stroke

$$P_2 = P\left(\frac{V}{V+v}\right)^2$$

After n^{th} stroke

$$P_n = P\left(\frac{V}{V+v}\right)^n$$

3. Three perfect gases at absolute temperatures T_1, T_2 and T_3 are mixed. If number of molecules of the gases are n_1, n_2 and n_3 respectively then temperature of mixture will be (assume no loss of energy)

(1) $\frac{T_1+T_2+T_3}{3}$ (2) $\frac{n_1^2T_1+n_2^2T_2+n_3^2T_3}{n_1+n_2+n_3}$ (3) $\frac{n_1T_1+n_2T_2+n_3T_3}{n_1+n_2+n_3}$ (4) $\frac{T_1+T_2+T_3}{n_1+n_2+n_3}$

Sol. Answer (3)

Absolute temperature = T_1, T_2, T_3.

Internal energy of gases = $\frac{n_1RT_1}{2}+\frac{n_2RT_2}{2}+\frac{n_3RT_3}{2}$

Average temperature = $\frac{\text{Internal energy of mixture}}{(n_1+n_2+n_3)\frac{R}{2}}$

4. Variation of atmospheric pressure, with height from earth is

(1) Linear (2) Parabolic (3) Exponential (4) Hyperbolic

Sol. Answer (3)

Variation of atmospheric pressure due to height is given by the barometric formula

$$P_h = P_0\, e^{-mgh/RT}$$

Hence the decrease will be exponential.

5. A narrow glass tube, 80 cm long and opens at both ends, is half immersed in mercury, now the top of the tube is closed and is taken out of mercury. A column of mercury 20 cm long remains in the tube. Find atmospheric pressure

(1) 20 cm of air column (2) 60 cm of Hg column

(3) 60 cm of air column (4) 20 cm of Hg column

Sol. Answer (2)

PV = constant

$P_1V_1 = P_2V_2$ [$P_1 = P_0$ atmospheric pressure]

$P_0 \times 40 = P_1 \times 60$ ... (i)

$P_1 + 20 = P_0$ ... (ii)

From (i)

$$P_1 = \frac{2P_0}{3}$$

From (ii)

$$\frac{2P_0}{3} + 20 = P_0 \Rightarrow P_0 = 60 \text{ cm of Hg.}$$

6. One mole of monatomic gas and three moles of diatomic gas are put together in a container. The molar specific heat (in $\text{JK}^{-1}\ \text{mol}^{-1}$) at constant volume is (Let $R = 8\ \text{JK}^{-1}\ \text{mol}^{-1}$)

(1) 18 (2) 19 (3) 20 (4) 21

Sol. Answer (1)

$n_1 = 1$ mole $f_1 = 3$

$n_2 = 3$ moles $f_2 = 5$

$R = 8\ \text{JK}^{-1}\ \text{mol}^{-1}$

Molar specific heat are given by the weighted means of the gases.

$$C_{v_f} = \frac{n_1 \times C_{v_1} + n_2 \times C_{v_2}}{n_1 + n_2}$$

$$C_{v_f} = \frac{1\times\frac{3}{2}R + 3\times\frac{5}{2}R}{4}$$

$$= \frac{3}{8}R + \frac{15}{8}R$$

$$= \frac{18}{8}R$$

$$C_{v_f} = 18$$

7. Two closed containers of equal volume filled with air at pressure P_0 and temperature T_0. Both are connected by a narrow tube. If one of the container is maintained at temperature T_0 and other at temperature T, then new pressure in the containers will be

(1) $\frac{2P_0T}{T+T_0}$ (2) $\frac{P_0T}{T+T_0}$ (3) $\frac{P_0T}{2(T+T_0)}$ (4) $\frac{T+T_0}{P_0}$

Sol. Answer (1)

$$\frac{P}{T} = \text{constant}$$

Initially $\frac{P_0}{T_0}+\frac{P_0}{T_0}=\frac{2P_0}{T_0}$

For two containers

$$\frac{P_0}{T_0}+\frac{P}{T}=\frac{2P_0}{T_0}$$

$$P = \frac{2P_0 \times T \times T_0}{T_0(T+T_0)}$$

or $P = \frac{2P_0T}{(T+T_0)}$

8. The temperature of a gas is –68°C. At what temperature will the average kinetic energy of its molecules be twice that of –68°C?

(1) 137°C (2) 127°C (3) 100°C (4) 105°C

Sol. Answer (1)

Average kinetic energy = $\frac{f}{2}RT$

or K.E.$_{avg} \propto T$

For K.E. energy to be doubles that of K.E. at – 68°C or 205 K.

The temperature must be 2 T or 410 K

When converted to °C = 410 – 273 = 137°C

9. An ideal gas is filled in a closed container and container is moving with uniform acceleration in horizontal direction. Neglect gravity. Pressure inside the container is

(1) Uniform everywhere (2) Less in front (3) Less at back (4) Less at top

Sol. Answer (2)

Each particle closes experience a pseudo force initials, themselves to give low pressure every where. This is because of Pascal's law.

10. One kg of a diatomic gas is at pressure of 8 × 10^4 N/m^2. The density of the gas is 4 kg/m^3. The energy of the gas due to its thermal motion will be

(1) 3×10^4 J (2) 5×10^4 J (3) 6×10^4 J (4) 7×10^4 J

Sol. Answer (2)

$PV = n\ RT$ ... (1)

$f = 4$ kg/m^3

$\therefore$ $v = 0.25$ m^3

$8 \times 10^4 \times \frac{1}{4} PV$ ... (2)

Energy of gas is given by $= \frac{f}{2} RT \times n$

$= \frac{5}{2} \times PV$ [From (1)]

$= \frac{5}{2} \times 2 \times 10^4 = 5 \times 10^4$ J

11. A container contains 32 g of O_2 at a temperature T. The pressure of the gas is P. An identical container containing 4 g of H_2 at a temperature $2T$ has a pressure of

(1) $8P$ (2) $4P$ (3) P (4) P_{18}

Sol. Answer (2)

Given, 1 mole of O_2 at temperature T, pressure P

and 2 moles of H_2 at a temperature $2T$

$$P_1 = \frac{n \times RT}{V}$$

$$P_0 = \frac{RT}{V} = P$$

$$P_H = \frac{4RT}{V} = 4P$$

12. An ideal gas is expanding such that PT = constant. The coefficient of volume expansion of the gas is

(1) $\frac{1}{T}$ (2) $\frac{2}{T}$ (3) $\frac{3}{T}$ (4) $\frac{4}{T}$

Sol. Answer (2)

PT = Constant

or $\frac{T^2}{V}$ = Constant $[PV = nRT] \Rightarrow T_2 = KV$ ... (i)

Differentiating w.r.t. T, we get

$$\frac{2T}{V} - \frac{K}{V}\frac{dV}{dT} \Rightarrow \frac{2T}{VK} = \frac{dV}{VdT}$$

$$\therefore \quad \frac{dV}{VdT} = \frac{2TV}{VT^2} = \frac{2}{T}$$

13. 50 cal of heat is required to raise the temperature of 1 mole of an ideal gas from 20°C to 25°C, while the pressure of the gas is kept constant. The amount of heat required to raise the temperature of the same gas through same temperature range at constant volume is (R = 2 cal/mol/K)

(1) 70 cal (2) 60 cal (3) 40 cal (4) 50 cal

Sol. Answer (3)

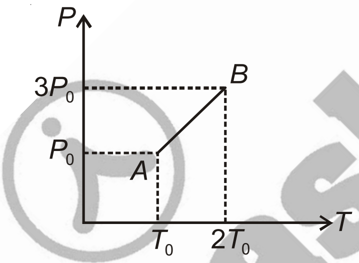
$$C_P = \frac{50}{AT} = 10 \text{ cal K}^{-1}\text{ mol}^{-1}$$

$$C_P = C_V + R$$

$$C_V = C_P = R$$

$$C_V = 8 \text{ cal K}^{-1}\text{ mol}^{-1}$$

14. Pressure versus temperature graph of an ideal gas is as shown in figure. Density of the gas at point A is ρ_0. Density at point B will be



(1) $\frac{3}{4}\rho_0$ (2) $\frac{3}{2}\rho_0$ (3) $\frac{4}{3}\rho_0$ (4) $2\rho_0$

Sol. Answer (2)

$$PV = nRT$$

$$P = \frac{\rho}{M}RT$$

Initially $\rho = \rho_0$, $P = P_0$, $T = T_0$

$$P_0 = \frac{\rho_0 R}{M}T_0 \text{ initially} \quad \text{... (i)}$$

$$3P_0 = \frac{\rho_x R}{M}2T_0 \text{ final} \quad \text{... (ii)}$$

Dividing (ii) by (i)

$$3 = \frac{\rho_x}{\rho_0}2$$

$$\frac{3}{2}\rho_0 = \rho_x$$

15. The energy (in eV) possessed by a neon atom at 27°C is

(1) 1.72×10^{-3} (2) 4.75×10^{-4} (3) 3.88×10^{-2} (4) 3.27×10^{-5}

Sol. Answer (3)

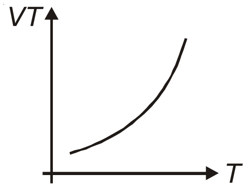
Neon is a monoatomic gas.

So, at 300 K its internal energy is given by $\frac{1}{2}fkT$

For one molecule $\frac{3}{2}kT$

16. If heat energy is given to an ideal gas at constant pressure, then select the graph which best represents the variation of VT with temperature (T).

(1)



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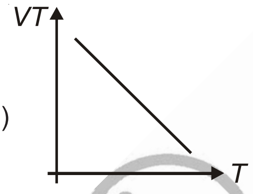

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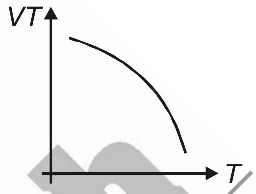
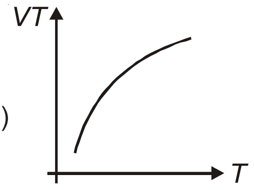


(4)



Sol. Answer (1)

$$PV = nRT$$

$$\frac{P}{nR} = \frac{T}{V}$$

and $\frac{V}{T} = \frac{nR}{P}$ = constant (K)

$$VT = KT^2$$

Assuming $VT = y$ and $x = T$

$$y = Kx^2$$

Which is equation of a parabola will focus on y-axis > facing upwards.

17. If hydrogen gas is heated to a very high temperature, then the fraction of energy possessed by gas molecules correspond to rotational motion

(1) $\frac{3}{5}$ (2) $\frac{2}{7}$ (3) $\frac{3}{7}$ (4) $\frac{2}{5}$

Sol. Answer (2)

Hydrogen is a diatomic molecules and if vibrational degrees of freedom are increased the degrees of freedom will be 3 translation 2 rotational and two vibrational.

$\therefore$ So total 7 degree of freedom.

Fraction of energy possessed due to rotational motion : Degree of freedom due to rotation total degree of freedom = $\frac{2}{7}$

18. The temperature (T) of one mole of an ideal gas varies with its volume (V) as $T = -\alpha V^3 + \beta V^2$, where α and β are positive constants. The maximum pressure of gas during this process is

(1) $\frac{\alpha\beta}{2R}$ (2) $\frac{\beta^2 R}{4\alpha}$ (3) $\frac{(\alpha+\beta)R}{2\beta^2}$ (4) $\frac{\alpha^2 R}{2\beta}$

Sol. Answer (2)

$T = -\alpha V^3 + \beta V^2$ ... (i)

and $PV = nRT$ ... (ii)

$n = 1$

So, $P = \frac{RT}{V}$

Multiplying $\frac{R}{V}$ in (i)

$\frac{RT}{V} = (-\alpha V^2 + \beta V)R$

or $P = (-\alpha V^2 + \beta V)R$ ... (iii)

$\frac{dP}{dV} = (-2\alpha V + \beta)R$

Maxima is when $\frac{dP}{dV} = 0$ and $\frac{d^2P}{dV^2}$ in negative, so

$O = (-2\alpha V + \beta)R$

$V = \frac{\beta}{2\alpha}$

Put in value of V in equation (iii)

$$P = \left(-\alpha\frac{\beta^2}{4\alpha^2} + \frac{\beta^2}{2\alpha}\right)R \Rightarrow P = \frac{\beta^2 R}{4\alpha}$$

19. Nitrogen gas is filled in an insulated container. If α fraction of moles dissociates without exchange of any energy, then the fractional change in its temperature is

(1) $\frac{-\alpha}{5+\alpha}$ (2) $\frac{\alpha}{3+\alpha}$ (3) $\frac{-3\alpha}{2+\alpha}$ (4) $\frac{5\alpha}{2+3\alpha}$

Sol. Answer (1)

Degree of freedom of diatomic nitrogen = 5

Degree of freedom of monoatomic nitrogen = 3

Let initial number of moles be n and α fraction dissociated.

So fraction dissociated = $n\alpha$ fraction remaining = $n - n\alpha$.

$n\alpha$ break into two so new atoms formed is actually $2n\alpha$.

Initial energy is given by = $n\times\frac{f}{2}\times RT$ = $n\times\frac{5}{2}\times RT$

Final energy = $(n-n\alpha)\frac{5}{2}RT_2+2n\alpha\times\frac{3}{2}RT_2$

$$= \frac{5}{2}nRT_2-\frac{5}{2}n\alpha RT_2+n\alpha 3RT_2$$

$$= \frac{5}{2}nRT_2+\frac{n\alpha RT_2}{2}$$

$$= \frac{(5+2)nRT_2}{2}$$

Change in energy is given on zero.

$$\frac{5nRT}{2} = \frac{(5+\alpha)nRT_2}{2}$$

$$\frac{5T}{5+\alpha} = T_2$$

$$\Delta T = T_2 - T$$

or $\Delta T = \frac{5T}{5+\alpha}-T = \frac{-\alpha}{5+\alpha}T$

Fractional change in temperature = $\frac{\Delta T}{T}$ or $-\frac{\alpha}{5+\alpha}$

20. An ideal gas undergoes a polytropic given by equation PV^n = constant. If molar heat capacity of gas during this process is arithmetic mean of its molar heat capacity at constant pressure and constant volume then value of n is

(1) Zero (2) –1 (3) +1 (4) γ

Sol. Answer (2)

Polytropic process

PV^n = constant

Given heat capacities is average of C_P and C_V. So

$$C = \frac{C_P+C_V}{2}$$

or $C = \frac{2C_V+R}{2}$

or $C = \frac{C_V+R}{2}$ ... (i)

Now formula for specific heat of polytropic process is given by

$$C = \frac{R}{y-1} + \frac{R}{1-n} \qquad \text{... (ii)}$$

or $\dfrac{R}{y-1} + \dfrac{R}{2} = \dfrac{R}{y-1} + \dfrac{R}{1-n}$ as $C_V = \dfrac{R}{y-1}$

$$\frac{R}{2} = \frac{R}{1-n}$$

or $n = -1$

21. If α moles of a monoatomic gas are mixed with β moles of a polyatomic gas and mixture behaves like diatomic gas, then [neglect the vibrational mode of freedom]

(1) $2\alpha = \beta$ (2) $\alpha = 2\beta$ (3) $\alpha = -3\beta$ (4) $3\alpha = -\beta$

Sol. Answer (1)

22. If different ideal gases are at the same temperature, pressure and have same volume, then all gases have same

(1) Density (2) Number of molecules

(3) Most probable speed (4) Internal energy per mole

Sol. Answer (2)

$$PV = nRT$$

or $\dfrac{PV}{RT} = n$

At the same pressure volume and temperature each molecule will have same number of moles *i.e.* same number of molecules of gas.

23. The internal energy of 10 g of nitrogen at N.T.P. is about

(1) 2575 J (2) 2025 J (3) 3721 J (4) 4051 J

Sol. Answer (2)

Number of moles of $N_2 = \dfrac{10}{28}$

$$U = \frac{f}{2} nRT$$

$$= \frac{5}{2} \times \frac{5}{14} \times R \times 273$$

$= 2025$ J

24. The mean free path of a molecule of He gas is α. Its mean free path along any arbitrary coordinate axis will be

(1) α (2) $\dfrac{\alpha}{3}$ (3) $\dfrac{\alpha}{\sqrt{3}}$ (4) 3α

Sol. Answer (3)

Mean free path of a molecule is the resultant of path along three separate axis and they will be equal.

So, $\alpha = \sqrt{\alpha_x^2 + \alpha_y^2 + \alpha_2^2}$

where $\alpha_x = \alpha_y^2 \alpha_2 =$ (say) a

$$\alpha = \sqrt{a^2 + a^2 + a^2}$$

or $a = \dfrac{\alpha}{\sqrt{3}}$

25. According to C.E. van der Waal, the interatomic potential varies with the average interatomic distance (R) as

(1) R^{-1} (2) R^{-2} (3) R^{-4} (4) R^{-6}

Sol. Answer (4)

Interatomic potential varies with average interatomic distance as R^{-6} which is a fact.

26. The value of critical temperature in terms of van der Waals' constants a and b is given by

(1) $T_C = \dfrac{8a}{27Rb}$ (2) $T_C = \dfrac{27a}{8Rb}$ (3) $T_C = \dfrac{a}{2Rb}$ (4) $T_C = \dfrac{a}{27Rb}$

Sol. Answer (1)

Critical temperature is given as :

$$T_C = \frac{8a}{27R_b}$$

27. To find out degree of freedom, the expression is

(1) $f = \dfrac{2}{\gamma - 1}$ (2) $f = \dfrac{\gamma + 1}{2}$ (3) $f = \dfrac{2}{\gamma + 1}$ (4) $f = \dfrac{1}{\gamma + 1}$

Sol. Answer (1)

$C_V = \dfrac{f}{2}R$ $C_P = \dfrac{f}{0}C_V + R = \dfrac{f}{2}R + R = \dfrac{(f+2)}{2}R$

$$\gamma = \frac{C_P}{C_V}$$

$$= \frac{(f+2)R \times 2}{2 \times fR}$$

$$\gamma = 1 + \frac{2}{f}$$

$$\gamma - 1 = \frac{2}{f}$$

$$f = \frac{2}{\gamma - 1}$$

28. Nitrogen gas N_2 of mass 28 g is kept in a vessel at pressure of 10 atm and temperature 57ºC. Due to leakage of N_2 gas its pressure falls to 5 atm and temperature to 27ºC. The amount of N_2 gas leaked out is

(1) $\frac{5}{63}$ g (2) $\frac{63}{5}$ g (3) $\frac{28}{63}$ g (4) $\frac{63}{28}$ g

Sol. Answer (2)

Mass = 28 g

$P_i = 10$ atm $T_i = 57°\text{C} = 330$ K

$P_f = 5$ atm $T_f = 27°\text{C} = 300$ K

Volume is kept constant.

$P_i = K \times n_i\, T_i$ ... (i)

$P_f = K \times n_f\, T_f$ ... (ii)

Dividing (i) by (ii)

$$\frac{P_i}{P_f} = \frac{n_i}{n_f}\frac{T_i}{T_f}$$

$$\frac{n_i}{n_f} = \frac{10}{5}\times\frac{300}{330}$$

or $$\frac{n_i}{n_f} = 2\times\frac{10}{11}$$

$$\frac{n_i}{n_f} = \frac{20}{11}$$

Now $n_i = 1$ mole of N_2

$$n_f = \frac{11}{20} \text{ moles}$$

or Mass of N_2 left $= \frac{11}{20} \times 28$

$\therefore$ Quantity released $= 28 - \frac{11}{20} \times 28$

$$= \frac{9}{20}\times 28 = \frac{63}{5}\text{g}$$

29. A diatomic gas of molecular mass 40 g/mol is filled in a rigid container at temperature 30ºC. It is moving with velocity 200 m/s. If it is suddenly stopped, the rise in the temperature of the gas is

(1) $\frac{32}{R}$ °C (2) $\frac{320}{R}$ °C (3) $\frac{3200}{R}$ °C (4) $\frac{3.2}{R}$ ºC

Sol. Answer (2)

Let there by n moles of gas.

Mass of gas = 40ng or $\frac{40n}{1000}$ or $0.04n$ kg

K.E. of gas in container $= \frac{1}{2} \times 0.04\ n \times (200)^2$

$= 0.02 \times n \times 4 \times 10^4$

$= 8 \times 10^2 \times n$ J

Now heat capacity of gas $(C) = \frac{f}{2}nR$

or $C = \frac{5}{2} R \times n$

or $C\Delta T = 8 \times 10^2 \times n$

or $\frac{5}{2} \times R \times n\ \Delta T = 8 \times 10^2 \times n$

$$\Delta T = \frac{8 \times 10^2}{R} \times \frac{2}{5}$$

$$\Delta T = \frac{16}{5} \times 10^2 = \frac{320}{R}\ ^\circ\text{C}$$

30. The ratio of average translatory kinetic energy of He gas molecules to O_2 gas molecules is

(1) $\frac{25}{21}$ (2) $\frac{21}{25}$ (3) $\frac{3}{2}$ (4) 1

Sol. Answer (4)

Both He and O_2 have 3 translatory degrees of freedom. At the same temperature, energy is divided equally in all degrees of freedom. Hence ratio of the translatory kinetic energy is one.

SECTION - C

Previous Years Questions

1. Two container A and B are partly filled with water and closed. The volume of A is twice that of B and it contains half the amount of water in B. If both are at same temperature, the water vapour in the container will have pressure in the ratio of

(1) 1 : 2 (2) 1 : 1 (3) 2 : 1 (4) 4 : 1

Sol. Answer (2)

Vapour pressure for the same liquid is always the same. So the ratio will be $P : P$ or 1 : 1.

2. At constant volume, temperature is increased then

(1) Collision on walls will be less

(2) Number of collisions per unit time will increase

(3) Collisions will be in straight lines

(4) Collisions will not change

Sol. Answer (2)

At constant volume if temperature is increased pressure will increase. Since pressure is increased due to collisions of particles will the wall of the container. So collisions per unit time will increase.

3. A polyatomic gas with *n* degree of freedom has a mean energy per molecule given by

(1) $\frac{nKT}{N}$ (2) $\frac{nKT}{2N}$ (3) $\frac{nKT}{2}$ (4) $\frac{nKT}{4}$

Sol. Answer (3)

Numbers of degrees of freedom = *n*.

Internal energy of gas = $\frac{n}{2}RT$

$K = \frac{R}{N}$ where *N* is the Avogadro's number.

or $NK = R$

Internal energy = $\frac{n}{2}NKT$

Internal energy per molecule = $\frac{n}{2}\frac{NKT}{N}$ or $\frac{nKT}{2}$

4. For a certain gas the ratio of specific heats is given to be $\gamma = 1.5$. For this gas

(1) $C_v = \frac{3R}{J}$ (2) $C_p = \frac{3R}{J}$ (3) $C_p = \frac{5R}{J}$ (4) $C_v = \frac{5R}{J}$

Sol. Answer (2)

For a certain gas $\frac{C_p}{C_v} = 1.5$

$C_p = C_v + R$

$1 + \frac{R}{C_v} = 1.5$

$R = \frac{C_v}{2}$

or $C_v = 2R$

$C_p = 3R$

5. According to kinetic theory of gases, at absolute zero temperature

(1) Water freezes (2) Liquid helium freezes

(3) Molecular motion stops (4) Liquid hydrogen freezes

Sol. Answer (3)

According to kinetic energy of gases at absolute temperature molecular motion stops as for ideal gases only in kinetic energy of gases is considered which is given by

K.E. = $\frac{f}{2}nKT$

So, $T = 0$ K and motion will be zero.

6. One mole of an ideal monoatomic gas requires 207 J heat to raise the temperature by 10 K when heated at constant pressure. If the same gas is heated at constant volume to raise the temperature by the same 10 K, the heat required is [Given the gas constant R = 8.3 J/mol-K]

(1) 198.7 J (2) 29 J (3) 215.3 J (4) 124 J

Sol. Answer (4)

$$C_P = \frac{207}{10} = 20.7 \text{ J/mol-K}$$

$$R = 8.3$$

and $C_V = C_P - R$

$= 12.4$ J/mol-K

$\Delta Q = C_V \Delta T$

$= 124$ J

7. Relation between pressure (P) and average kinetic energy per unit volume of gas (E) is

(1) $P = \frac{2}{3}E$ (2) $P = \frac{1}{3}E$ (3) $P = \frac{1}{2}E$ (4) $P = 3E$

Sol. Answer (1)

Relation between pressure (P) and average kinetic energy is given by

$$P = \frac{1}{3}mN\bar{v}^2 \quad \text{... (i)}$$

$$E = \frac{1}{2}m\bar{v}^2 \quad \text{... (ii)}$$

Using (i) and (ii)

$$P = \frac{2}{3}E$$

8. If C_s be the velocity of sound in air and C be the rms velocity, then

(1) $C_s < C$ (2) $C_s = C$ (3) $C_s = C\left(\frac{\gamma}{3}\right)^{1/2}$ (4) None of these

Sol. Answer (3)

Velocity of sound in air is given by

$$C_s = \sqrt{\frac{\gamma P}{\rho}} \text{ or } \sqrt{\frac{\gamma RT}{M}}$$

$$C = \sqrt{\frac{3RT}{M} = P}$$

$$C_s = C\sqrt{\frac{\gamma}{3}}$$

9. The temperature of gas is raised from 27°C to 927°C. The rms speed is

(1) $\sqrt{\frac{927}{27}}$ times the earlier value (2) Remain the same

(3) Gets halved (4) Get doubled

Sol. Answer (4)

$$V = \sqrt{\frac{3RT}{M}}$$

$$V = K\sqrt{T}$$

$$V_1 = K\sqrt{300}$$

$$V_2 = K\sqrt{1200}$$

$$\frac{V_1}{V_2} = \frac{\sqrt{300}}{\sqrt{1200}}$$

$$\frac{2\sqrt{300}}{\sqrt{300}}V_1 = V_2$$

or $V_2 = 2V_1$

10. The equation of state, corresponding to 8 g of O_2 is

(1) $PV = 8RT$ (2) $PV = \frac{RT}{4}$ (3) $PV = RT$ (4) $PV = \frac{RT}{2}$

Sol. Answer (2)

8 g of O_2 = $\frac{1}{4}$ moles

$$PV = nRT$$

$$PV = \frac{1}{4}RT \qquad \left[\text{as } n = \frac{1}{4}\right]$$

11. At 0 K, which of the following properties of a gas will be zero?

(1) Kinetic energy (2) Potential energy (3) Density (4) Mass

Sol. Answer (1)

By definition at absolute zero the kinetic energy of a gas is zero.

12. The amount of heat energy required to raise the temperature of 1 g of Helium at NTP from T_1K to T_2K is

(1) $\frac{3}{2}N_a k_B(T_2 - T_1)$ (2) $\frac{3}{4}N_a k_B(T_2 - T_1)$ (3) $\frac{3}{4}N_a k_B \frac{T_2}{T_1}$ (4) $\frac{3}{8}N_a k_B(T_2 - T_1)$

Sol. Answer (4)

Mole of helium is 4 g

So, number of moles of helium = $\frac{1}{4}$ moles

NTP there is constant pressure

C_P of gas = $\frac{f}{2}R = \frac{3R}{2}$

$$\Delta Q = C_P \times n\,\Delta T$$

$$= \frac{3}{2}R \times \frac{1}{4} \times (T_2 - T_1)$$

$$= \frac{3R}{8}(T_2 - T_1)$$

13. At 10ºC the value of the density of a fixed mass of an ideal gas divided by its pressure is x. At 110ºC, this ratio is

(1) $\frac{283}{383}x$ (2) x (3) $\frac{383}{283}x$ (4) $\frac{10}{110}x$

Sol. Answer (1)

$$PV = nRT$$

$$\frac{P}{\rho} = \frac{RT}{M}$$

$$x = \frac{RT}{M}$$

$T_1 = 283$ K $T_2 = 383$ K

$x_1 = \frac{R}{M} \times 283$ $x_2 = \frac{R}{M} \times 383$

$$\frac{x_1}{x_2} = \frac{283}{383}$$

$$x_2 = \frac{383}{283}$$

14. The degrees of freedom of a triatomic gas is (consider moderate temperature)

(1) 6 (2) 4 (3) 2 (4) 8

Sol. Answer (1)

A non-linear triatomic gas has 3 translators and 3 rotatory degrees of freedom.

15. The equation of state for 5 g of oxygen at a pressure P and temperature T, when occupying a volume V, will be (where R is the gas constant)

(1) $PV = \frac{5}{32}RT$ (2) $PV = 5RT$ (3) $PV = \frac{5}{2}RT$ (4) $PV = \frac{5}{16}RT$

Sol. Answer (1)

Number of moles (n) = $\frac{5}{32}$

$-PV = nRT$

$PV = \frac{5}{32}RT$

SECTION - D

Assertion-Reason Type Questions

1. A : For a real gas internal energy depends on its temperature as well as volume also.

R : For a real gas interatomic potential energy depends on volume and kinetic energy depends on temperature.

Sol. Answer (1)

The assertion is correct and the reason is the correct explanation of assertion.

2. A : The gravitational force between the gas molecules is ineffective due to extremely small size and very high speed.

R : No force of interaction acts between molecules of an ideal gas.

Sol. Answer (2)

Both the statements are true but reason is the incorrect explanation of assertion. The assertion happens to be self explanatory.

3. A : Average velocity of gas molecules is zero.

R : Due to random motion of gas molecules, velocities of different molecules cancel each other.

Sol. Answer (1)

The assertion is true but reason is correct explanation of assertion.

4. A : At constant volume on increasing temperature the collision frequency increases.

R : Collision frequency ∝ temperature of gas.

Sol. Answer (3)

The assertion is true but collision frequency does not increase linearly with temperature.

5. A : Two gases with the same average translational kinetic energy have same temperature even if one has greater rotational energy as compared to other.

R : Only average translational kinetic energy of a gas contributes to its temperature.

Sol. Answer (1)

The assertion is true and reason is correct explanation of assertion.

6. A : All molecular motion ceases at –273.15°C.

R : Temperature below –273.15°C cannot be attained.

Sol. Answer (2)

Both the statements are correct but reason is not the correct explanation for assertion.

7. A : Magnitude of mean velocity of the gas molecules is same as their mean speed.

 R : The only difference between mean velocity and mean speed is that mean velocity is a vector and mean speed is a scalar.

Sol. Answer (4)

Mean velocity of a gas is not the same as mean speed. Hence both the statements are correct.

8. A : Mean free path of gas molecules varies inversely as density of the gas.

 R : Mean free path varies inversely as pressure of the gas.

Sol. Answer (2)

Mean free path is given by = $\dfrac{V}{\sqrt{2}N\pi d^2}$

Where

N is total number of molecules.

V is volume.

d is the diameter of molecule.

$\dfrac{N}{V}$ is the number velocity of gas hence assertion is true. But the mean free path does not depend on pressure.

9. A : Number of air molecules in a room in winter is more than the number of molecules in the same room in summer.

 R : At a given pressure and volume, the number of molecules of a given mass of a gas is directly proportional to the absolute temperature.

Sol. Answer (3)

The assertion is true as at a lower temperature there is a higher density.

According to $PV = nRT$

$$\pi \propto \frac{1}{n}$$

Hence reason is false.

10. A : Evaporation occurs at any temperature whereas the boiling point depends on the external pressure.

 R : Evaporation of a liquid occurs from the surface of a liquid at all temperature whereas boiling takes place at a temperature determined by the external pressure.

Sol. Answer (1)

The assertion is true and the reason is the correct explanation of the assertion.

❑ ❑ ❑

Chapter 14

Oscillations

Solutions

SECTION - A

Objective Type Questions

1. If a particle is executing simple harmonic motion, then acceleration of particle

(1) Is uniform (2) Varies linearly with time

(3) Is non uniform (4) Both (2) & (3)

Sol. Answer (3)

If a particle is executing S.H.M.

$a\alpha - \omega^2 x$

Hence it is not uniform and depends on *x* rather than time.

Hence answer is (3).

2. What is the phase difference between acceleration and velocity of a particle executing simple harmonic motion?

(1) Zero (2) $\frac{\pi}{2}$ (3) π (4) 2π

Sol. Answer (2)

$v = A\omega \cos(\omega t + \phi)$

and $a = -A\omega^2 \sin(\omega t + \phi)$

$\because \cos(\omega t + \phi + \pi/2) = -\sin(\omega t + \phi)$

$a = A\omega^2 \cos(\omega t + \phi + \pi/2)$

Hence velocity lags $\pi/2$ with acceleration.

3. The shape of graph plotted between velocity and position of a particle executing simple harmonic motion is

(1) A straight line (2) An ellipse (3) A parabola (4) A hyperbola

Sol. Answer (2)

$$v = \omega\sqrt{A^2 - x^2} \qquad \frac{v^2}{\omega^2} + x^2 = A^2 \quad \Rightarrow \quad \frac{v^2}{\omega^2 A^2} + \frac{x^2}{A^2} = 1$$

This is the equation of an ellipse.

Hence answer is (2)

4. If particle is executing simple harmonic motion with time period T, then the time period of its total mechanical energy is

(1) Zero (2) $\frac{T}{2}$ (3) $2T$ (4) Infinite

Sol. Answer (4)

The total mechanical energy doesn't change in an undamped S.H.M. $\therefore$ frequency = 0.

Hence time period is infinite.

5. Identify the correct definition

(1) If after every certain interval of time, particle repeats its motion then motion is called periodic motion

(2) To and fro motion of a particle over the same path about its mean position in certain time interval is called oscillatory motion

(3) Oscillatory motion described in terms of single sine and cosine functions is called simple harmonic motion

(4) All of these

Sol. Answer (4)

All the above definition are true.

Hence answer is (4)

6. The equation of simple harmonic motion may not be expressed as (each term has its usual meaning)

(1) $x = A\sin(\omega t + \phi)$ (2) $x = A\cos(\omega t - \phi)$

(3) $x = a\sin \omega t + b\cos \omega t$ (4) $x = A\sin (\omega t + \phi) + B\sin (2\omega t + \phi)$

Sol. Answer (4)

The fourth option is a superposition of two S.H.M.'s will different frequencies and time periods.

Hence it is not a true S.H.M.

7. Select wrong statement about simple harmonic motion

(1) The body is uniformly accelerated

(2) The velocity of the body changes smoothly at all instants

(3) The amplitude of oscillation is symmetric about the equilibrium position

(4) The frequency of oscillation is independent of amplitude

Sol. Answer (1)

In S.H.M..

$$a = -\omega^2 x$$

Thus acceleration varies linearly with time.

8. The displacement of a particle executing S.H.M. is given by $x = 0.01 \sin 100\pi(t + 0.05)$. The time period is

(1) 0.01 s (2) 0.02 s (3) 0.1 s (4) 0.2 s

Sol. Answer (2)

$$x = 0.01 \sin 100\pi(t + 0.05)$$

Here $\omega = 100\pi$

$$T = \frac{2\pi}{\omega} = \frac{2\pi}{100\pi} = \frac{1}{50} = 0.02 \text{ s}$$

9. A particle moves under force $F = -5(x - 2)^3$. Motion of the particle is

(1) Translatory (2) Oscillatory (3) S.H.M. (4) All of these

Sol. Answer (2)

$$F = -5(x - 2)^3$$

Acceleration is negative when $(x - 2)$ is positive and positive when $(x - 2)$ is negative.

Hence it is an oscillatory motion about $x = 2$.

10. For a particle showing motion under the force $F = -5(x - 2)^2$, the motion is

(1) Translatory (2) Oscillatory (3) S.H.M. (4) All of these

Sol. Answer (1)

$$F = -5(x - 2)^2$$

The motion depicts a non uniform translatory motion as the acceleration just keeps increasing in the negative direction. This is because $(x - 2)$ is always positive.

11. For a particle showing motion under the force $F = -5(x - 2)$, the motion is

(1) Translatory (2) Oscillatory (3) S.H.M. (4) Both (2) & (3)

Sol. Answer (4)

Force varies linearly with time with respect to $-(x - 2)$

$$F \propto -(x - 2)$$

Hence motion of the particle is an S.H.M.

12. A boy is swinging in a swing. If he stands, the time period will

(1) First decrease, then increase (2) Decrease

(3) Increase (4) Remain same

Sol. Answer (2)

A swing is like a pendulum. So

$$T = 2\pi\sqrt{\frac{l}{g}}$$

When the boy stands the C.O.M. will become higher. Thus 'l' will become shorter and so according to the equation of time period. Time period will decrease.

13. Time period of a simple pendulum in a freely falling lift will be

(1) Finite (2) Infinite (3) Zero (4) All of these

Sol. Answer (2)

$$T = \sqrt{\frac{l}{g}}$$

In a freely falling lift $g = 0$.

Hence T = infinite.

14. If effective length of a simple pendulum is equal to radius of earth (R), time period will be

(1) $T = \pi\sqrt{\frac{R}{g}}$ (2) $T = 2\pi\sqrt{\frac{2R}{g}}$ (3) $T = 2\pi\sqrt{\frac{R}{g}}$ (4) $T = 2\pi\sqrt{\frac{R}{2g}}$

Sol. Answer (4)

$$T = 2\pi\sqrt{\frac{1}{g\left(\frac{1}{R}+\frac{1}{l}\right)}}$$

$\because \quad l = R \quad \therefore \quad T = 2\pi\sqrt{\frac{R}{2g}}$

15. A particle is executing S.H.M. with time period T. If time period of its total mechanical energy is T' then $\frac{T'}{T}$ is

(1) 2 (2) $\frac{1}{2}$ (3) Zero (4) Infinite

Sol. Answer (4)

Total mechanical energy will never change so $T' = \infty \therefore \frac{T'}{T} = \infty$

16. A body executing S.H.M. along a straight line has a velocity of 3 ms^{-1} when it is at a distance of 4 m from its mean position and 4 ms^{-1} when it is at a distance of 3 m from its mean position. Its angular frequency and amplitude are

(1) 2 rad s^{-1} & 5 m (2) 1 rad s^{-1} & 10 m (3) 2 rad s^{-1} & 10 m (4) 1 rad s^{-1} & 5 m

Sol. Answer (4)

$v = \omega\sqrt{A^2 - x^2}$

$v_1 = 3$ m/s $\quad x_1 = 4$ m

$v_2 = 4$ m/s $\quad x_2 = 3$ m

$3 = \omega\sqrt{A^2 - 4^2} \quad$ ... (i)

$4 = \omega\sqrt{A^2 - 3^2} \quad$ ... (ii)

Solving (i) and (ii), we get

$A = 5$ m and $\omega = 1$ rad/s

17. Two identical springs have the same force constant 73.5 Nm^{-1}. The elongation produced in each spring in three cases shown in Figure-1, Figure-2 and Figure-3 are (g = 9.8 ms^{-2})

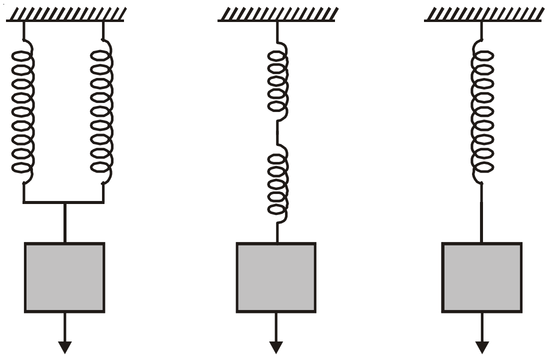


Figure 1 Figure 2 Figure 3

(1) $\frac{1}{6}\text{m}, \frac{2}{3}\text{m}, \frac{1}{3}\text{m}$ (2) $\frac{1}{3}\text{m}, \frac{1}{3}\text{m}, \frac{1}{3}\text{m}$ (3) $\frac{2}{3}\text{m}, \frac{1}{3}\text{m}, \frac{1}{6}\text{m}$ (4) $\frac{1}{3}\text{m}, \frac{4}{3}\text{m}, \frac{2}{3}\text{m}$

Sol. Answer (4)

k = 73.5 Nm^{-1} Force = 5 × 9.8

In figure (1)

$$5 \times 9.8 = (2\ k)\ x_1$$

$$\therefore \quad x_1 = \frac{5\times 9.8}{2\times 73.5} = \frac{1}{3}$$

In figure (2)

$$5 \times 9.8 = \frac{k\times k}{k+k}\times x_2$$

or $$5 \times 9.8 = \frac{k}{2}\times x_2$$

$$x_2 = \frac{98}{73.5} = \frac{4}{3}$$

In figure (3)

$$5 \times 9.8 = kx_3$$

$$x_3 = \frac{5\times 9.8}{73.5} = \frac{2}{3}$$

18. The frequency of oscillation of a mass m suspended by a spring is ν_1. If length of spring is cut to one third then the same mass oscillates with frequency ν_2, then

(1) $\nu_2 = 3\nu_1$ (2) $3\nu_2 = \nu_1$ (3) $\nu_2 = \sqrt{3}\,\nu_1$ (4) $\sqrt{3}\,\nu_2 = \nu_1$

Sol. Answer (3)

$\omega_{old} = \sqrt{\frac{k_{old}}{m}}$

When divided into 3 parts the spring constant of smaller parts

$\therefore \; k_{final} = 3k_{old}$

$\therefore \; \omega_{final} = \sqrt{3}\,\omega_{old}$

$\omega = 2\pi\nu$

Hence $\nu_{final} = \sqrt{3}\,\nu_{old} \Rightarrow \nu_2 = \sqrt{3}\nu_1$

19. Two particles executing S.H.M. of same frequency, meet at $x = +A/2$, while moving in opposite directions. Phase difference between the particles is

(1) $\frac{\pi}{6}$ (2) $\frac{\pi}{3}$ (3) $\frac{5\pi}{6}$ (4) $\frac{2\pi}{3}$

Sol. Answer (4)

$x = A \sin \omega t$

When displacement

$x = \frac{A}{2}$

$\frac{A}{2} = A \sin (\omega t + \phi)$

$\sin^{-1}\frac{1}{2} = \omega t + \phi$

$\omega t + \phi = 30° \text{ or } 150°$

When particles are in opposite direction at one lime phase is 30° and at the other 150°. So phase difference is 120°.

20. A particle is executing S.H.M. with time period T. Starting from mean position, time taken by it to complete $\frac{5}{8}$ oscillations, is

(1) $\frac{T}{12}$ (2) $\frac{T}{6}$ (3) $\frac{5T}{12}$ (4) $\frac{7T}{12}$

Sol. Answer (4)

Total distance covered by particle = 4 A

For $\frac{5}{8}$ of oscillation means that it has completed $\frac{1}{2}$ the oscillation taking $\frac{T}{2}$ seconds. Now it has to cover $\frac{1}{8}$ oscillation more. The whole path may be divided into 8 parts of $\frac{A}{2}$ hence it has to travel $\frac{A}{2}$ distance from mean position.

$\frac{A}{2} = A \sin \omega t$

$\frac{\pi}{6} = 8\ \omega t$

$t = \frac{T}{12}$ $\left[\text{Putting } \omega = \frac{2\pi}{T}\right]$

Total time = $\frac{T}{2} + \frac{T}{12} = \frac{7T}{12}$

21. A particle is executing S.H.M.. between $x = \pm A$. The time taken to go from 0 to $\frac{A}{2}$ is T_1 and to go from $\frac{A}{2}$ to A is T_2 ; then

(1) $T_1 < T_2$ (2) $T_1 > T_2$ (3) $T_1 = T_2$ (4) $T_1 = 2T_2$

Sol. Answer (1)

The velocity is greater closer to the mean position so it will take less time gains from 0 to $\frac{A}{2}$ than from $\frac{A}{2}$ to A.

22. The displacements of two particles executing S.H.M. on the same line are given as $y_1 = a\sin\left(\frac{\pi}{2}t + \phi\right)$ and $y_2 = b\sin\left(\frac{2\pi}{3}t + \phi\right)$. The phase difference between them at $t = 1$ s is

(1) π (2) $\frac{\pi}{2}$ (3) $\frac{\pi}{4}$ (4) $\frac{\pi}{6}$

Sol. Answer (4)

Phase difference between them is just difference in the angular values.

Phase difference = $\left(\frac{2\pi}{3} + \phi\right) - \left(\frac{\pi}{2} + \phi\right) = \frac{\pi}{6}$

23. For a particle executing simple harmonic motion, the amplitude is A and time period is T. The maximum speed will be

(1) $4AT$ (2) $\frac{2A}{T}$ (3) $2\pi\sqrt{\frac{A}{T}}$ (4) $\frac{2\pi A}{T}$

Sol. Answer (4)

Maximum speed is given by

$v = A\omega$

and $\omega = \frac{2\pi}{T}$

Hence $v = \frac{2\pi}{T}A$

24. A particle is executing S.H.M.. with amplitude A and has maximum velocity v_0. Its speed at displacement $\frac{3A}{4}$ will be

(1) $\frac{\sqrt{7}}{4}v_0$ (2) $\frac{v_0}{\sqrt{2}}$ (3) v_0 (4) $\frac{\sqrt{3}}{2}v_0$

Sol. Answer (1)

$$v = \omega\sqrt{A^2 - x^2}$$

$$x = \frac{3}{4}A$$

$$v = \omega\sqrt{A^2 - \frac{9A^2}{16}}$$

$$v = \omega A\sqrt{\frac{7}{16}}$$

or $v = v_0\sqrt{\frac{7}{4}}$ as $(v_0 = A\omega)$

25. A particle executes simple harmonic motion according to equation $4\frac{d^2x}{dt^2} + 320x = 0$. Its time period of oscillation is

(1) $\frac{2\pi}{5\sqrt{3}}$ s (2) $\frac{\pi}{3\sqrt{2}}$ s (3) $\frac{\pi}{2\sqrt{5}}$ s (4) $\frac{2\pi}{\sqrt{3}}$ s

Sol. Answer (3)

$$4\frac{d^2x}{dt^2} + 320x = 0$$

$$4\,a = -\,320\,x$$

$$a = -\,80\,x$$

Since $a = -\,\omega^2\,x$ in S.H.M.

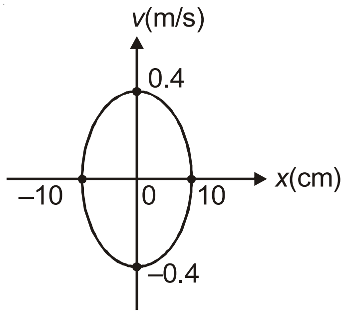
$$80 = \omega^2$$

$$\sqrt{16\times 5} = \omega$$

or $\omega = 4\sqrt{5}$

$$T = \frac{2\pi}{\omega} = \frac{2\pi}{4\sqrt{3}} = \frac{\pi}{2\sqrt{5}}\text{ s}$$

26. The plot of velocity (v) versus displacement (x) of a particle executing simple harmonic motion is shown in figure. The time period of oscillation of particle is



(1) $\frac{\pi}{2}$ s (2) π s (3) 2π s (4) 3π s

Sol. Answer (1)

A = 10 cm $A\omega = 0.4$ m/s

= 0.1 m

$\therefore$ $\omega = 4$ rad/s

$$T = \frac{2\pi}{4} = \frac{\pi}{2}\text{ s}$$

27. A particle of mass 10 g is undergoing S.H.M. of amplitude 10 cm and period 0.1 s. The maximum value of force on particle is about

(1) 5.6 N (2) 2.75 N (3) 3.5 N (4) 4 N

Sol. Answer (4)

$T = 0.1$ $m = 0.01$ kg

$\therefore$ $\omega = 20\pi$ rad/s

Amplitude $A = 0.1$ m

$a = -\omega^2 x$

Maximum acceleration = $-\omega^2 A$

Maximum force = $-m\omega^2 A$

$F_{max} = -0.01 \times (20\pi)^2 \times 0.1$

$F_{max} = -0.001 \times 400\pi^2$

$= -3.95$ N

or -4 N approximately

28. Two identical pendulums oscillate with a constant phase difference $\frac{\pi}{4}$ and same amplitude. If the maximum velocity of one is v, the maximum velocity of the other will be

(1) v (2) $\sqrt{2}v$ (3) $2v$ (4) $\frac{v}{\sqrt{2}}$

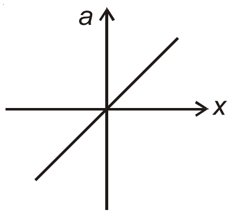
Sol. Answer (1)

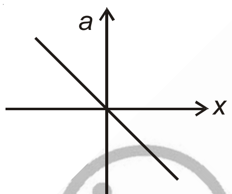
If the phase difference is constant, they are moving with same frequency and ω.

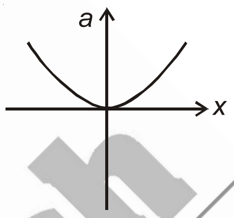
Since maximum velocity $A\omega = v$ (given)

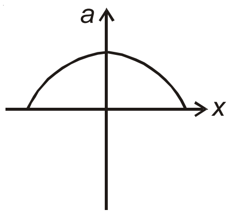
Maximum velocity of other will still be v.

29. Which of the following graphs best represents the variation of acceleration 'a' with displacement x?

(1)


(2)


(3)


(4)


Sol. Answer (2)

$a = -kx$ is an S.H.M.

Hence it will be a straight line with negative slope as in option (2)

30. A body executes S.H.M. with an amplitude A. At what displacement from the mean position, is the potential energy of the body one-fourth of its total energy?

(1) $\frac{A}{4}$ (2) $\frac{A}{2}$

(3) $\frac{3A}{4}$ (4) Some other fraction of A

Sol. Answer (2)

Potential energy at displacement x from mean position is given by

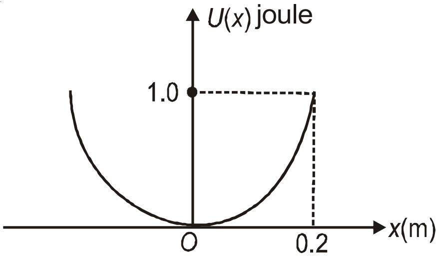
$$\text{P.E.} = \frac{1}{2}kx^2$$

Let total energy be $E = \frac{1}{2}kA^2$

$$\frac{1}{2}kx^2 = \frac{E}{4} = \frac{1}{8}kA^2$$

$$x = \frac{A}{2}$$

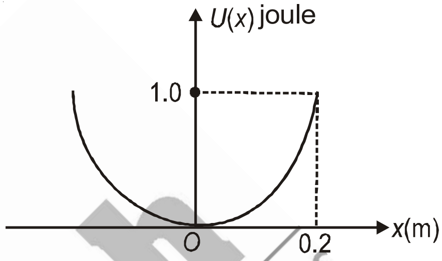
31. A particle of mass 4 kg moves simple harmonically such that its *PE*(*U*) varies with position *x*, as shown. The period of oscillations is



(1) $\frac{2\pi}{25}$ s (2) $\frac{\pi\sqrt{2}}{5}$ s (3) $\frac{4\pi}{5}$ s (4) $\frac{2\pi\sqrt{2}}{5}$ s

Sol. Answer (4)

Mass = 4 kg



Maximum P.E. = $\frac{1}{2}kA^2$

$$1 = \frac{1}{2}\times k\times(0.2)^2$$

$$\frac{2}{0.04} = k$$

$$k = 50 \text{ N/m}$$

$$T = 2\pi\sqrt{\frac{m}{k}}$$

$$T = 2\pi\sqrt{\frac{4}{50}}$$

$$= \frac{2\sqrt{2}\pi}{5}\text{s}$$

32. The kinetic energy and potential energy of a particle executing S.H.M. are equal, when displacement in terms of amplitude '*A*' is

(1) $\frac{A}{2}$ (2) $\frac{A}{\sqrt{2}}$ (3) $\frac{A\sqrt{2}}{3}$ (4) $A\sqrt{2}$

Sol. Answer (2)

Total energy = $\frac{1}{2}kA^2$

When P.E. is half of total energy P.E. = K.E.

$$\Rightarrow \frac{1}{2}kx^2 = \frac{1}{2}k(A^2 - x^2)$$

$$x^2 = A^2 - x^2 \Rightarrow 2x^2 = A^2$$

$$x = \frac{A}{\sqrt{2}}$$

33. A block is resting on a piston which executes simple harmonic motion with a period 2.0 s. The maximum velocity of the piston, at an amplitude just sufficient for the block to separate from the piston is

(1) 1.57 ms^{-1} (2) 3.12 ms^{-1} (3) 2.0 ms^{-1} (4) 6.42 ms^{-1}

Sol. Answer (2)

Period (T) = 2 s

$$\omega = \frac{2\pi}{2} = \pi \text{ rad/s}$$

When block just represent from a piston, maximum acceleration must be equal to *g*.

$$g = -\omega^2 x$$

Acceleration is maximum when $x = A$

$$g = -\omega^2 A$$

or $A = \frac{9.8}{\pi^2}$

Maximum velocity = $A\omega$

$$= \frac{9.8}{\pi^2} \times \pi$$

$$= \frac{9.8}{\pi} \text{ m/s}$$

= 3.119 m/s = 3.12 m/s

34. A simple pendulum suspended from the ceiling of a stationary lift has period T_0. When the lift descends at steady speed, the period is T_1, and when it descends with constant downward acceleration, the period is T_2. Which one of the following is true?

(1) $T_0 = T_1 = T_2$ (2) $T_0 = T_1 < T_2$ (3) $T_0 = T_1 > T_2$ (4) $T_0 < T_1 < T_2$

Sol. Answer (2)

Pseudo force only when there is an acceleration.

Hence $T_0 = T_1$ as there is uniform downward motion.

When it moves downward with a steady acceleration then pseudo force acts upwards, reducing net '*g*'

Since $T_2 = 2\pi\sqrt{\frac{l}{g_{\text{net}}}}$

When *g* reduces time period T_2 increases

$$T_0 = T_1 < T_2$$

35. If a Second's pendulum is moved to a planet where acceleration due to gravity is 4 times, the length of the second's pendulum on the planet should be made

(1) 2 times (2) 4 times (3) 8 times (4) 15 times

Sol. Answer (2)

Time period of a pendulum

$$T = 2\pi\sqrt{\frac{l}{g}} \text{ or } T_2\sqrt{\frac{l}{g}}$$

If g becomes 4 times. l must also be increased by 4 times to keep T constant.

36. A simple pendulum with a metallic bob has a time period T. The bob is now immersed in a non-viscous liquid and oscillated. If the density of the liquid is 1/4 that of metal, the time period of the same pendulum will be

(1) $\frac{T}{\sqrt{3}}$ (2) $\frac{2T}{\sqrt{3}}$ (3) $\frac{4}{3}T$ (4) $\frac{2}{3}T$

Sol. Answer (2)

Normal time period $T = 2\pi\sqrt{\frac{l}{g}}$

When immersed in a liquid. It experiences an upthrust.

$$\text{Upthrust} = \frac{\rho}{4} \times \text{volume } g$$

Upward acceleration = Upward force/mass of ball = $\frac{g}{4}$

$$T' = 2\pi\sqrt{\frac{l}{g_{eff}}}$$

$$g_{\text{eff}} = g - \frac{g}{4} = \frac{3}{4}g$$

$$T' = 2\pi = \sqrt{\frac{l}{3g}\times 4} = \frac{2T}{\sqrt{3}}$$

37. Two pendulums of length 1.21 m and 1.0 m start vibrating. At some instant, the two are in the mean position in same phase. After how many vibrations of the longer pendulum, the two will be in phase?

(1) 10 (2) 11 (3) 20 (4) 21

Sol. Answer (1)

Lengths l_1 = 1.21 m l_2 = 1 m

$$T_1 = 2\pi\sqrt{\frac{l_1}{g}} \qquad T_2 = 2\pi\sqrt{\frac{l_2}{g}}$$

$$T_1 = \frac{11}{10}T_2$$

or $10\ T_1 = 11T_2$

Hence it oscillations of longer pendulum is equal to 11 oscillation of shorter one.

Hence the will be in phase again after 10 oscillations of longer pendulum.

38. The time period of oscillations of a simple pendulum is 1 minute. If its length is increased by 44%. then its new time period of oscillation will be

(1) 96 s (2) 58 s (3) 82 s (4) 72 s

Sol. Answer (4)

Let initial length be l_1

Final length $l_2 = l_1 \times \frac{144}{100}$

$$T_1 = 2\pi\sqrt{\frac{l_1}{g}}$$

$$T_2 = 2\pi\sqrt{\frac{l_1}{g}\times\frac{144}{100}}$$

or $T_2 = 1.2\ T_1$

$T_1 = 60$ s

So $T_2 = 72$ s

39. If the length of a clock pendulum increases by 0.2% due to atmospheric temperature rise, then the loss in time of clock per day is

(1) 86.4 s (2) 43.2 s (3) 72.5 s (4) 32.5 s

Sol. Answer (1)

Time period $= 2\pi\sqrt{\frac{l}{g}}$

$$T \propto \sqrt{l}$$

$$\frac{T'}{T} \propto \sqrt{\frac{l'}{l}}$$

$$T' = T\sqrt{\frac{l + l \propto \Delta\theta}{l}}$$

$$T' = T\left(1 + \frac{1}{2} \propto \Delta\theta\right)\ [\alpha\Delta\theta = 0.002]$$

$$\Delta T = T' - T = \frac{1}{2}T \propto \Delta\theta = T \times 0.001$$

Time lost in time t is

$\Delta T = \frac{1}{2}$ $t = 1$ day $= 24 \times 3600$ s $= 86400$ s

$$\Delta T = \left(\frac{\Delta T}{T}\right)\times t$$

$\Delta T = 0.001 \times 86400$

$\Delta T = 86.4$ s

40. A simple pendulum is oscillating in a trolley moving on a horizontal straight road with constant acceleration *a*. If direction of motion of trolley is taken as positive *x* direction and vertical upward direction as positive *y* direction then the mean position of pendulum makes an angle

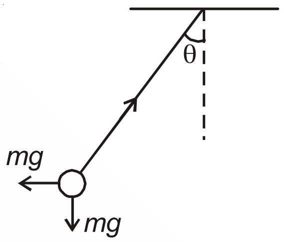
(1) $\tan^{-1}\left(\frac{g}{a}\right)$ with *y* axis in +*x* direction

(2) $\tan^{-1}\left(\frac{a}{g}\right)$ with *y* axis in –*x* direction

(3) $\tan^{-1}\left(\frac{a}{g}\right)$ with *y* axis in +*x* direction

(4) $\tan^{-1}\left(\frac{g}{a}\right)$ with *y* axis in –*x* direction

Sol. Answer (2)



$T\sin\theta = ma$ ... (i)

$T\cos\theta = mg$ ... (ii)

Dividing (i) and (ii)

$$T\cos\theta = \frac{a}{g}$$

$$\theta = \tan^{-1}\left(\frac{a}{g}\right)$$

41. The time period of oscillations of a second's pendulum on the surface of a planet having mass and radius double those of earth is

(1) 4 s (2) 1 s (3) $\sqrt{2}$ s (4) $2\sqrt{2}$ s

Sol. Answer (4)

$$g_1 = \frac{Gm}{R^2}$$

$$g_2 = \frac{G\times 2m}{4R^2} = \frac{g_1}{2}$$

$$T_1 = 2\pi\sqrt{\frac{l}{g_1}}$$

$$T_2 = 2\pi\sqrt{\frac{l}{g_2}}$$

$$T_2 = \sqrt{2}T_1$$

Since T_1 is time period of seconds pendulum $T_1 = 2$.

Hence $T_2 = 2\sqrt{2}$

42. The shape of graph between time period of a simple pendulum and its length is

(1) Straight line (2) Parabolic

(3) Hyperbolic (4) Elliptical

Sol. Answer (2)

43. A hollow metal sphere is filled with water through a small hole in it. It is hung by a long thread and is made to oscillate. Water slowly flows out of the hole at the bottom. Select the correct variation of its time period

(1) The period will go on increasing till the sphere is empty

(2) The period will go on decreasing till the sphere is empty

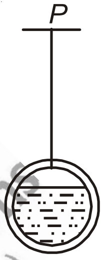
(3) The period will not be affected at all

(4) The period will increase first, then decrease to initial value till the sphere is empty

Sol. Answer (4)

As the water level goes down, the distance of C.O.M.

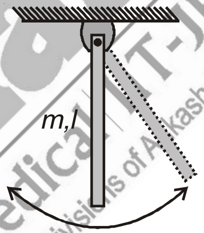
From point of oscillation P keeps increasing.



Since T = $2\pi\sqrt{\frac{l}{g}}$

The time period of pendulum keep increasing.

44. A uniform rod of mass m and length l is suspended about its end. Time period of small angular oscillations is



(1) $2\pi\sqrt{\frac{l}{g}}$ (2) $2\pi\sqrt{\frac{2l}{g}}$ (3) $2\pi\sqrt{\frac{2l}{3g}}$ (4) $2\pi\sqrt{\frac{l}{3g}}$

Sol. Answer (3)

This is the case of a physical pendulum.

$$T = 2\pi\sqrt{\frac{I_{\text{com}}}{mg\,L_{\text{com}}}}$$

$$L_{\text{com}} = \frac{L}{2} \qquad I_{\text{com}} = \frac{mL^2}{3}$$

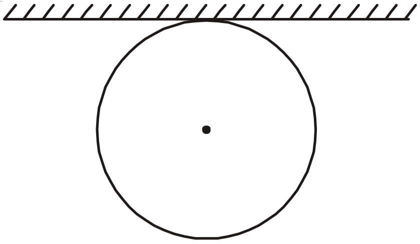
$$T = 2\pi\sqrt{\frac{2l}{3g}}$$

45. A uniform disc of mass M and radius R is suspended in vertical plane from a point on its periphery. Its time period of oscillation is

(1) $2\pi\sqrt{\frac{3R}{g}}$ (2) $2\pi\sqrt{\frac{R}{3g}}$ (3) $2\pi\sqrt{\frac{2R}{3g}}$ (4) $2\pi\sqrt{\frac{3R}{2g}}$

Sol. Answer (4)

It is the case of a physical pendulum.



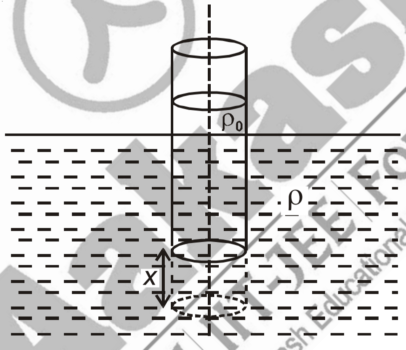
$$T = 2\pi\sqrt{\frac{I_{\text{c.o.m.}}}{mg\,L_{\text{com}}}}$$

$$I_{\text{com}} = \frac{MR^2}{2} + MR^2 = \frac{3}{2}MR^2$$

$$L_{\text{com}} = R$$

$$T = 2\pi\sqrt{\frac{3R}{2g}}$$

46. A solid cylinder of density ρ_0 , cross-section area A and length l floats in a liquid of density ρ (> ρ_0) with its axis vertical, as shown. If it is slightly displaced downward and released, the time period will be

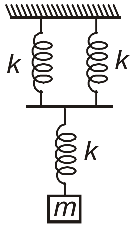


(1) $2\pi\sqrt{\frac{l}{g}}$ (2) $2\pi\sqrt{\frac{\rho_0 l}{\rho g}}$ (3) $2\pi\sqrt{\frac{\rho l}{\rho_0 g}}$ (4) $2\pi\sqrt{\frac{l}{2g}}$

Sol. Answer (2)

The time period of a floating uniform cylinder is simply given as $R = l$.

47. A block of mass m hangs from three springs having same spring constant k. If the mass is slightly displaced downwards, the time period of oscillation will be



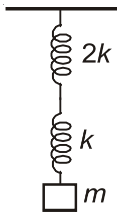
(1) $2\pi\sqrt{\frac{m}{3k}}$ (2) $2\pi\sqrt{\frac{3m}{2k}}$ (3) $2\pi\sqrt{\frac{2m}{3k}}$ (4) $2\pi\sqrt{\frac{3k}{m}}$

Sol. Answer (2)

The first two springs are in parallel.

So, k_{eq} of 1st 2 will be = $2k$

Then it becomes



The springs $2k$ and k are in series.

So, $k_{eq} = \dfrac{2k \times k}{2k + k}$

$= \dfrac{2\,k \times k}{3\,k} = \dfrac{2}{3}k$

$T = 2\pi\sqrt{\dfrac{m}{k_{eq}}}$

$\Rightarrow \quad T = 2\pi\sqrt{\dfrac{3m}{2k}}$

48. Two masses m_1 = 1 kg and m_2 = 0.5 kg are suspended together by a massless spring of spring constant 12.5 Nm^{-1}. When masses are in equilibrium m_1 is removed without disturbing the system. New amplitude of oscillation will be

(1) 30 cm (2) 50 cm (3) 80 cm (4) 60 cm

Sol. Answer (3)

Points of equilibrium of the spring will be when no force acts on it.

or $kx = (m_1 + m_2)g$

$x = \dfrac{(m_1 + m_2)g}{k}$

The new equilibrium position which will be the mean position of S.H.M. will be simply $\dfrac{m_2 g}{k}$

New amplitude will be maximum displacement from $\dfrac{m_2 g}{k}$ which is :

$A = \dfrac{(m_1 + m_2)g}{k} - \dfrac{m_2 g}{k}$

or $A = \dfrac{m_1 g}{k}$

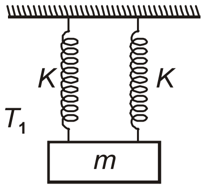
or $A = \dfrac{1 \times 10}{12.5}$

or $A = \dfrac{4}{5}m$

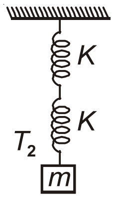
$\therefore$ A = 0.8 m or 80 cm

49. A mass m is attached to two springs of same force constant K, as shown in following four arrangements. If T_1, T_2, T_3 and T_4 respectively be the time periods of oscillation in the following arrangements, in which case time period is maximum?

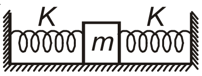
(a)



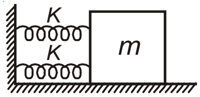
(b)



(c)



(d)



(1) (a)
(2) (b)
(3) (c)
(4) (d)

Sol. Answer (2)

$$T = 2\pi\sqrt{\frac{m}{K}}$$

Time period is maximum when K is minimum.

In (a), (c) and (d) the spring constants are in parallel so the $K_{eq} = 2K$.

Only in case (b) springs are in series.

So, $K_{eq} = \frac{K}{2}$

Hence time period in this case will be maximum.

50. A clock S is based on oscillations of a spring and a clock P is based on pendulum motion. Both clocks run at the same rate on earth. On a planet having same density as earth but twice the radius then

(1) S will run faster than P
(2) P will run faster than S
(3) Both run at same rate
(4) Both run at same rate but different than earth

Sol. Answer (2)

Time period of spring = $2\pi\sqrt{\frac{k}{m}}$

Time period of pendulum = $2\pi\sqrt{\frac{l}{g}}$

Time period of spring will not be affected by gravitational acceleration.

Let mass of earth be m

Mass of new planet = $\rho\times\frac{4}{3}\pi(2R)^3 = 8\text{ m}$

$$g_2 = \frac{GM_2}{(R_2)^2} = \frac{G\times 8M}{(2R)^2} = 2\text{ g}$$

$$T_2 = 2\pi\sqrt{\frac{l}{2g}}$$

$$T_2 = \frac{T}{\sqrt{2}}$$

Hence P will move faster.

51. A 100 g mass stretches a particular spring by 9.8 cm, when suspended vertically from it. How large a mass must be attached to the spring if the period of vibration is to be 6.28 s?

(1) 1000 g (2) 10^5 g (3) 10^7 g (4) 10^4 g

Sol. Answer (4)

At point of equilibrium $kx = mg$

$$k \times 9.8 \times 10^{-2} = 100 \times 10^{-3} \times 9.8$$

$$k = 100 \times 10^{-1}$$

$$k = 10 \text{ N/m}$$

Period of vibration needed = 6.28 s

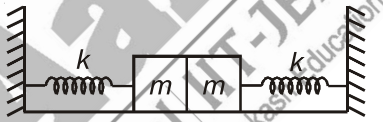
$$T = 2\pi\sqrt{\frac{m}{k}}$$

$$6.28 = 2 \times 3.14\sqrt{\frac{m}{10}}$$

$$1 = \frac{m}{10}$$

$$m = 10 \text{ kg or } 10^4 \text{ g}$$

52. An assembly of identical spring-mass systems is placed on a smooth horizontal surface as shown. At this instant, the springs are relaxed. The left mass is displaced to the left and the right mass is displaced to the right by same distance and released. The resulting collision is elastic. The time period of the oscillations of system is



(1) $2\pi\sqrt{\frac{2m}{k}}$ (2) $2\pi\sqrt{\frac{m}{2k}}$ (3) $\pi\sqrt{\frac{m}{k}}$ (4) $2\pi\sqrt{\frac{m}{k}}$

Sol. Answer (3)

If there was no collision each spring will oscillate with period

$$T = 2\pi\sqrt{\frac{m}{k}}$$

Because of collisions the springs are only compressed but cannot extend beyond their natural length. Hence the perform only half oscillation.

Hence $T = 2\pi\sqrt{\frac{m}{k}} \div 2$

or $T = \pi\sqrt{\frac{m}{k}}$

53. A spring block system in horizontal oscillation has a time-period T. Now the spring is cut into four equal parts and the block is re-connected with one of the parts. The new time period of vertical oscillation will be

(1) $\frac{T}{\sqrt{2}}$ (2) $2T$ (3) $\frac{T}{2}$ (4) $\frac{T}{2\sqrt{2}}$

Sol. Answer (3)

When spring is cut into 4 parts. The spring constant of each part will become 4k.

$$T_2 = 2\pi\sqrt{\frac{m}{4k}}$$

$$T_2 = \frac{T}{2}$$

54. A block of mass m is suspended separately by two different springs have time period t_1 and t_2. If same mass is connected to parallel combination of both springs, then its time period is given by

(1) $\frac{t_1 t_2}{t_1 + t_2}$ (2) $\frac{t_1 t_2}{\sqrt{t_1^2 + t_2^2}}$ (3) $\sqrt{\frac{t_1 t_2}{t_1 + t_2}}$ (4) $t_1 + t_2$

Sol. Answer (2)

$$t_1 = 2\pi\sqrt{\frac{m}{k_1}} \quad , \quad t_2 = 2\pi\sqrt{\frac{m}{k_a}} \quad , \quad t_{eq} = 2\pi\sqrt{\frac{m}{k_1 + k_2}}$$

Let $2\pi\sqrt{m}$ be any constant c.

$$t_1 = \frac{c}{\sqrt{k_1}} \quad , \quad t_2 = \frac{c}{\sqrt{k_2}}$$

$$k_1 = \frac{c^2}{t_1^2} \quad , \quad k_2 = \frac{c}{t_2^2}$$

$$t_{eq} = 2\pi\sqrt{\frac{m}{c^2/t_1^2 + c^2/t_2^2}}$$

$$t_{eq} = 2\pi\sqrt{\frac{m\ t_1^2 + t_2^2}{c^2 t_2^2 + c^2 t_1^2}}$$

$$t_{eq} = \frac{t_1 t_2}{\sqrt{t_1^2 + t_2^2}}$$

55. In damped oscillations, damping force is directly proportional to speed of oscillator. If amplitude becomes half of its maximum value in 1 s, then after 2 s amplitude will be (A_0– initial amplitude)

(1) $\frac{1}{4}A_0$ (2) $\frac{1}{2}A_0$ (3) A_0 (4) $\frac{\sqrt{3}A_0}{2}$

Sol. Answer (1)

$$A = A_0\, e^{-bt}$$

Amplitude becomes half hence

$$\frac{A_0}{2} A_0\, e^{-bt}\ [t = 1]$$

$$\therefore \quad e^{-b} = \frac{1}{2}$$

∴ In two seconds

$$A = A_0\left(\frac{1}{2}\right)^2$$

$$A = \frac{A_0}{4}$$

56. In forced oscillations, a particle oscillates simple harmonically with a frequency equal to

(1) Frequency of driving force

(2) Natural frequency of body

(3) Difference of frequency of driving force and natural frequency

(4) Mean of frequency of driving force and natural frequency

Sol. Answer (1)

In forced oscillations a particle oscillator simple harmonically with a frequency equal to driving frequency.

57. Resonance is a special case of

(1) Forced oscillations (2) Damped oscillations

(3) Undamped oscillations (4) Coupled oscillations

Sol. Answer (1)

Resonance is a special case of force oscillation due to which oscillation to place with greater amplitude.

58. The S.H.M. of a particle is given by the equations = 2 sin ωt + 4 cos ωt. Its amplitude of oscillation is

(1) 4 units (2) 2 units

(3) 6 units (4) $2\sqrt{5}$ units

Sol. Answer (4)

$$x = 2 \sin \omega t + 4 \cos \omega t$$

It can also be written as

$$x = \sqrt{2^2+4^2}\left(\frac{2}{\sqrt{2^2+4^2}}\sin\omega t\frac{4}{\sqrt{2^2+4^2}}\cos\omega t\right)$$

$$x = \sqrt{20}\sin(\omega t+\phi)$$

$$\sqrt{20} = \text{Amplitude}$$

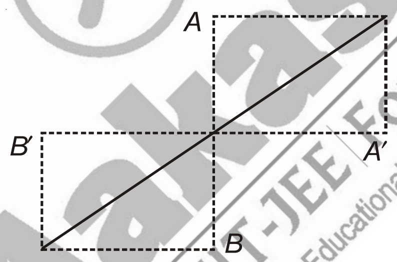
or Amplitude = $2\sqrt{5}$

59. If two mutually perpendicular simple harmonic motion of same amplitude, frequency and having zero phase difference superimpose on a particle, then its resultant path will be

(1) A straight line
(2) A circle
(3) An ellipse
(4) A hyperbola

Sol. Answer (1)

If $A - B$ is the path followed by one particle superimpose, then the result will be as shown and the particle will oscillate diagonally.



60. Which of the following represents a S.H.M.?

(1) sin ω*t* – cos ω*t*
(2) sin ω*t* + cos ω*t*
(3) sin ω*t* + 2 cos ω*t*
(4) All of these

Sol. Answer (4)

All of them are superposition of two S.H.M. in the same phase and hence they all represent S.H.M's.

SECTION - B

Objective Type Questions

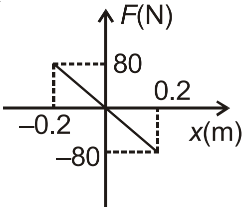
1. The circular motion of a particle with constant speed is

(1) Periodic but not simple harmonic
(2) Simple harmonic but not periodic
(3) Period and simple harmonic
(4) Neither periodic nor simple harmonic

Sol. Answer (1)

The motion repeats itself after same intervals hence it is periodic. Put since acceleration is not proportional to – *x*, the motion is periodic but not simple harmonic.

2. A body of mass 0.01 kg executes simple harmonic motion about $x = 0$ under the influence of a force as shown in figure. The time period of S.H.M. is



(1) 1.05 s (2) 0.52 s (3) 0.25 s (4) 0.03 s

Sol. Answer (4)

Maximum restoring force on particle

$F = 80$ N

$x = -0.2$

Since $F = -kx$

$80 = k \times 0.2$

$400 = k$

$$T = 2\pi\sqrt{\frac{m}{k}}$$

$$= 2\pi\sqrt{\frac{0.01}{400}} \text{ kg}$$

$$= 2\pi\sqrt{\frac{1}{40000}}$$

$$= 2\pi\sqrt{\frac{1}{2\times10^2}}$$

$$= \frac{1}{2\times10^2}$$

≈ 0.03 s

3. A 1.00×10^{-20} kg particle is vibrating under simple harmonic motion with a period of 1.00×10^{-5} s and with a maximum speed of 1.00×10^3 m/s. The maximum displacement of particle from mean position is

(1) 1.59 mm (2) 1.00 m (3) 10 m (4) 3.18 mm

Sol. Answer (1)

$m = 1 \times 10^{-20}$ kg $T = 1 \times 10^{-5}$ kg

Maximum speed $= A\omega = 1 \times 10^3$ m/s ... (i)

$$\omega = \frac{2\pi}{T} = 2\pi \times 10^5 \text{ rad/s}$$

Putting value of ω in (i)

$$A \times 2\pi \times 10^5 = 1 \times 10^3$$

$$A = \frac{1}{2\pi\times10^2}$$

$$A = 1.59 \text{ mm}$$

4. The equation of an S.H.M. with amplitude A and angular frequency ω in which all the distances are measured from one extreme position and time is taken to be zero at the other extreme position is

(1) $x = A \sin \omega t$
(2) $x = A(\cos \omega t + \sin \omega t)$
(3) $x = A - A \cos \omega t$
(4) $x = A + A \cos \omega t$

Sol. Answer (4)

At $t = 0$ the distance from 1 extreme is 2 A

At $\omega t = \pi$ $x = 0$

Hence by resulting values we can get equation for S.H.M.. from S.H.M..

5. A body oscillates with S.H.M. according to the equation $x = (5.0 \text{ m}) \cos [(2\pi \text{ rad s}^{-1})t + \pi/4]$

At $t = 1.5$ s, its acceleration is

(1) – 139.56 m/s^2
(2) 139.56 m/s^2
(3) 69.78 m/s^2
(4) – 69.78 m/s^2

Sol. Answer (2)

$$x = 5 \cos (2\pi t + \pi/4)$$

$$t = \frac{3}{2} \text{ s}$$

$$x = 5 \cos (3\pi + \pi/4)$$

$$x = 5 \cos \left(\frac{13\pi}{4}\right)$$

$$x = -5 \cos \frac{\pi}{4}$$

$$x = -\frac{5}{\sqrt{2}}$$

Acceleration

$$a = -\omega^2 x$$

$$a = -4\pi^2 x - \frac{5}{\sqrt{2}}$$

$$a \simeq 139.56 \text{ m/s}^2$$

6. The time period of a particle executing S.H.M. is 8 s. At $t = 0$ it is at the mean position. The ratio of distance covered by the particle in 1st second to the 2nd second is

(1) $\left(\sqrt{2}-1\right)$s (2) $\sqrt{2}$ s (3) $\left(\sqrt{2}+1\right)$s (4) $\frac{1}{\sqrt{2}}$s

Sol. Answer (3)

$T = 8$ s $\quad\quad \omega = \frac{2\pi}{8} = \frac{\pi}{4}$

$$x_1 = A \sin \frac{\pi}{4} = \frac{A}{\sqrt{2}}$$

$$x_2 = A \sin \frac{\pi}{4} \times 2 - A \sin \frac{\pi}{4} = A - \frac{A}{\sqrt{2}} = \frac{A}{\sqrt{2}}(\sqrt{2}-1)$$

$$\frac{x_1}{x_2} = \frac{1}{\sqrt{2}-1} \times \frac{\sqrt{2}+1}{\sqrt{2}+1} = \sqrt{2}+1$$

7. Two particle executing S.H.M. of same amplitude of 20 cm with same period along the same line about same equilibrium position. The maximum distance between the two is 20 cm. Their phase difference in radian is equal to

(1) $\frac{\pi}{3}$ (2) $\frac{\pi}{2}$ (3) $\frac{2\pi}{3}$ (4) $\frac{4\pi}{5}$

Sol. Answer (1)

$x_1 = A \sin (\omega t + \phi_1)$

$x_2 = A \sin (\omega t + \phi_2)$

$x_1 - x_2 = A \sin (\omega t + \phi_1) - A \sin (\omega t + \phi_2)$

$$20 = 2 \times 20 \sin \left(\frac{\phi_1 - \phi_2}{2}\right) \cdot \cos\left[\omega t + \left(\frac{\phi_1 + \phi_2}{2}\right)\right]$$

$\frac{1}{2} = \sin\left(\frac{\phi_1 - \phi_2}{2}\right) \cdot \cos\left(\omega t + \left(\frac{\phi_1 + \phi_2}{2}\right)\right)$ for maximum value. $\Rightarrow \frac{\phi_1 - \phi_2}{2} = \frac{\pi}{6} \Rightarrow \phi_1 - \phi_2 = \frac{\pi}{3}$

8. A particle execute S.H.M. along a straight line. The amplitude of oscillation is 2 cm. When displacement of particle from the mean position is 1 cm, the magnitude of its acceleration is equal to magnitude of its velocity. The time period of oscillation is

(1) $\frac{2\pi}{\sqrt{2}}$ (2) $\frac{\sqrt{2}}{2\pi}$ (3) $\frac{2\pi}{\sqrt{3}}$ (4) $\frac{\sqrt{3}}{2\pi}$

Sol. Answer (3)

$$A = 2 \text{ cm} = 2 \times 10^{-2}$$

$$a = -\omega^2 x$$

and $v = \omega\sqrt{A^2 - x^2}$

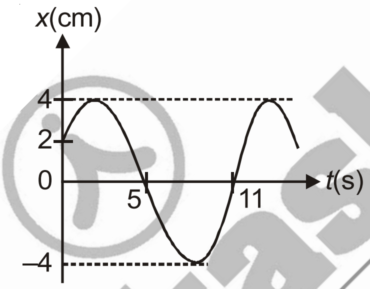
$$\omega^2 \times 1 \times 10^{-2} = \omega\sqrt{(4-1)10^{-4}}$$

$$\omega \times 1 \times 10^{-2} = \sqrt{3} \times 10^{-2}$$

$$\omega = \sqrt{3}$$

$$T = \frac{2\pi}{\omega} = \frac{2\pi}{\sqrt{3}}$$

9. Figure shows the position-time graph of an object in S.H.M. The correct equation representing this motion is



(1) $2\sin\left(\frac{2\pi}{5}t + \frac{\pi}{6}\right)$ (2) $4\sin\left(\frac{\pi}{5}t + \frac{\pi}{6}\right)$ (3) $4\sin\left(\frac{\pi}{6}t + \frac{\pi}{3}\right)$ (4) $4\sin\left(\frac{\pi}{6}t + \frac{\pi}{6}\right)$

Sol. Answer (4)

Time period is 12 s from diagram.

$$\omega = \frac{2\pi}{12} = \frac{\pi}{6}$$

Amplitude $A = 4$

Initial phase is determined by putting known values in the equation.

$$2 = 4\sin\left(\frac{\pi}{6}t + \phi\right)$$

$$\sin^{-1}\frac{1}{2} = \phi \; [t = 0]$$

$$\frac{\pi}{6} = \phi$$

Hence equation is $x = \left(\frac{\pi}{6}t + \frac{\pi}{6}\right)$

10. A particle executes S.H.M. according to equation $x = 10\ (\text{cm}) \cos\left[2\pi t + \frac{\pi}{2}\right]$, where t is in second. The magnitude of the velocity of the particle at $t = \frac{1}{6}$ s will be

(1) 24.7 cm/s (2) 20.5 cm/s (3) 28.3 cm/s (4) 31.4 cm/s

Sol. Answer (4)

$$x = 10\cos\left[2\pi t + \frac{\pi}{2}\right]$$

At $t = \frac{1}{6}$ s

$$x = 10\cos\left[\frac{\pi}{2} + \frac{\pi}{3}\right]$$

$$x = -10\sin\frac{\pi}{3}$$

$$x = -5\sqrt{3}$$

$$v = \omega\sqrt{A^2 - x^2}$$

$$v = 2\pi\sqrt{100 - 75}$$

$$v = 10\pi$$

or $v = 31.4$ cm/s

11. A particle executes S.H.M. and its position varies with time as $x = A\sin\omega t$. Its average speed during its motion from mean position to mid-point of mean and extreme position is

(1) Zero (2) $\frac{3A\omega}{\pi}$ (3) $\frac{A\omega}{2\pi}$ (4) $\frac{2A\omega}{\pi}$

Sol. Answer (2)

Phase at mean position = 0

Phase at mid point

$$\frac{A}{2} = A\sin\phi$$

$$\phi = \frac{\pi}{6}$$

Time it takes to travel a phase difference of ϕ

$$t = \frac{2\pi}{\omega} \times \frac{\phi}{2\pi}$$

or $t = \dfrac{\phi}{\omega}$

or $t = \dfrac{\pi}{6\omega}$

$$\text{Average speed} = \frac{\text{Total distance}}{\text{Time taken}}$$

$$= \frac{A/2}{\pi/6\omega}$$

$$= \frac{3A\omega}{\pi}$$

12. A particle of mass m in a unidirectional potential field have potential energy $U(x) = \alpha + 2\beta x^2$, where α and β are positive constants. Find its time period of oscillation.

(1) $2\pi\sqrt{\dfrac{2\beta}{m}}$ (2) $2\pi\sqrt{\dfrac{m}{2\beta}}$ (3) $\pi\sqrt{\dfrac{m}{\beta}}$ (4) $\pi\sqrt{\dfrac{\beta}{m}}$

Sol. Answer (3)

$$U(x) = \alpha + 2\beta x^2$$

$$F = -\frac{dU(x)}{dx}$$

$$F = -4\beta x$$

$$T = 2\pi\sqrt{\frac{m}{k}}$$

$$T = 2\pi\sqrt{\frac{m}{4\beta}} \qquad \text{cos } [k = \beta]$$

$$T = \pi\sqrt{\frac{m}{\beta}}$$

13. A particle is executing S.H.M. and its velocity v is related to its position (x) as $v^2 + ax^2 = b$, where a and b are positive constants. The frequency of oscillation of particle is

(1) $\dfrac{1}{2\pi}\sqrt{\dfrac{b}{a}}$ (2) $\dfrac{\sqrt{a}}{2\pi}$ (3) $\dfrac{\sqrt{b}}{2\pi}$ (4) $\dfrac{1}{2\pi}\sqrt{\dfrac{a}{b}}$

Sol. Answer (2)

$$v^2 + ax^2 = b$$

$$v^2 = b - ax^2$$

$$v^2 = a\left(\frac{b}{a} - x^2\right)$$

Comparing it to equation

$$v^2 = \omega^2 \left(A^2 - x^2\right)$$

$$\omega = \sqrt{a}$$

$$f = \frac{\omega}{2\pi} = \frac{\sqrt{a}}{2\pi}$$

14. A loaded vertical spring executes S.H.M. with a time period of 4 s. The difference between the kinetic energy and potential energy of this system varies with a period of

(1) 2 s (2) 1 s (3) 8 s (4) 4 s

Sol. Answer (1)

$$T = 4 \text{ s} \qquad \omega = \frac{2\pi}{T} = \frac{\pi}{2} \text{ rad/s}$$

$$x = A \sin \omega t \qquad v = A\omega \cos \omega t$$

$$\text{K.E.} = \frac{1}{2}mv^2 \qquad \frac{1}{2}mA^2\omega^2 \cos^2\omega t \qquad \text{... (i)}$$

$$\text{P.E.} = \frac{1}{2}kx^2 \qquad \frac{1}{2}kA^2 \sin^2\omega t \qquad \text{... (ii)}$$

$$\omega = \sqrt{\frac{k}{m}}$$

or $k = m\omega^2$ putting this value in (ii).

$$\text{K.E.} - \text{P.E.} = \frac{1}{2}m\omega^2A^2 \left(\cos^2\omega t - \sin^2\omega t\right)$$

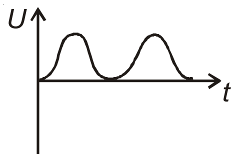
$$\text{K.E.} - \text{P.E.} = E_{\text{max.}} (\cos 2\omega t)$$

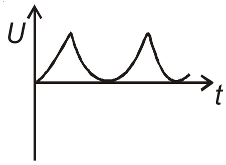
Hence time period of difference of K.E. and P.E. is

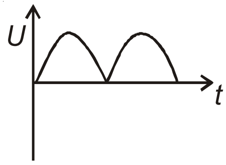
$$T = \frac{2\pi}{2\omega}$$

or $T = 2$ s

15. As a body performs S.H.M., its potential energy U varies with time t as indicated in

(1)


(2)


(3)


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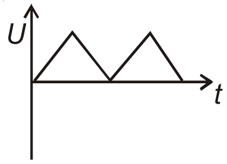


Sol. Answer (1)

Potential energy $=\frac{1}{2}kx^2 = \frac{1}{2}A^2\omega^2\sin^2(\omega t + \phi)$

The graph for $\sin^2(\omega t + \phi)$ is given by (1).

16. A particle is performing S.H.M. with energy of vibration 90 J and amplitude 6 cm. When the particle reaches at distance 4 cm from mean position, it is stopped for a moment and then released. The new energy of vibration will be

(1) 40 J (2) 50 J (3) 90 J (4) 60 J

Sol. Answer (1)

Energy = 90 J Amplitude = 6 cm

Maximum energy $= \frac{1}{2}mA^2\omega^2 = 90$

or $m\omega^2 = \frac{180}{36\times10^{-4}}$

$\therefore$ $m\omega^2 = 30 \times 10^2$

When particle is stopped the point where it is stopped is the new amplitude but angular velocity will remain same.

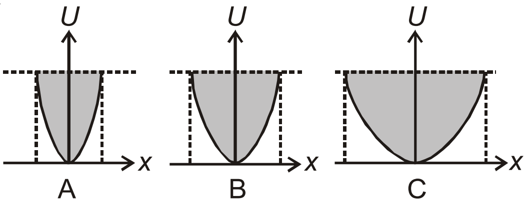
$E = \frac{1}{2}mA_2^2\omega^2$

or $E = 3000\ A_2^2$

$A_2 = 4 \times 10^{-2}$

$A_2 = 3000$

17. The variations of potential energy (U) with position x for three simple harmonic oscillators A, B and C are shown in figure. The oscillators have same mass. The time period of oscillation is greatest for



(1) A (2) B (3) C (4) Same for all

Sol. Answer (3)

$$U = \frac{1}{2}kx^2$$

$$x^2 = \frac{2U}{k}$$

or $x \propto \frac{1}{k}$ (Since U is constant)

Also $T = 2\pi\sqrt{\frac{m}{k}}$

or $T \propto \frac{1}{\sqrt{k}}$

Therefore $x \propto T$

Hence the oscillation with maximum x will have the maximum time period.

18. If the particle repeats its motion after a fixed time interval of 8 s then after how much time its maximum value of PE will be attained after attaining its minimum value?

(1) 2 s (2) 4 s (3) 8 s (4) 1 s

Sol. Answer (1)

$T = 8$ s

Maximum value of potential energy is reached two times per oscillation which is $\frac{T}{4}$ time away from mean position which has minimum value at position.

19. A particle is executing S.H.M. with total mechanical energy 90 J and amplitude 6 cm. If its energy is somehow decreased to 40 J then its amplitude will become

(1) 2 cm (2) 4 cm (3) $\frac{8}{3}$ cm (4) $\frac{4}{3}$ cm

Sol. Answer (2)

$$\frac{1}{2}mA^2\omega^2 = 90 \text{ J}$$

m and ω remaining same energy is reduced to 40 J.

$$\frac{A_1^2}{A_2^2} = \frac{9}{4}$$

or $\frac{A_1}{A_2} = \frac{3}{2}$

or $A_2 = 4$ cm

20. A linear harmonic oscillator of force constant 6×10^5 N/m and amplitude 4 cm, has a total energy 600 J. Select the correct statement.

(1) Maximum potential energy is 600 J (2) Maximum kinetic energy is 480 J

(3) Minimum potential energy is 120 J (4) All of these

Sol. Answer (4)

$k = 6 \times 10^5$ N/m

Amplitude = 4 cm = 4×10^{-2} m

$$\frac{1}{2}kx^2 = \frac{1}{2} \times 6 \times 10^5 \times (4 \times 10^{-2})^2$$

or $E = 480$ J

Since energy of S.H.M. is 480 J and there is 600 J provided to the oscillation there must be 600 – 120 = 480 J stored as energy.

21. A second's pendulum is mounted in a rocket. Its period of oscillation will decrease when rocket is

(1) Moving down with uniform acceleration

(2) Moving around the earth in geostationary orbit

(3) Moving up with uniform velocity

(4) Moving up with uniform acceleration

Sol. Answer (1)

$$T = 2\pi\sqrt{\frac{l}{g}}$$

When the rocket is moving down with acceleration Pseudo force is acting upwards reducing effective gravitational acceleration (g).

22. The curve between square of frequency of oscillation and length of the simple pendulum is

(1) Straight line (2) Parabola (3) Ellipse (4) Hyperbola

Sol. Answer (4)

$l = kT^2$

$$T = 2\pi\sqrt{\frac{l}{g}}$$

$$f = \frac{1}{2\pi}\sqrt{\frac{g}{l}}$$

or $f^2 = \dfrac{k}{l}$

This is the equation of hyperbola between f^2 and l.

23. A simple pendulum of mass *m* executes S.H.M. with total energy *E*. If at an instant it is at one of extreme positions, then its linear momentum after a phase shift of $\frac{\pi}{3}$ rad will be

(1) $\sqrt{2mE}$ (2) $\sqrt{\frac{3mE}{2}}$ (3) $2\sqrt{mE}$ (4) $\sqrt{\frac{2mE}{3}}$

Sol. Answer (2)

Energy = E_0

After a phase shift of $\frac{\pi}{3}$

$$E = E_0 \cos^2 \frac{\pi}{3}$$

$$\frac{P^2}{2m} = \frac{E_0 3}{4}$$

$$P = \sqrt{\frac{3mE}{2}}$$

24. A small iron ball of mass *m* is suspended with the help of a massless rod of length *L* and is free to oscillate in vertical plane. Its time period of oscillation is

(1) $2\pi\sqrt{\frac{mL}{2g}}$ (2) $2\pi\sqrt{\frac{mL}{g}}$ (3) $2\pi\sqrt{\frac{L}{g}}$ (4) $2\pi\sqrt{\frac{m}{gL}}$

Sol. Answer (3)

Since this is the case of a massless rod, the condition is same as that of a pendulum.

$$T = 2\pi\sqrt{\frac{L}{g}}$$

25. A rectangular block of mass *m* and area of cross-section *A* floats in a liquid of density ρ. If it is given a small vertical displacement from equilibrium it undergoes oscillations with a time period *T*, then

(1) $T \propto \frac{1}{\sqrt{m}}$ (2) $T \propto \sqrt{\rho}$ (3) $T \propto \frac{1}{\sqrt{A}}$ (4) $T \propto \frac{1}{\rho}$

Sol. Answer (3)

Time period of a floating cylinder is given by

$$T = 2\pi\sqrt{\frac{L\rho_s}{\rho_L g}}$$

When ρ_s is density of limit

$$T = 2\pi\sqrt{\frac{L^3\rho_s}{L^2\rho_L g}}$$

$$T = 2\pi\sqrt{\frac{M_s}{A\rho_L g}}$$

$$T \propto \frac{1}{\sqrt{A}}$$

26. A body of mass 5 kg hangs from a spring and oscillates with a time period of 2π second. If the body is removed, the length of the spring will decrease by

(1) *glk* metre (2) *klg* metre (3) 2π metre (4) *g* metre

Sol. Answer (4)

$T = 2\pi$ sec Mass = 5 kg

Spring constant = k

$\omega = 1$ rad/sec

Now $\omega = \sqrt{\frac{k}{m}}$

So, $k = 5$

Equilibrium position when it is oscillating is at

$k\Delta x = mg$

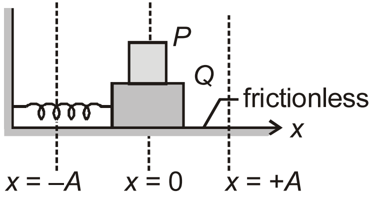
or $\Delta x = \frac{mg}{k}$

When the mass is removed the spring will return to its natural length, which is Δx upwards.

Since $m = 5$ and $k = 5$

$\Delta x = g$ metre

27. In the figure shown, there is friction between the blocks *P* and *Q* but the contact between the block *Q* and lower surface is frictionless. Initially the block *Q* with block *P* over it lies at $x = 0$, with spring at its natural length. The block *Q* is pulled to right and then released. As the spring - blocks system undergoes S.H.M. with amplitude *A*, the block *P* tends to slip over *Q*. *P* is more likely to slip at

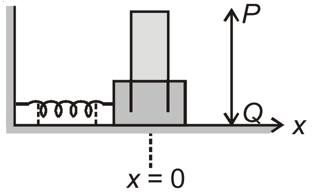


(1) $x = 0$ (2) $x = +A$ (3) $x = +\frac{A}{2}$ (4) $x = +\frac{A}{\sqrt{2}}$

Sol. Answer (2)

The block is most likely to slip when there is maximum acceleration.

This happens when the blocks are at the extremities where the displacement is either $+A$ or $-A$.



28. A flat horizontal board moves up and down under S.H.M. vertically with amplitude A. The shortest permissible time period of the vibration such that an object placed on the board may not lose contact with the board is

(1) $2\pi\sqrt{\frac{g}{A}}$ (2) $2\pi\sqrt{\frac{A}{g}}$ (3) $2\pi\sqrt{\frac{2A}{g}}$ (4) $\frac{\pi}{2}\sqrt{\frac{A}{g}}$

Sol. Answer (2)

Maximum acceleration of the system $(a_{max}) = -\omega^2 A$

For a block to escape the board the acceleration must be equal to 9 at the top-most point.

$$g = \omega^2 A$$

$$\omega = \sqrt{\frac{g}{A}}$$

Time period $= \frac{2\pi}{\omega} = \sqrt{\frac{A}{g}}$

29. A simple pendulum with iron bob has a time period T. The bob is now immersed in a non-viscous liquid and oscillated. If the density of liquid is $\frac{1}{12}$ th that of iron, then new time period will be

(1) $T\sqrt{\frac{8}{7}}$ (2) $T\sqrt{\frac{12}{13}}$ (3) $T\sqrt{\frac{12}{11}}$ (4) $T\sqrt{\frac{6}{5}}$

Sol. Answer (3)

When bob is inserted, in liquid effective of is reduced because of the force of upthrust.

ρ_S is density of solid.

ρ_L is density of liquid.

V is volume of solid

and $T = 2\pi\sqrt{\frac{l}{g}}$

$$T_{\text{new}} = 2\pi\sqrt{\frac{l}{g_{\text{new}}}}$$

$$T_{\text{new}} = 2\pi\sqrt{\frac{l}{g - \frac{\rho_L}{\rho_S}g}}$$

$$T_{\text{new}} = 2\pi\sqrt{\frac{l\times 12}{g\times 11}}$$

or $$T_{\text{new}} = \sqrt{\frac{12}{11}}T$$

30. When a mass *m* is attached to a spring it oscillates with period 4 s. When an additional mass of 2 kg is attached to a spring, time period increases by 1 s. The value of *m* is

(1) 3.5 kg (2) 8.2 kg (3) 4.7 kg (4) 2.6 kg

Sol. Answer (1)

$$\omega_1 = \sqrt{\frac{k}{m}}$$

$$\omega_2 = \sqrt{\frac{k}{m+2}}$$

$$\frac{\omega_1}{\omega_2} = \sqrt{\frac{m+2}{m}}$$

Since $\omega = \frac{2\pi}{T}$

$$\frac{T_2}{T_1} = \sqrt{\frac{m+2}{m}}$$

$$\left(\frac{5}{4}\right)^2 = \frac{m+2}{m}$$

$$\frac{25}{16} = \frac{m+2}{m}$$

$25\text{ m} = 16\text{ m} + 32$

$9\text{ m} = 32$

$$m = 3\frac{5}{9}\text{ kg}$$

$m \simeq 3.5$ kg

SECTION - C

Previous Years Questions

1. Out of the following functions representing motion of a particle which represents S.H.M.?

(A) $y = \sin\omega t - \cos\omega t$

(B) $y = \sin^3\omega t$

(C) $y = 5\cos\left(\frac{3\pi}{4} - 3\omega t\right)$

(D) $y = 1 + \omega t + \omega^2 t^2$

(1) Only (A) and (B)

(2) Only (A)

(3) Only (D) does not represent S.H.M.

(4) Only (A) and (C)

Sol. Answer (4)

Only (A) and (C) are of the form

$x = A\sin(\omega t + \phi)$

Hence they are the only ones which represents an S.H.M.

2. Two particles are oscillating along two close parallel straight lines side by side, with the same frequency and amplitudes. They pass each other, moving in opposite directions when their displacement is half of the amplitude. The mean positions of the two particles lie on a straight line perpendicular to the paths of the two particles. The phase difference is

(1) π

(2) $\frac{\pi}{6}$

(3) 0

(4) $\frac{2\pi}{3}$

Sol. Answer (4)

$v_1 = A\omega\cos\omega t$ ... (i)

$v_2 = A\omega\cos\omega t + \phi$ ... (ii)

According to equation $v_1 = -v_2$ when

$x = \frac{A}{2}$

$\frac{A}{2} = A\sin\omega t$

$\omega t = \frac{\pi}{6}$ when $x = \frac{A}{2}$

$\cos\omega t = -\cos(\omega t + \phi)$ equating (i) and (ii)

$$\cos^{-1} - \frac{\sqrt{3}}{2} = \frac{\pi}{6} + \phi$$

$$\frac{5\pi}{6} - \frac{\pi}{6} = \phi$$

$$\phi = \frac{2\pi}{3}$$

3. Two Simple Harmonic Motions of angular frequency 100 and 1000 rad s^{-1} have the same displacement amplitude. The ratio of their maximum accelerations is

(1) $1 : 10^4$ (2) $1 : 10$ (3) $1 : 10^2$ (4) $1 : 10^3$

Sol. Answer (3)

Maximum acceleration occurs at the extreme points of an S.H.M.. motion.

$a = -\omega^2 x$

At $x = A$ $a = -\omega^2 A$

$a_1 = (100)^2 A$

$a_2 = (1000)^2 A$

$$\frac{a_1}{a_2} = \frac{1}{100}$$

$a_1 : a_2 = 1 : 10^2$

4. A point performs simple harmonic oscillation of period T and the equation of motion is given by $x = a\sin\left(\omega t + \frac{\pi}{6}\right)$. After the elapse of what fraction of the time period the velocity of the point will be equal to half of its maximum velocity?

(1) $\frac{T}{12}$ (2) $\frac{T}{8}$ (3) $\frac{T}{6}$ (4) $\frac{T}{3}$

Sol. Answer (1)

Maximum velocity = $a\omega$

$v = a\omega \cos \omega t + \frac{\pi}{6}$

Let time where $v = \frac{a\omega}{2}$

Let $\frac{a\omega}{2} = a\omega \cos \omega t + \frac{\pi}{6}$

$$\frac{\pi}{3} = \omega t + \frac{\pi}{6}$$

or $\omega t = \frac{\pi}{6}$

$\frac{2\pi}{T} = \frac{\pi}{6}$ $\left[\omega = \frac{2\pi}{T}\right]$

$t = \frac{T}{12}$

5. Which of the following is simple harmonic motion?

   (1) Particle moving in a circle with uniform speed

   (2) Wave moving through a string fixed at both ends

   (3) Earth spinning about its axis

   (4) Ball bouncing between two rigid vertical walls

Sol. Answer (2)

A wave on a string is an example of simple harmonic motion as the displacement of particles in the motion may be described by

$x = A \sin \omega t$

6. A particle executes S.H.M.. along x-axis. The force acting on it is given by

   (1) $A \cos (kx)$ (2) Ae^{-kx} (3) kx (4) $-kx$

Sol. Answer (4)

Force acts along $-kx$ according to theory of S.H.M..

7. Which one of the following statements is true for the speed v and the acceleration a of a particle executing simple harmonic motion?

   (1) When v is maximum, a is maximum

   (2) Value of a is zero, whatever may be the value of v

   (3) When v is zero, a is zero

   (4) When v is maximum, a is zero

Sol. Answer (4)

Acceleration (a) is zero is the mean position where velocity is maximum.

8. A particle executing simple harmonic motion of amplitude 5 cm has maximum speed of 31.4 cm/s. The frequency of its oscillation is

   (1) 4 Hz (2) 3 Hz (3) 2 Hz (4) 1 Hz

Sol. Answer (4)

$A = 5$ cm

Maximum speed $(A\omega) = 31.4$

$$\omega = \frac{31.4}{5}$$

or $2\pi f = 31.4$

$$f = \frac{31.4}{10 \times 3.14}$$

$f = 1$ Hz

9. The phase difference between the instantaneous velocity and acceleration of a particle executing simple harmonic motion is

(1) π (2) 0.707π (3) Zero (4) $0.5\ \pi$

Sol. Answer (4)

$$v = A\omega\cos(\omega + \phi)$$

$$a = -A\omega^2 \sin(\omega t + \phi)$$

Now $a = +A\omega^2 \cos\left(\omega t + \phi + \frac{\pi}{2}\right)$

Hence $A\phi = \left(\omega t + \phi + \frac{\pi}{2}\right) - (\omega t + \phi)$

$$= \frac{\pi}{2}$$

10. A particle executes simple harmonic oscillation with an amplitude a. The period of oscillation is T. The minimum time taken by the particle to travel half of the amplitude from the equilibrium position is

(1) $\frac{T}{8}$ (2) $\frac{T}{12}$ (3) $\frac{T}{2}$ (4) $\frac{T}{4}$

Sol. Answer (2)

$$x = a\sin\omega t$$

$$\frac{a}{2} = a\sin\omega t$$

$$\therefore\quad \omega t = \frac{\pi}{6}$$

$$t = \frac{\pi}{6}\times\frac{1}{\omega} = \frac{\pi}{6}\times\frac{T}{2\pi}$$

$$t = \frac{T}{12}$$

11. A simple pendulum performs simple harmonic motion about $x = 0$ with an amplitude a and time period T. The speed of the pendulum at $x = \frac{a}{2}$ will be

(1) $\frac{\pi a\sqrt{3}}{T}$ (2) $\frac{\pi a\sqrt{3}}{2T}$ (3) $\frac{\pi a}{T}$ (4) $\frac{3\pi^2 a}{T}$

Sol. Answer (1)

$v = A\omega \cos \omega t$

$x = \dfrac{A}{2}$

$\omega \dfrac{A}{2} = A \sin \omega t$

$\dfrac{\pi}{6} = \omega t$

$v = A\omega \cos \dfrac{\pi}{6}$

$v = A\omega \dfrac{\sqrt{3}}{2}$

$v = \dfrac{2\pi}{T} \dfrac{\sqrt{3}}{2}$

$v = \dfrac{\pi\sqrt{3}}{T} A$

12. Which one of the following equations of motion represents simple harmonic motion? (where k, k_0, k_1 and a are all positive)

(1) Acceleration = kx
(2) Acceleration = $k_0x + k_1x^2$
(3) Acceleration = $-k(x + a)$
(4) Acceleration = $k(x + a)$

Sol. Answer (3)

According to equation of S.H.M..

$a = -\omega^2 x$.

The only option of the same form is the third one k_0.

Acceleration = $-k(x + a)$

Hence answer is (3)

13. The displacement of a particle along the x-axis is given by $x = a\sin^2\omega t$. The motion of the particle corresponds to

(1) Simple harmonic motion of frequency $\dfrac{\omega}{2\pi}$
(2) Simple harmonic motion of frequency $\dfrac{\omega}{\pi}$
(3) Simple harmonic motion of frequency $\dfrac{3\omega}{2\pi}$
(4) Non-simple harmonic motion

Sol. Answer (2)

$$x = a\sin^2 \omega t$$

$$x = \frac{a(1-\cos 2\omega t)}{2}$$

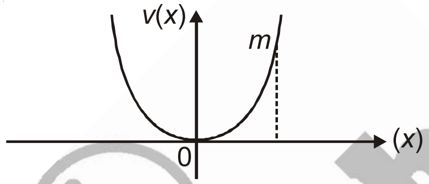
$$2x - a = -\cos 2\omega t$$

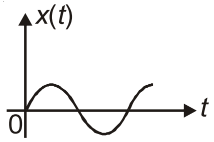
or $\cos 2\omega t = a - 2x$

The period of this function is $T = \frac{2\pi}{2\omega} = \frac{\pi}{\omega}$

Hence frequency $= \frac{1}{T} = \frac{\omega}{\pi}$

14. A particle of mass m is released from rest and follows a parabolic path as shown. Assuming that the displacement of the mass from the origin is small. Which graph correctly depicts the position of the particle as a function of time?



(1)


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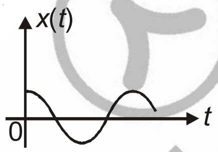

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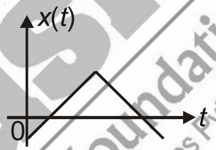

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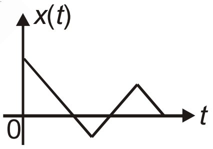


Sol. Answer (2)

Particle of mass m is released in a parabolic path. It will perform S.H.M.. just like a pendulum.'

The particle is released from amplitude.

Option (2) represents graph of an S.H.M.. starting from amplitude position.

15. In a simple harmonic motion, when the displacement is one-half the amplitude, what fraction of the total energy is kinetic?

(1) $\frac{1}{2}$ (2) $\frac{3}{4}$ (3) Zero (4) $\frac{1}{4}$

Sol. Answer (2)

K.E. of half of amplitude $= \left(x = \frac{A}{2}\right)$

K.E. of $\frac{1}{2}k(A^2 - x^2) = \frac{1}{2}k\left(A^2 - \frac{A^2}{4}\right)$

K.E. $= \frac{1}{2}k\left(\frac{3A^2}{4}\right)$

Fraction of the total energy is kinetic energy $= \frac{K.E.}{T.E.} = \frac{\frac{1}{2}k\left(\frac{3A^2}{4}\right)}{\frac{1}{2}kA^2} = \frac{3}{4}$

16. A linear harmonic oscillator of force constant 2 × 10^6 N/m and amplitude 0.01 m has a total mechanical energy of 160 J. Its

(1) Maximum P.E. is 160 J
(2) Maximum P.E. is zero
(3) Maximum P.E. is 100 J
(4) Maximum P.E. is 120 J

Sol. Answer (1)

At maximum potential energy all mechanical energy is stored as potential energy.

Hence maximum P.E. = Total mechanical energy

= 160 J

17. Displacement between maximum potential energy position and maximum kinetic energy position for a particle executing simple harmonic motion is

(1) $\pm\frac{a}{2}$
(2) $+a$
(3) $\pm a$
(4) -1

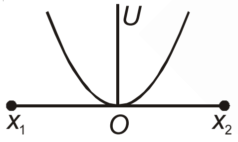
Sol. Answer (3)

Maximum P.E. is at extremities and maximum K.E. is at mean position.

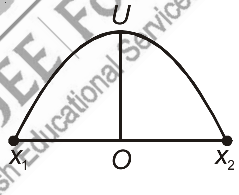
Hence the difference in between the two position is ± *a*.

18. A particle of mass *m* oscillates with simple harmonic motion between points x_1 and x_2, the equilibrium position being *O*. Its potential energy *U* is plotted. It will be as given below in the graph

(1)



(2)



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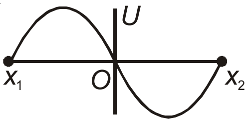
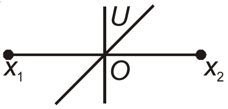


(4)



Sol. Answer (1)

In S.H.M.. potential energy is minimum at mean position and maximum at the extremities. Also graph will be parabolic as

$$U = \frac{1}{2}kx^2$$

Hence answer is (1).

19. The potential energy of a simple harmonic oscillator when the particle is half way to its end point is

(1) $\frac{2}{3}E$
(2) $\frac{1}{8}E$
(3) $\frac{1}{4}E$
(4) $\frac{1}{2}E$

Sol. Answer (3)

$$E = \frac{1}{2}kA^2 \quad \text{[where } E \text{ is total energy]}$$

When $x = \frac{A}{2}$

$$E_x = \frac{1}{2}kx^2 = \frac{1}{2}\frac{kA^2}{4} = \frac{kA^2}{8}$$

or $E_x = \frac{E}{4}$

20. The particle executing simple harmonic motion has a kinetic energy $K_0\cos^2\omega t$. The maximum values of the potential energy and the total energy are respectively

(1) $\frac{K_0}{2}$ and K_0 (2) K_0 and $2K_0$ (3) K_0 and K_0 (4) 0 and $2K_0$

Sol. Answer (3)

Let kinetic energy at 4 point be $K = K_0\cos^2\omega t$

At maximum value of K $\cos^2\omega t = 1$ and $K = K_0$

Maximum value of K.E. = Maximum value of P.E. = Total mechanical energy as mechanical energy is converted in S.H.M.

21. If the length of a simple pendulum is increased by 2%, then the time period

(1) Increases by 1% (2) Decreases by 1% (3) Increases by 2% (4) Decreases by 2%

Sol. Answer (1)

$$T = 2\pi\sqrt{\frac{l}{g}}$$

If length is increased by 2%

$$T_2 = 2\pi\sqrt{\frac{l}{g}\times\frac{10^2}{100}}$$

or $T_2 = 2\pi\sqrt{\frac{l}{g}(1+0.02)}$

or $T_2 = 2\pi\sqrt{\frac{l}{g}}\times 1.01$ [By binomial theorem]

or $T_2 = T + \frac{T}{100}$

$\therefore$ T_2 is 1% more than T.

22. Two simple pendulums of length 5 m and 20 m respectively are given small linear displacements in one direction at the same time. They will again be in the same phase when the pendulum of shorter length has completed ______ oscillations.

(1) 2 (2) 1 (3) 5 (4) 3

Sol. Answer (1)

$l_1 = 5$ m $\qquad l_2 = 20$ m

$T_1 = 2\pi\sqrt{\frac{5}{g}} \qquad T_2 = 2\pi\sqrt{\frac{20}{g}}$

$$\frac{T_1}{T_2} = \frac{1}{2}$$

$$2T_1 = T_2$$

Hence they will be in phase again when shorter one has completed 2 oscillation.

23. Two masses M_A and M_B are hung from two strings of length l_A and l_B respectively. They are executing S.H.M. with frequency relation $f_A = 2f_B$, then relation

(1) $l_A = \frac{l_B}{4}$, does not depend on mass

(2) $l_A = 4l_B$, does not depend on mass

(3) $l_A = 2l_B$ and $M_A = 2M_B$

(4) $l_A = \frac{l_B}{2}$ and $M_A = \frac{M_B}{2}$

Sol. Answer (1)

Mass M_A and M_B

Length l_A and l_B

If $f_A = 2f_B$

$T_B = 2T_A \qquad$ [as $f = \frac{2\pi}{T}$ given]

$$2\pi\sqrt{\frac{l_A}{g}} = 4\pi\sqrt{\frac{l_B}{g}}$$

$$\frac{l_A}{g} = 4l_B$$

or $l_B = \frac{l_A}{4}$ which does not depend on mass.

24. A mass m is vertically suspended from a spring of negligible mass, the system oscillates with a frequency n. What will be the frequency of the system, if a mass $4m$ is suspended from the same spring?

(1) $\frac{n}{2}$ (2) $4n$ (3) $\frac{n}{4}$ (4) $2n$

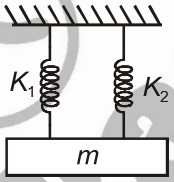
Sol. Answer (1)

$$\omega = 2\pi n = \sqrt{\frac{k}{m}}$$

$$= n \propto \frac{1}{\sqrt{m}}$$

When m becomes 4 m hence n is halved $\frac{n}{2}$

25. A mass is suspended separately by two different springs in successive order then time periods is t_1 and t_2 respectively. If it is connected by both the springs as shown in figure then time period is t_0, the correct relation is



(1) $t_0^2 = t_1^2 + t_2^2$ (2) $t_0^{-2} = t_1^{-2} + t_2^{-2}$ (3) $t_0^{-1} = t_1^{-1} + t_2^{-1}$ (4) $t_0 = t_1 + t_2$

Sol. Answer (2)

$$t_1 = 2\pi\sqrt{\frac{m}{k_1}} \qquad t_2 = 2\pi\sqrt{\frac{m}{k_2}}$$

The springs in parallel have $k_{eq} = k_1 + k_2$

$$t_0 = 2\pi\sqrt{\frac{m}{k_1+k_2}}$$

$$t_0 = 2\pi\sqrt{\frac{m}{4\pi^2\left(\frac{m}{t_1^2}+\frac{m}{t_2^2}\right)}}$$

$$t_0 = \sqrt{\frac{t_1^2 t_2^2}{t_1^2+t_2^2}}$$

$$\frac{1}{t_0^2} = \frac{t_1^2+t_2^2}{t_1^2+t_2^2} \qquad \frac{1}{t_0^2} = \frac{1}{t_2^2}+\frac{1}{t_1^2}$$

26. The time period of mass suspended from a spring is T. If the spring is cut into four equal parts and the same mass is suspended from one of the parts, then the new time period will be

(1) $\frac{T}{4}$ (2) T (3) $\frac{T}{2}$ (4) $2T$

Sol. Answer (3)

$$T = 2\pi\sqrt{\frac{m}{k}}$$

The k of spring becomes 4 k when cut.

$$T' = 2\pi\sqrt{\frac{m}{4k}} \quad \text{or } T' = \frac{T}{2}$$

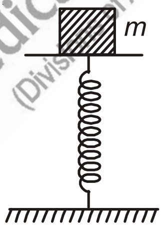
27. The period of oscillation of a mass M suspended from a spring of negligible mass is T. If along with it another mass M is also suspended, the period of oscillation will now be

(1) $\sqrt{2}T$ (2) T (3) $\frac{T}{\sqrt{2}}$ (4) $2T$

Sol. Answer (1)

$$T \propto \sqrt{m} \quad \frac{T'}{T} = \sqrt{\frac{2M}{M}} \Rightarrow T' = \sqrt{2}T$$

28. A mass of 2.0 kg is put on a flat pan attached to a vertical spring fixed on the ground as shown in the figure. The mass of the spring and the pan is negligible. When pressed slightly and released the mass executes a simple harmonic motion. The spring constant is 200 N/m. What should be the minimum amplitude of the motion so that the mass gets detached from the pan (take g = 10 m/s^2)?



(1) 10.0 cm (2) Any value less than 12.0 cm

(3) 4.0 cm (4) 8.0 cm

Sol. Answer (1)

When it disconnects from plates acceleration is maximum for minimum amplitude. Acceleration is maximum at the extremities.

When block leaves from $a = g$

$$g = -\omega^2 x$$

$$g = -\omega^2 a$$

$g = -\frac{k}{m}a$

$-g\frac{m}{k} = a$

$| a | = \frac{10\times 2}{200}$

$a = 10$ cm

29. A particle, with restoring force proportional to displacement and resisting force proportional to velocity is subjected to a force F sinωt. If the amplitude of the particle is maximum for $\omega = \omega_1$, and the energy of the particle maximum for $\omega = \omega_2$, then

(1) $\omega_1 \neq \omega_0$ and $\omega_2 = \omega_0$

(2) $\omega_1 = \omega_0$ and $\omega_2 = \omega_0$

(3) $\omega_1 = \omega_0$ and $\omega_2 \neq \omega_0$

(4) $\omega_1 \neq \omega_0$ and $\omega_2 \neq \omega_0$

Sol. Answer (2)

$F = F_0 \sin \omega t$ is the equation of forces vibration.

In the case of resonance ω is the resonating frequency.

At the same ω amplitude and energy is maximum.

Hence $\omega_1 = \omega_2 = \omega$

30. When an oscillator completes 100 oscillations its amplitude reduced to $\frac{1}{3}$ of initial value. What will be its amplitude, when it completes 200 oscillations?

(1) $\frac{1}{8}$ (2) $\frac{2}{3}$ (3) $\frac{1}{6}$ (4) $\frac{1}{9}$

Sol. Answer (4)

$A = A_0 e^{-bt}$

When $t = 200$ T $\qquad A = \frac{A_0}{3}$

$\frac{A_0}{3} = A_0 e^{-b\times 100\text{ T}}$

$e^{-100b\text{T}} = \frac{1}{3}$

$A' = A_0(e^{-b\times 200\text{ T}})$

$A' = A_0(e^{-b\times 100\text{ T}})^2$

$A' = A_0\left(\frac{1}{3}\right)^2$

$A' = \frac{A_0}{9}$

31. In case of a forced vibrations, the resonance wave becomes very sharp when the

(1) Damping force is small (2) Restoring force is small

(3) Applied periodic force is small (4) Quality factor is small

Sol. Answer (1)

When restoring force is very small there is very little dissipation of energy and the driving force can deliver maximum amplitude.

32. Two S.H.M.'s with same amplitude and time period, when acting together in perpendicular directions with a phase difference of $\frac{\pi}{2}$, give rise to

(1) Straight motion (2) Elliptical motion (3) Circular motion (4) None of these

Sol. Answer (3)

Let x be $x = a \sin \omega t$

and y be $y = a \sin (\omega t + \delta)$ or $y = a \cos \omega t$

If they are perpendicular $x^2 + y^2 = a^2$ which is the equation of circle.

33. The equations of two S.H.M.'s is given as $x = a \cos (\omega t + \delta)$ and $y = a \cos (\omega t + \alpha)$, where $\delta = \alpha + \frac{\pi}{2}$, the resultant of the two S.H.M.'s represents

(1) A hyperbola (2) A circle (3) An ellipse (4) None of these

Sol. Answer (2)

$x = a \cos (\omega t + \delta)$

$y = a \cos (\omega t + \delta)$ ... (i)

$\delta = \alpha + \frac{\pi}{2}$

$a - a \sin (\omega t + \alpha)$ ... (ii)

Squaring both (i) and (ii) it is of the form.

$x^2 + y^2 = a^2$

Hence it represents a circle.

34. The damping force on an oscillator is directly proportional to the velocity. The units of the constant of proportionality are

(1) kg ms^{-1} (2) kg ms^{-2} (3) kg s^{-1} (4) kg s

Sol. Answer (3)

$F = kv$

$k = \frac{F}{v}$

$[k] = [F]\ [v]^{-1}$

$[k] = [\text{kg ms}^{-2}\ \text{m}^{-1}\text{s}]$

$[k] = \text{kg s}^{-1}$

35. A wave has S.H.M. whose period is 4 s while another wave which also possess S.H.M. has its period 3 s. If both are combined, then the resultant wave will have the period equal to

(1) 4 s (2) 5 s (3) 12 s (4) 3 s

Sol. Answer (3)

$T_1 = 4$ s

$T_2 = 3$ s

The resultant wave will have a time period equal to LCM of the two waves.

LCM of 4 and 3 is 12

Hence $T = 12$ s

SECTION - D

Assertion - Reason Type Questions

1. A : Simple harmonic motion is not a uniform motion.

R : Simple harmonic motion can be regarded as the projection of uniform circular motion.

Sol. Answer (2)

Simple harmonic motion is not a uniform motion as acceleration velocity and displacement are all variable with time simple harmonic motion can be regarded as a **project ion** of uniform circular motion but this is not the correct explanation of assertion.

2. A : In simple harmonic motion, the velocity is maximum when the displacement is minimum.

R : Displacement and velocity of S.H.M. differ in phase by $\pi/2$.

Sol. Answer (1)

The assertion is true and the reason is the correct explanation of the given assertion.

3. A : In reality the amplitude of a freely oscillating pendulum decreases gradually with time.

R : The frequency of the pendulum decreases with time.

Sol. Answer (3)

Assertion is true as damping and dissipative forces are present reducing the energy and hence amplitude of the pendulum.

The frequency positive remains constant.

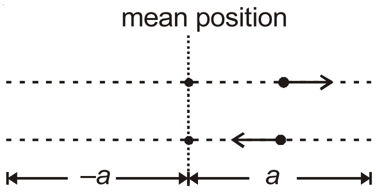
4. A : The graph of velocity as a function of displacement for a particle executing S.H.M. is an ellipse.

R : The velocity and displacement are related as $v = \omega\sqrt{A^2 - x^2}$

Sol. Answer (1)

The assertion is true and the explanation gives the equation of velocity v_s displacement (x) which is in the form of an ellipse.

5. A : The phase difference between the two particles shown below is π. (Assuming both particles have same time periods and same amplitudes).



R : If the particles cross each other while they move in the opposite direction, they have a phase difference of π radian.

Sol. Answer (4)

The phase difference between two particles is π only when they pass the **mean point** with opposite velocities at the same point.

Both the assertion and reason are hence false.

6. A : All trigonometric functions are periodic.

R : All trigonometric functions can represent S.H.M.

Sol. Answer (3)

All trigonometric function may be periodic but not all can represent S.H.M. Examples of exception include tan, cot, cosec etc. Hence answer is (3)

7. A : In a S.H.M. both kinetic energy and potential energy oscillates with double the frequency of S.H.M.

R : Frequency of oscillation of total energy in S.H.M. is infinite

Sol. Answer (3)

$$\text{K.E.} = \frac{1}{2}mA^2\omega^2\cos^2(\omega t + \phi) \qquad \text{P.E.} = \frac{1}{2}mA^2\omega^2\sin^2(\omega t + \phi)$$

$\cos^2\phi$ and $\sin^2\phi$ may both be written in the form of doubles angles. Hence they represent S.H.M. with angular frequency = 2ω.

Total energy of an S.H.M. is always constant. Constant values are said to have infinite time period and zero frequency.

8. A : If a clock based on simple pendulum is taken to hill it will become slower.

R : With increase of height above surface of earth g decreases so T will increase.

Sol. Answer (1)

$$T = 2\pi\sqrt{\frac{l}{g}}$$

The assertion is the correct explanation of the reason.

9. A : If a spring block system, oscillating in a vertical plane is made to oscillate on a horizontal surface, the time period will remain same.

R : The time period of spring block system does not depend on g.

Sol. Answer (2)

$$T = 2\pi\sqrt{\frac{m}{k}}$$

Gives the time period of spring block system any time period remains the same in both cases.

Time period of spring block system doesn't depend on g but that explanation alone is not enough to explain the non-variation time period of S.H.M.

10. A : In a forced oscillator the energy transferred from driving force to damped oscillator is maximum in resonance state.

R : The amplitude of forced oscillator depends on the frequency of external force.

Sol. Answer (2)

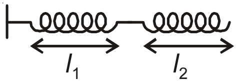
The assertion and reason are both true. But the reason does not exsplain why maximum energy transfer occurs in that state. It merely says that the amplitude depends on frequency of external force.

11. A : If length of a spring is halved, then its force constant becomes double.

R : The spring constant is inversely proportional to length of spring.

Sol. Answer (1)

Suppose a spring of natural length l into made of two parts l_1 and l_2.



The entire spring is displaced by a distance Δx.

$$\Delta x = \Delta x_1 + \Delta x_2$$

Now $\Delta x_1 : \Delta x_2 = l_1 : l_2$

$$\frac{F}{k_1} : \frac{F}{k_2} : = l_1 : l_2$$

$$\frac{k_2}{k_1} = \frac{l_1}{l_2}$$

$$k \propto \frac{1}{l}$$

So if length is halved k_{eq} is doubled.

12. A : When soldier cross a bridge, they are asked to break steps.

R : If they do not break steps, then they will apply large force on bridge simultaneously.

Sol. Answer (3)

When soldiers cross a bridge, they are asked to break steps. So the assertion is true.

They are told to do this to avoid forced vibration to be created on the bridge. If it is the same as natural frequency of the bridge, it may cause resonance. The bridge may oscillate with a higher amplitude and the bridge may fall.

13. A : In S.H.M. the change in velocity is not uniform.

R : In S.H.M. the acceleration of body varies linearly with its displacement.

Sol. Answer (1)

Both the assertion and reason are correct and reason the correct explanation of assertion.

$a = -\omega^2 x$

❑ ❑ ❑

Chapter 15

Waves

Solutions

SECTION - A

Objective Type Questions

1. Which of the following phenomenon cannot take place with sound waves?

(1) Polarisation (2) Refraction (3) Diffraction (4) Reflection

Sol. Answer (1)

Polarisation is a phenomenon which cannot take place with mechanical waves.

2. The speed of sound in air is independent from its

(1) Amplitude (2) Frequency (3) Phase (4) All of these

Sol. Answer (4)

Speed of sound in air $(v) = \sqrt{\frac{\gamma P}{\rho}}$

All the other options are function of the wave but speed of sound depends on the medium. Hence, answer will be (4).

3. The waves which cannot travel without medium are

(1) X-rays (2) Radio waves (3) Light waves (4) Sound waves

Sol. Answer (4)

Sound waves being mechanical waves need a mechanical medium for their propagation.

4. When a wave propagating through a medium encounters a change in medium, then which of the following property remains same?

(1) Speed (2) Amplitude (3) Frequency (4) Wavelength

Sol. Answer (3)

The energy carried by a wave is a function of its frequency. If there is no loss of energy in the charge of medium the frequency still remains the same.

5. A transverse wave travels along *x*-axis. The particles of medium move

(1) Along *x*-axis (2) Along *y*-axis

(3) Along *z*-axis (4) Either along *y*-axis or *z*-axis

Sol. Answer (4)

In a transverse wave the energy may transfer along *x*-direction but particles are displaced perpendicular to the transfer of energy.

6. The phenomenon of sound propagation in air is

(1) An isothermal process (2) An adiabatic process

(3) An isobaric process (4) An isochoric process

Sol. Answer (2)

The phenomenon of sound propagation was found to be almost an adiabatic process by Laplace's theory.

7. If at STP, velocity of sound in a gas (γ = 1.5) is 600 m/s, the r.m.s. velocity of the gas molecules at STP will be

(1) 400 m/s (2) 600 m/s (3) $600\sqrt{2}$ m/s (4) $300\sqrt{2}$ m/s

Sol. Answer (3)

Velocity of sound = $\sqrt{\dfrac{\gamma RT}{M}}$

RMS speed = $\sqrt{\dfrac{3RT}{M}}$

$$\frac{v_s}{r_{\text{rms}}} = \sqrt{\frac{\gamma}{3}}$$

$$\frac{v_s}{r_{\text{rms}}} = \sqrt{\frac{1}{2}}$$

$$v_{\text{rms}} = 600\sqrt{2} \text{ m/s}$$

8. In a stretched string,

(1) Only transverse waves can exist (2) Only longitudinal waves can exist

(3) Both transverse and longitudinal waves can exist (4) None of these

Sol. Answer (3)

In a solid both transverse and longitudinal waves may pass.

9. Two strings of same material are stretched to the same tension. If their radii are in the ratio 1 : 2, then respective wave velocities in them will be in ratio

(1) 4 : 1 (2) 2 : 1 (3) 1 : 2 (4) 1 : 4

Sol. Answer (2)

Let density of material be ρ

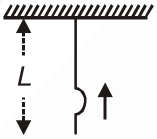
Areas of cross section $A_1 = \pi r_1^2$, $A_2 = \pi r_2^2$ where $r_2 = 2r_1$

$\therefore \quad \mu_1 = \pi r_1^2 \rho$, $\mu_2 = \pi 4 r_1^2 \rho$

$\therefore \quad v_1 = \sqrt{\dfrac{T}{\pi r_1^2 \rho}}$ and $v_2 = \dfrac{1}{2}\sqrt{\dfrac{T}{\pi r_1^2 \rho}}$

$\therefore \quad v_1 : v_2 = 2 : 1$

10. A pulse is generated at lower end of a hanging rope of uniform density and length L. The speed of the pulse when it reaches the mid point of rope is



(1) $\sqrt{2gL}$ (2) $\sqrt{gL}$ (3) $\sqrt{\dfrac{gL}{2}}$ (4) $\dfrac{\sqrt{gL}}{2}$

Sol. Answer (3)

$$v = \sqrt{\frac{T}{\mu}}$$

Weight of the string below the rope stretching it = $\dfrac{\mu L}{2}g$

This is equal to T at the middle.

$$\therefore \quad \text{Velocity at middle} = \sqrt{\frac{\mu L g}{2\mu}}$$

$$= \sqrt{\frac{gL}{2}}$$

11. Which of the following equations represents a transverse wave travelling along –y axis?

(1) $x = A \sin(\omega t - ky)$ (2) $x = A \sin(\omega t + ky)$ (3) $y_0 = A \sin(\omega t - kx)$ (4) $y_0 = A \sin(\omega t + kx)$

Sol. Answer (2)

Velocity of wave = $-\dfrac{\omega}{k}$

Also since the wave is travelling in the y direction, displacement of the particles will be in x-direction.

So, equation will be of the form $x = A \sin(\omega t + ky)$

Putting positive values of ω and k in the velocity equation will give negative value of velocity. Hence, wave is travelling in –ve direction.

12. A wave is represented by $x = 4\cos\left(8t - \frac{y}{2}\right)$, where x and y are in metre and t in second. The frequency of the wave (in s^{-1}) is

(1) $\frac{4}{\pi}$ (2) $\frac{8}{\pi}$ (3) $\frac{2}{\pi}$ (4) $\frac{\pi}{4}$

Sol. Answer (1)

$$x = 4\cos\theta\left(8t - \frac{y}{2}\right)$$

Comparing with $x = A \sin (kx - \omega t)$

$\omega = 8$

and $\omega = 2\pi f$

$$f = \frac{8}{2\pi}$$

$$f = \frac{4}{\pi}$$

13. A wave is represented by the equation $y = A\sin\left(10\pi x + 15\pi t + \frac{\pi}{6}\right)$ where x is in metre and t in second. The expression represents

(1) A wave travelling in negative x-direction with a velocity of 1.5 m/s

(2) A wave travelling in positive x direction with a velocity of 1.5 m/s

(3) A wave traveling in positive x-direction with wavelength 0.2 m

(4) A wave travelling in negative x-direction with a velocity of 150 m/s

Sol. Answer (1)

$$y = A\sin\left(10\pi x + 15\pi t + \frac{\pi}{6}\right)$$

$$v = -\frac{\omega}{k}$$

$$v = -\frac{15\pi}{10\pi}$$

$\therefore$ $v = -1.5$ m/s

Hence, velocity is 1.5 m/s in negative x-direction.

14. A travelling wave in a string is represented by $y = 3\sin\left(\frac{\pi}{2}t - \frac{\pi}{4}x\right)$. The phase difference between two particles separated by a distance 4 cm is (Take x and y in cm and t in seconds)

(1) $\frac{\pi}{2}$ rad (2) $\frac{\pi}{4}$ rad (3) π rad (4) 0

Sol. Answer (3)

$$y = 3\sin\left(\frac{\pi}{2}t - \frac{\pi}{4}x\right)$$

Take x = 0 and x = 4 cm

$$y_1 = 3\sin\frac{\pi}{2}t \text{ and } y_2 = 3\sin\frac{\pi}{2}t - \pi$$

Phase difference in between the two particles is π.

15. A transverse wave is described by the equation $y = A\sin 2\pi(nt - x/\lambda_0)$. The maximum particle velocity is equal to 3 times the wave velocity if

(1) $\lambda_0 = \frac{\pi A}{3}$ (2) $\lambda_0 = \frac{2\pi A}{3}$ (3) $\lambda_0 = \pi A$ (4) $\lambda_0 = 3\pi A$

Sol. Answer (2)

$$y = A\sin 2\pi(nt - x/\lambda_0)$$

Particle velocity is $\frac{dy}{dt}$ and maximum particle velocity is $A\omega$.

$$\omega = 2\pi n$$

$$\therefore \quad A\omega = 2\pi nA$$

Wave velocity (v) = $\frac{\omega}{k}$ = $\frac{2\pi n}{2\pi/\lambda_0}$

$$2\pi nA = 3\lambda_0 n$$

$$\lambda_0 = \frac{2\pi A}{3}$$

16. If $\vec{u}$ is instantaneous velocity of particle and $\vec{v}$ is velocity of wave, then

(1) $\vec{u}$ is perpendicular to $\vec{v}$ (2) $\vec{u}$ is parallel to $\vec{v}$

(3) $|\vec{u}|$ is equal to $|\vec{v}|$ (4) $|\vec{u}| = (\text{slope of wave form})|\vec{v}|$

Sol. Answer (4)

$\vec{u}$ may be perpendicular or parallel to $\vec{v}$ depending on whether it is a transverse or longitudinal wave.

$$y = A\sin kx - \omega t$$

$$\frac{dy}{dt} = A\omega\cos kx - \omega t$$

$$\frac{dy}{dt} = v$$

$$u = -A\omega\cos kx - \omega t$$

$$|v| = \frac{\omega}{k}$$

Slope of $y = A\sin kx - \omega t$

$$\frac{dy}{dx} = Ak\cos kx - \omega t$$

$$\left|\frac{dy}{dx}\right| = |v|\left|\frac{dy}{dx}\right|$$

$u = |v|$ (Slope of waveform)

17. In a simple harmonic wave, minimum distance between particles in same phase always having same speed, is

(1) $\lambda/4$ (2) $\lambda/3$ (3) $\lambda/2$ (4) λ

Sol. Answer (1)

$$y = A\sin(\omega t - kx)$$

$$\frac{dy}{dt} = A\omega\cos(\omega t - kx)$$

Take $x = 0$ and $x = x_1$

$$v_1 = A\omega\cos(\omega t)$$

$$v_2 = A\omega\cos(\omega t + kx)$$

$$|v_1| = |v_2|$$

$$|\cos(\omega t)| = |\cos(\omega t + kx)|$$

$\therefore \quad kx = \dfrac{\pi}{2}$

or $\quad x = \dfrac{\lambda}{4}$

18. The sound intensity level at a point 4 m from the point source is 10 dB, then the sound level at a distance 2 m from the same source will be

(1) 26 dB (2) 16 dB (3) 23 dB (4) 32 dB

Sol. Answer (2)

$$I \propto \frac{1}{r^2}$$

$\therefore$ If at two m intensity is I_1 at 4 m, intensity is $\dfrac{I_1}{4}$

19. The tones that are separated by three octaves have a frequency ratio of

(1) 3 (2) 6 (3) 8 (4) 16

Sol. Answer (3)

Each octaves is double the frequency of the previous octave.

If initial frequency is f.

Final frequency = 2 × 2 × 2 f or $2^3 f$ or 8 f

$\therefore$ Frequency ratio = 8 : 1.

20. On the superposition of the two waves given as $y_1 = A_0 \sin(\omega t - kx)$ and $y_2 = A_0 \cos\left(\omega t - kx + \frac{\pi}{6}\right)$, the resultant amplitude of oscillations will be

(1) $\sqrt{3}A_0$ (2) $\frac{A_0}{2}$ (3) A_0 (4) $\frac{3}{2}A_0$

Sol. Answer (3)

Resultant amplitude is given by $A_r^2 = A_1^2 + A_2^2 + 2A_1A_2 \cos\phi$

$$y_1 = A_0 \sin(\omega t - kx)$$

$$y_2 = A_0 \cos\left(\omega t - kx + \frac{\pi}{6}\right)$$

or $$y_2 = A_0 \sin\left(\omega t - kx + \frac{\pi}{6} + \frac{\pi}{2}\right)$$

$$A_r^2 = A_0^2 + A_0^2 + 2A_0^2 \cos\frac{2\pi}{3}$$

$$A_r^2 = 2A_0^2 + 2A_0^2 \times \frac{-1}{2}$$

$\therefore$ $A_r = A_0$

21. Two waves of amplitudes A_0 and xA_0 pass through a region. If $x > 1$, the difference in the maximum and minimum resultant amplitude possible is

(1) $(x + 1)A_0$ (2) $(x - 1)A_0$ (3) $2xA_0$ (4) $2A_0$

Sol. Answer (4)

Amplitudes are A_0 and xA_0.

$\therefore$ Maximum amplitude where they are in phase are $A_0 + xA_0$.

Minimum amplitude $xA_0 - A_0$

Difference between the two = $2A_0$.

22. Which of the following represents a standing wave?

(1) $y = A \sin(\omega t - kx)$ (2) $y = Ae^{-bx} \sin(\omega t - kx + \alpha)$

(3) $y = A \sin kx \sin(\omega t - \theta)$ (4) $y = (ax + b) \sin(\omega t - kx)$

Sol. Answer (3)

In a standing wave, the amplitude is an oscillating function of x in :

$$y = A \sin kx \sin(\omega t + \theta)$$

$A \sin kx$ represents the amplitude and is of the correct form to be a standing wave.

$$y = 3 \sin \frac{\pi x}{3} \cos 40\pi t$$

23. The equation of standing wave in a stretched string is given by $y = 5\sin\left(\frac{\pi x}{3}\right)\cos(40\pi t)$, where x and y are in cm and t in second. The separation between two consecutive nodes is (in cm)

(1) 1.5 (2) 3 (3) 6 (4) 4

Sol. Answer (2)

$$y = 5\sin\frac{\pi x}{3}\cos 40\pi t$$

At the nodes the values of x is such that y = 0.

Taking position 1 at x = 0 to make sine function zero; the value of sine function will be zero node for $\frac{\pi x}{3} = \pi$.

$\therefore \quad x = 3$

Hence, shortest distance between two nodes is 3 cm.

24. In a stationary wave

(1) Strain is maximum at nodes (2) Strain is minimum at nodes

(3) Strain is maximum at antinodes (4) Amplitude is zero at all points

Sol. Answer (1)

Where the slope of wave is higher the strain will be higher.

25. Select the correct statement about the reflection and refraction of a wave at the interface between the medium 1 and 2 the

(1) Reflected wave has a phase change of π

(2) Wavelength of reflected wave is less than that of incident wave

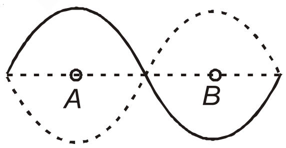
(3) Frequency of transmitted wave is same as that of incident wave

(4) Frequency of wave changes as per nature of boundary

Sol. Answer (3)

It is not said which of waves 1 and 2 is denser. But frequency of a wave remains same in all media. Hence option (3) is correct.

26. In the standing wave shown, particles at the positions A and B have a phase difference of



(1) 0 (2) $\frac{\pi}{2}$ (3) $\frac{5\pi}{6}$ (4) π

Sol. Answer (4)

Let, $y_A = A \sin \omega t$

$y_A = A \sin \omega t + \phi$

To convert $\sin\theta$ to $-\sin\theta$, ϕ must be π.

Hence phase difference between is π.

27. A 12 m long vibrating string has the speed of wave 48 m/s. To what frequency it will resonate?

(1) 2 cps (2) 4 cps (3) 6 cps (4) All of these

Sol. Answer (4)

$v = 48$ m/s, $l = 12$ m, $f = \dfrac{nv}{2l}$

$f = 2n$ (where $n = 1, 2, 3$ .....)

Hence answer is (4).

28. A certain string will resonant to several frequencies, the lowest of which is 200 cps. What are the next three higher frequencies to which it resonants?

(1) 400, 600, 800 (2) 300, 400, 500 (3) 100, 150, 200 (4) 200, 250, 300

Sol. Answer (1)

Resonant frequency occurs according to $\dfrac{nv}{2l}$ and when $n = 1$ frequency is minimum.

Hence $\dfrac{v}{2l} = 200$ [$n = 1$]

Other resonant frequencies will be simply multiples of fundamental frequency.

Hence (1) is the answer.

29. The tension in a wire is decreased by 19%. The percentage decrease in frequency will be

(1) 0.19% (2) 10% (3) 19% (4) 0.9%

Sol. Answer (2)

Velocity in a wave = $\sqrt{\dfrac{T}{\mu}}$

Fundamental frequency of waves $\dfrac{v}{2l}$

$$f = \sqrt{\frac{T}{\mu}} \times \frac{1}{2l} \qquad \text{... (i)}$$

If T decreases by 19% value of T will be $T - 0.19$ T

Putting this value in (i)

$$f' = \sqrt{\frac{T}{\mu}}\frac{(1-0.19)^{1/2}}{2l}$$

$$f' = f\left(1 - \frac{1}{2} \times 0.19\right) \qquad \text{[Binomial theorem]}$$

$f' = f - 0.1$ f

Hence, the frequency decreases by 0.1 f are 10% of initial value.

30. The length of a sonometer wire is 0.75 m and density 9×10^3 Kg/m^3. It can bear a stress of 8.1×10^8 N/m^2 without exceeding the elastic limit. The fundamental frequency that can be produced in the wire, is

(1) 200 Hz (2) 150 Hz (3) 600 Hz (4) 450 Hz

Sol. Answer (1)

$l = 0.75$ m $\rho = 9 \times 10^3$ Kg/m^3

Limiting stress = 8.1×10^8 N/m^2

Let area be equal to A.

Tension (T) = Stress × Area

$= 8.1 \times 10^8 \times A$

Mass / length(μ) = ρA

$$\text{Velocity } (v) = \sqrt{\frac{T}{\mu}} = \frac{8.1\times10^8 \times A}{9\times10^3 \times A}$$

$$= \sqrt{\frac{8.1\times10^5}{9}}$$

$$= \sqrt{9\times10^4} = 3 \times 10^2 \text{ m/s}$$

$$\text{Maximum fundamental frequency} = \frac{v}{2l}$$

$$= \frac{300}{2\times0.75} = 200 \text{ Hz}$$

31. An aluminium rod having a length 100 cm is clamped at its middle point and set into longitudinal vibrations. Let the rod vibrate in its fundamental mode. The density of aluminium is 2600 kg/m^3 and its Young's modulus is 7.8×10^{10} N/m^2. The frequency of the sound produced is

(1) 1250 Hz (2) 2740 Hz (3) 2350 Hz (4) 1685 Hz

Sol. Answer (2)

$$v = \sqrt{\frac{y}{\rho}} = \sqrt{\frac{7.8\times10^{10}}{2600}} = 5480 \text{ ml}$$

Since rod is clamped at the middle, the middle point is a pressure antinode and free ends are nodes. In the fundamental mode there are no other nodes and antinodes. The length of the rod is therefore half the wavelength.

So, $\lambda = 2l = 2m$

$$\text{Frequency} = \frac{v}{\lambda} = \frac{5480}{2} = 2740 \text{ Hz}$$

32. The string of a violin has a frequency of 440 cps. If the violin string is shortened by one fifth, its frequency will be changed to

(1) 440 cps (2) 880 cps (3) 550 cps (4) 2200 cps

Sol. Answer (4)

Fundamental frequency = 440 cps = $\frac{v}{2l}$

If l is made one fifth $\frac{v}{2\times l/5}$ or $\frac{5v}{2l}$

Since $\frac{v}{2l}$ = 440

$$5\frac{v}{2l} = 5\times 440 = 2200$$

33. A wire of length one metre under a certain initial tension emits a sound of fundamental frequency 256 Hz. When the tension is increased by 1 kg wt, the frequency of the fundamental node increases to 320 Hz. The initial tension is

(1) 3/4 kg wt (2) 4/3 kg wt (3) 16/9 kg wt (4) 20/9 kg wt

Sol. Answer (3)

Let tension be T

$$f_1 = \sqrt{\frac{T}{\mu}}\times\frac{1}{2l} = 256 \qquad \text{... (i)}$$

$$f_2 = \sqrt{\frac{T+10}{\mu}}\times\frac{1}{2l} = 320 \qquad \text{... (ii)}$$

$$\sqrt{\frac{T}{T+10}} = \frac{256}{320} \qquad \text{[Dividing (i) by (ii)]}$$

or $\frac{T}{T+10} = \frac{(16)^2}{(16)^2\times(20)^2}$

or $\frac{T}{T+10} = \frac{16^2}{(20)^2}$

or 400 T = 256 T^2 + 2560

or 144 T = 2560

or $T = \frac{2560}{144}$

or $T = \frac{2560}{16\times 9}$

or $T = \frac{160}{9}$ Newton

$= \frac{16}{9}$ kg-wt

34. In case of closed pipe which harmonic the p^{th} overtone will be

(1) $2p + 1$ (2) $2p - 1$ (3) $p + 1$ (4) $p - 1$

Sol. Answer (1)

In case of closed pipe the p^{th} overtone will be $2p + 1$ harmonic.

35. The pitch of an organ pipe is highest when the pipe is filled with

(1) Air (2) Hydrogen (3) Oxygen (4) Carbon dioxide

Sol. Answer (2)

$v = f\lambda$

$= \lambda$ is constant for an organ pipe

$$v = \sqrt{\frac{\gamma RT}{M}}$$

$$v = \frac{1}{\sqrt{M}}$$

v is maximum when M is least. Thus, velocity of sound in air is maximum when M is least.

Since $f \propto v$ so $f \propto \dfrac{1}{\sqrt{M}}$

Hence, frequency is maximum when M is least.

Hence, among options answer is H_2.

36. A cylindrical tube, open at both ends, has a fundamental frequency f in air. The tube is dipped vertically in water so that half of it is in water. The fundamental frequency of the air column is now

(1) $\dfrac{f}{2}$ (2) $\dfrac{3f}{4}$ (3) f (4) $2f$

Sol. Answer (3)

Fundamental frequency of open organ pipe is $f = \dfrac{v}{2l}$

If closed organ pipe $\dfrac{v}{4l}$

Initial length $l_1 = l$

$$\therefore \quad f_1 = \frac{v}{2l}$$

Final length of air column $l_2 = \dfrac{l}{2}$

$$f_2 = \frac{v}{4l/2}$$

$$= \frac{v}{2l}$$

37. For a certain organ pipe, three successive resonance frequencies are observed at 425, 595, and 765, Hz respectively, Taking the speed of sound in air to be 340 m/s the fundamental frequency of the pipe (in Hz) is

(1) 425 (2) 170 (3) 85 (4) 245

Sol. Answer (3)

Frequencies are 425, 595, 765.

Among the options the HCF is here 85.

Since resonant frequencies are odd multiples of fundamental frequency.

The fundamental frequency is 85 Hz.

38. A closed pipe of length 10 cm has its fundamental frequency half that of the second overtone of an open pipe. The length of the open pipe

(1) 10 cm (2) 20 cm (3) 30 cm (4) 40 cm

Sol. Answer (3)

$l = 0.1\text{ m}$

Fundamental frequency of pipe $(f_1) = \frac{v}{4l}$ or $f_1 = \frac{v}{0.4}$

Frequency of 2nd overtone of open pipe 2 :

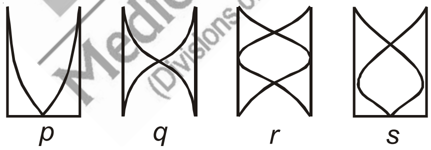
$$f_2 = \frac{3v}{2l}$$

$$2f_1 = f_2$$

$$2 \times \frac{v}{0.4} = \frac{3v}{2l}$$

$$l = 0.3\text{ m}$$

39. The vibrations of four air columns under identical conditions are represented in the figure below. The ratio of frequencies $n_p : n_q : n_r : n_s$ will be



(1) 12 : 6 : 3 : 4 (2) 1 : 2 : 4 : 3 (3) 4 : 2 : 3 : 1 (4) 6 : 2 : 3 : 4

Sol. Answer (2)

P, S, will be 1st and 2nd harmonics of closed tube.

$$P = \frac{v}{4l},\ S = \frac{v}{4l}$$

Q, R are the 1st and 2nd harmonics of open pipe.

$$Q = \frac{v}{2l},\ R = \frac{v}{l}$$

$\therefore\ P : Q : R : S = 1 : 2 : 4 : 3$

40. In resonance tube two successive positions of resonance are obtained at 15 cm and 48 cm. If the frequency of the fork is 500 cps, the velocity of sound is

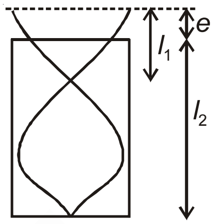
(1) 330 m/s (2) 300 m/s (3) 1000 m/s (4) 360 m/s

Sol. Answer (1)

$$l_1 + e = \frac{\lambda}{4}$$

$$l_2 + e = \frac{3\lambda}{4}$$

$$l_2 - l_1 = \frac{\lambda}{2}$$



$$0.48 - 0.15 = \frac{\lambda}{2}$$

$$0\ \lambda = 0.66$$

Velocity = $f\lambda = 500 \times 0.66 = 330$ m/s

41. During superposition of two waves of nearly equal frequencies, beats frequency is defined as the

(1) Sum of frequencies of interfering waves

(2) Number of times the resultant intensity becomes maximum or minimum in one second

(3) Average of frequencies of interfering waves

(4) Number of times the resultant amplitude becomes maximum or minimum in one second

Sol. Answer (2)

Beats is the difference in the frequencies of two superimposing waves. Beats are noticed when the resultant wave acquire its higher amplitudes, due to both waves, sounding higher than the regular sound.

The beats would occur $f_1 - f_2 = \Delta f$ times per second. Hence answer is (2).

42. A tuning fork of unknown frequency produces 4 beats per second when sounded with another tuning fork of frequency 254 Hz. It gives the same number of beats per second when unknown tuning fork loaded with wax. The unknown frequency before loading with wax is

(1) 258 (2) 254 (3) 250 (4) Can't be determined

Sol. Answer (1)

Since there are 4 beats. We know that the unknown frequency (f).

$f = 254 + 4$

Since in the second case after loading with wax frequency of 2nd fork must have reduced.

Initial frequency must be

$f = 254 + 4 = 258$ Hz

43. Ten tuning forks are arranged in increasing order of frequency in such a way that any two consecutive tuning forks produce 4 beats per second. The highest frequency is twice that of the lowest. Possible highest and lowest frequencies (in Hz) are

(1) 80 and 40 (2) 100 and 50 (3) 44 and 22 (4) 72 and 36

Sol. Answer (4)

Let frequencies be $f_1, f_2 \dots f_{10}$.

So, $f_{10} = f_1 + 9 \times$ (number of beats)

$f_{10} = f_1 + 36$

Hence, answer must be (4).

44. The displacement at a point due to two waves are $y_1 = 4\sin(500\pi t)$ and $y_2 = 2\sin(506\pi t)$. The result due to their superposition will be

(1) 3 beats per second with intensity relation between maxima and minima equal to 2

(2) 3 beats per second with intensity relation between maxima and minima equal to 9

(3) 6 beats per second with intensity relation between maxima and minima equal to 2

(4) 6 beats per second with intensity relation between maxima and minima equal to 9

Sol. Answer (2)

$y_1 = 4\sin 500\pi t$

$y_2 = 2\sin 506\pi t$

Frequency of $y_1(f_1) = \dfrac{\omega}{2\pi} = \dfrac{500\pi}{2\pi}$ = 250 Hz

Frequency of $y_2(f_2) = \dfrac{\omega}{2\pi} = \dfrac{506\pi}{2\pi}$ = 253 Hz

Intensity relation $\dfrac{A_{\max}}{A_{\min}} = \dfrac{(A_1 + A_2)^2}{(A_1 - A_2)^2}$

$= \dfrac{36}{4} = 9$

45. A tuning fork vibrating with a sonometer having a wire of length 20 cm produces 5 beats per second. The beats frequency does not change if the length of the wire is changed to 21 cm. The frequency of the tuning fork must be

(1) 200 Hz (2) 210 Hz (3) 205 Hz (4) 215 Hz

Sol. Answer (3)

Let frequency of tuning fork be f.

From question we know the frequencies of sonometer wire $\left(\dfrac{v}{2l}\right)$ are

$\dfrac{v}{2\times 0.2}$ and $\dfrac{v}{2\times 0.21}$

Now $\dfrac{v}{0.4} - f = 8$ ... (i)

$f - \dfrac{v}{0.42} = 5$ ... (ii)

Solving (i) and (ii), answer is (3)

46. A tuning fork and an air column whose temperature is 51°C produce 4 beats in one second, when sounded together. When the temperature of air column decreases the number of beats per second decreases. When the temperature remains 16°C only one beat per second is produced. The frequency of the tuning fork is

(1) 100 Hz (2) 75 Hz (3) 150 Hz (4) 50 Hz

Sol. Answer (4)

$$\frac{F+4}{F+1}=\sqrt{\frac{273+51}{273+16}}$$

$$\frac{f+4}{f+1}=\sqrt{\frac{324}{289}}$$

$$\frac{f+4}{f+1}=\frac{18}{17}$$

$f=50$ Hz

47. A man standing on a platform observes that the frequency of the sound of a whistle emitted by a train drops by 140 Hz. If the velocity of sound in air is 330 m/s and the speed of the train is 70 m/s, the frequency of the whistle is

(1) 571 Hz (2) 800 Hz (3) 400 Hz (4) 260 Hz

Sol. Answer (2)

Velocity of sound in air = 330 m/s.

Speed of train = 70 m/s

Let initial frequency be f_0.

$$f = f_0 \times \frac{v}{v+v_s}$$

$$f_0 - f = 140$$

$$f_0\left(1-\frac{330}{400}\right)=140$$

f_0 = 800 Hz

48. A sound source is moving towards a stationary observer with (1/10) of the speed of sound. The ratio of apparent to real frequency is

(1) $\frac{10}{9}$ (2) $\frac{11}{10}$ (3) $\left(\frac{11}{10}\right)^2$ (4) $\left(\frac{9}{10}\right)^2$

Sol. Answer (1)

$$f = f_0 \frac{v}{v - v_s}$$

$$f = f_0 \frac{v}{v - v/10}$$

$$f = \frac{10f_0}{9}$$

$$\therefore \quad f : f_0 = \frac{10}{9}$$

49. A train moves towards a stationary observer with a speed 34 m/s. The train sounds a whistle and its frequency registered by the observer is f_1. If the speed of the train is reduced to 17 m/s, the frequency registered is f_2. If the speed of sound is 340 m/s then the ratio $\frac{f_1}{f_2}$ is

(1) $\frac{18}{19}$ (2) $\frac{1}{2}$ (3) 2 (4) $\frac{19}{18}$

Sol. Answer (4)

$$f = f_0 \frac{v}{v - v_s}$$

$$f_1 = f_0 \frac{340}{340 - 34}$$

$$f_2 = f_0 \frac{340}{340 - 17}$$

$$f_1 = \frac{10}{9} f_0$$

$$f_2 = \frac{20}{19}$$

$$\frac{f}{f_2} = \frac{19}{18}$$

50. An observer is approaching with a speed v, towards a stationary source emitting sound waves of wavelength λ_0. The wavelength shift detected by the observer is (Take c = speed of sound)

(1) $\frac{\lambda_0 v}{c}$ (2) $\frac{\lambda_0 c}{v}$ (3) $\frac{\lambda_0 v^2}{c^2}$ (4) Zero

Sol. Answer (4)

In Doppler effect only change in frequency is observed and not change in wavelength if observer approaches the source.

SECTION - B

Objective Type Questions

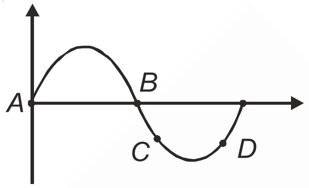
1. The longitudinal wave can be observed in

(1) Elastic media (2) Inelastic media (3) Both (1) & (2) (4) None of these

Sol. Answer (1)

Longitudinal waves travel due to compressions and rarefactions. If medium is inelastic it does not allow constituent compressions and rarefactions.

2. A transverse pulse is shown in the figure, on which 4 points are shown at any instant. Which of the following points are in a state to move upwards in subsequent time?



(1) A, B (2) A, D (3) B, C (4) B, D

Sol. Answer (3)

$$y = A_0 \sin(\omega t - kx)$$

$$\frac{dy}{dt} = V_P = A_0\omega \cos(\omega t - kx)$$

Values for V_P at B and C are positive force they are in a state to move upwards.

3. A rope of length L and mass M hangs freely from the ceiling. If the time taken by a transverse wave to travel from the bottom to the top of the rope is T, then time to cover first half length is

(1) T (2) $T\left(\frac{\sqrt{2}-1}{\sqrt{2}}\right)$ (3) $\frac{T}{\sqrt{2}}$ (4) $\frac{T}{2}$

Sol. Answer (3)

$$v = \sqrt{\frac{N}{\mu}}$$

The tension N in the string varies as :

$N = \pi\frac{Mg}{L}\times x$ where x is length from the ground.

$dt = \frac{dx}{v_x}$ and $v_x = \sqrt{\frac{Mgx}{L\times M/L}} = \sqrt{gx}$

$$\int_0^T dt = \int_0^L \frac{dx}{\sqrt{gx}}$$

$$T = \int_0^L 2\sqrt{x}\,dx$$

$$T = \int_0^L 2\sqrt{L_g} \qquad \text{... (i)}$$

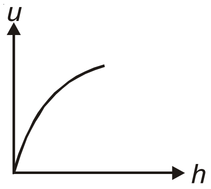
If time to cover half length is T_2.

$$T_2 = \sqrt{2Lg} \qquad \text{[By putting limits 0 to } L/2 \text{ in equation (i)]}$$

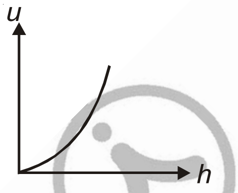
$$\frac{T}{\sqrt{2}} = T_2$$

4. A uniform rope having some mass hangs vertically from a rigid support. A transverse wave pulse is produced at the lower end. The speed (u) of the wave pulse varies with height (h) from the lower end as

(1)



(2)



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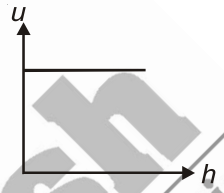
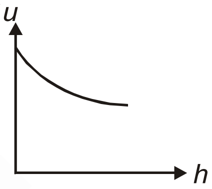


(4)



Sol. Answer (2)

Velocity of wave at a distance h from lower end is

$$v = \sqrt{gh}$$

or $v^2 = gh$

This is of the form of a parabola ($y = kx^2$).

Hence answer is (2)

5. A transverse pulse generated at the bottom of a uniform rope of length L, travels in upward direction. The time taken by it to travel the full length of rope will be

(1) $\sqrt{\frac{L}{2g}}$ (2) $\sqrt{\frac{2L}{g}}$ (3) $\sqrt{\frac{L}{g}}$ (4) $\sqrt{\frac{4L}{g}}$

Sol. Answer (4)

Velocity of wave at a distance x from lower end is

$$v_x = \sqrt{2gx}$$

$$\text{Time } dt = \frac{dx}{\sqrt{2gx}}$$

Integrating for 0 to L we get

$$\sqrt{\frac{4l}{g}}$$

6. Which one of the following represents a wave?

(1) $y = A \sin (\omega t - kx)$

(2) $y = A \cos^2 (at - bx + c) + A \sin^2(at - bx + c)$

(3) $y = A \sin kx$

(4) $y = A \sin \omega t$

Sol. Answer (1)

$$\frac{d^2y}{dx^2} = -\frac{1}{v^2}\frac{d^2y}{dt^2}$$ is satisfied only by functions of the form $f(kx - \omega t)$

The only equation in the option which satisfies the above equation.

7. Which of the following functions for y can never represent a travelling wave?

(a) $(x^2 - vt)^2$ (b) $\log\left[\frac{(x+vt)}{x_0}\right]$ (c) $e^{\left\{-\frac{(x+vt)}{x_0}\right\}^2}$ (d) $\frac{1}{x+vt}$

(1) Only (a) (2) (b) & (c) (3) (c) & (d) (4) Only (c)

Sol. Answer (1)

The only function in the given function which is not of the form $f(kx - \omega t)$ is the first one (a)

Hence option (1) is correct.

8. In a sinusoidal wave, the time required for a particular point to move from maximum displacement to zero displacement is 0.170 s. The frequency of wave is

(1) 0.73 Hz (2) 0.36 Hz (3) 1.47 Hz (4) 2.94 Hz

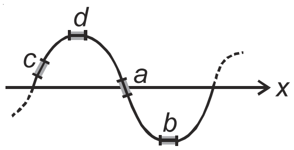
Sol. Answer (3)

Time period from maximum displacement T_0 zero displacement is $\frac{T}{4}$ = 0.170 s

$\therefore$ Total time = 4 × 0.17 = 0.688

Frequency = $\frac{1}{T}$ = 1.47 Hz

9. Figure shows a snapshot for a travelling sine wave along a string. Four elemental portions a, b, c and d are indicated on the string. The elemental portion which has maximum potential energy is/are



(1) a (2) b (3) c (4) b and d

Sol. Answer (1)

Maximum potential energy is stored where kinetic energy, *i.e.*, velocity is zero as the total energy of an element of a wave is constant in its oscillating direction. All the energy is stored as potential energy of the wire at points b and d.

10. A sinusoidal wave of frequency 500 Hz has a speed of 350 m/s. The phase difference between two displacements at a certain point at times 1 m apart is

(1) $\frac{\pi}{4}$ (2) $\frac{\pi}{2}$ (3) π (4) $\frac{3\pi}{2}$

Sol. Answer (3)

$v = 350$ m/s $f = 500$ Hz

$$v = \frac{\omega}{k}$$

$$k = \frac{2\pi f}{v}$$

$$k = \frac{2\pi \times 500}{350}$$

$$k = \frac{2\pi}{0.7}$$

$\therefore$ $\lambda = 0.7$ m

Let equation of wave be

$y = A \sin (kx - \omega t)$

Let $x_1 = 0$ $x_2 = 1$ m

$y_1 = A \sin (\omega t)$

$$y_2 = A \sin \left(\frac{2\pi}{0.7} \times 1 + \omega t\right)$$

Hence phase difference = $\frac{20\pi}{7}$ or approximately

Phase difference $\approx 3\pi$

Which is same as $\Delta\phi = \pi$

11. The equation of travelling wave is $y = a \sin 2\pi\left(pt - \frac{x}{5}\right)$. Then the ratio of maximum particle velocity to wave velocity is

(1) $\frac{\pi a}{5}$ (2) $2\sqrt{5}\pi a$ (3) $\frac{2\pi a}{5}$ (4) $\frac{2\pi a}{\sqrt{5}}$

Sol. Answer (3)

Equation of travelling wave

$$y = a \sin 2\pi\left(pt - \frac{x}{5}\right)$$

Maximum particle velocity (v_y) = $A\omega$ or $v_y = a \times 2\pi p$

Wave velocity (v) = $\dfrac{\omega}{k} = \dfrac{2\pi p}{2\pi/5} = 5p$

$\therefore \quad \dfrac{v_y}{v} = \dfrac{2\pi a}{5}$

12. A travelling wave pulse is given by $y = \dfrac{4}{3x^2 + 48t^2 + 24xt + 2}$ where x and y are in metre and t is in second. The velocity of wave is

(1) 4 m/s (2) 2 m/s (3) 8 m/s (4) 12 m/s

Sol. Answer (1)

$$y = \frac{4}{3x^2 + 48t^2 + 24xt + 2}$$

We need to convert it into the form of $f(kx - \omega t)$

$$y = \frac{4}{3(x^2 + 16t^2 + 8x) + 2}$$

$$y = \frac{4}{3(x + 4t)^2 + 2}$$

$$v = \frac{\omega}{k}$$

Hence $v = \dfrac{4}{1}$ = 4 m/s

13. The ratio of maximum particle velocity to wave velocity is [where symbols have their usual meanings]

(1) kA (2) $A\omega$ (3) $k\omega$ (4) $\dfrac{\omega}{k}$

Sol. Answer (1)

Maximum particle velocity (v_y) = $A\omega$

Wave velocity (v) = $\dfrac{\omega}{k}$

$\therefore \quad \dfrac{v_y}{v} = A_k$

14. What is the phase difference between the displacement wave and pressure wave in sound wave?

(1) Zero (2) $\dfrac{\pi}{2}$ (3) π (4) $\dfrac{\pi}{4}$

Sol. Answer (2)

Phase difference between the pressure and displacement wave will always be $\dfrac{\pi}{2}$.

15. The driver of a car travelling with speed 30 m/s towards a hill sounds a horn of frequency 600 Hz. If the velocity of sound in air is 330 m/s, the frequency of reflected sound as heard by driver is

(1) 500 Hz (2) 550 Hz (3) 555.5 Hz (4) 720 Hz

Sol. Answer (4)

Velocity of sound = 330 m/s

Frequency of incident sound on wall (f_1) = $\frac{v}{v-v_s}\times f$

Frequency of sound observed by driver $(f_2)=\frac{v+v_s}{v}\times f_1$

or $f_2 = \frac{v+v_s}{v-v_s}\times 600$

or $f_2 = \frac{360}{300}\times 600$

or f_2 = 720 Hz

16. The ratio of intensities between two coherent sound sources is 4 : 1. The difference of loudness in dB between maximum and minimum intensities when they interfere in the space is

(1) $20\log_{10}(3)$ (2) $10\log_{10}(2)$ (3) $20\log_{10}(2)$ (4) $10\log_{10}(3)$

Sol. Answer (3)

Loudness in dB = $10\log_{10}\frac{I}{I_0}$

Let $L_1 = 10\log_{10}\frac{I}{I_0}$

$L_2 = 10\log_{10}\frac{4I}{I_0}$

$L_2 - L_1 = 10\log_{10}4$

$= 20\log_{10}2$

17. The intensity of sound reduces by 20% on passing through a glass slab. If sound of intensity I is made to cross through two such slabs, then the intensity of emergent sound will be

(1) $0.36\ I$ (2) $0.64\ I$ (3) $0.4\ I$ (4) $0.8\ I$

Sol. Answer (2)

Let intensity of sound initially be = I_0

After passing through glass slab intensity is = $\frac{80}{100}I_0 = 0.8I_0$

After passing through 2nd slab it further reduces by 20% and only 80% is left.

Hence final intensity = $\frac{80}{100}\times 0.8I_0 = 0.64I_0$

18. Two periodic waves of intensities I_1 and I_2 pass through a region at the same time in the same direction. The sum of the maximum and minimum intensities is

(1) $2(I_1 + I_2)$ (2) $I_1 + I_2$ (3) $(\sqrt{I_1}+\sqrt{I_2})^2$ (4) $(\sqrt{I_1}-\sqrt{I_2})^2$

Sol. Answer (1)

$$I_{\max} = \left(\sqrt{I_1}+\sqrt{I_2}\right)^2 = I_1 + I_2 + 2\sqrt{I_1 I_2}$$

$$I_{\min} = \left(\sqrt{I_1}-\sqrt{I_2}\right)^2 = I_1 + I_2 - 2\sqrt{I_1 I_2}$$

$I_{\max} + I_{\min} = 2(I_1 + I_2)$

19. A stationary wave is represented by $y = A \sin(100t) \cos(0.01x)$, where y and A are in millimetres, t is in second and x is in metre. The velocity of the constituent wave is

(1) 10^4 m/s (2) Not derivable (3) 1 m/s (4) 10^2 m/s

Sol. Answer (1)

$y = A \sin 100t \cos 0.01x$

$\omega = 100$ $k = 0.01$

$$v = \frac{\omega}{k}$$

or $v = 10^4$ m/s

20. The length of a sonometer wire AB is 110 cm. Where should the two bridges be placed from A to divide the wire in 3 segments whose fundamental frequencies are in the ratio of 1 : 2 : 3?

(1) 60 cm and 90 cm (2) 30 cm and 60 cm (3) 30 cm and 90 cm (4) 40 cm and 80 cm

Sol. Answer (1)

$L_{AB} = 110$ cm

Fundamental frequencies = $\frac{v}{2l_1} : \frac{v}{2l_2} : \frac{v}{2l_3}$ are given as 1 : 2 : 3

Hence, $l_2 = \frac{l_1}{2}$ and $l_3 = \frac{l_1}{3}$

Also $l_1 + l_2 + l_3 = 110$

$$l_1 + \frac{l}{2} + \frac{l_1}{3} = 110$$

$6l_1 + 3l_1 + 2l_1 = 660$

$$l_1 = \frac{660}{11}$$

$\therefore$ $l_1 = 60$ cm

$\therefore$ $l_2 = 30$ cm

$\therefore$ $l_3 = 20$ cm

Hence answer is (1)

21. Standing waves are produced in 10 m long stretched string fixed at both ends. If the string vibrates in 5 segments and wave velocity is 20 m/s, the frequency is

(1) 5 Hz (2) 10 Hz (3) 2 Hz (4) 4 Hz

Sol. Answer (1)

The question refers to the 5th harmonic of a vibrating wave.

Frequency of 5th harmonic is = $\frac{nv}{2l} = \frac{5\times 20}{2\times 10}$ = 5 Hz

22. If the tension and diameter of a sonometer wire of fundamental frequency *n* is doubled and density is halved then its fundamental frequency will become

(1) $\frac{n}{4}$ (2) $\sqrt{2n}$ (3) n (4) $\frac{n}{\sqrt{2}}$

Sol. Answer (3)

Fundamental frequency (n) = $\frac{v}{2l}$

or $n = \sqrt{\frac{T}{\mu}}\times\frac{1}{2l}$ ... (i)

Tension becomes $2T$ ... (ii)

$v' = A\rho$ per metre

or $v' = \pi r^2\rho$

Now, $\mu' = \pi(2r)^2\frac{\rho}{2}$

or $\mu' = 2\pi r^2\rho$

or $\mu' = 2\mu$ ... (iii)

Putting (ii) and (iii) in equation (i),

$n' = n$

23. Two waves have equations $x_1 = a\sin(\omega t + \phi_1)$ and $x_2 = a\sin(\omega t + \phi_2)$. If in the resultant wave the frequency and amplitude remain equal to amplitude of superimposing waves, the phase difference between them is

(1) $\frac{\pi}{6}$ (2) $\frac{2\pi}{3}$ (3) $\frac{\pi}{4}$ (4) $\frac{\pi}{3}$

Sol. Answer (2)

$x_1 = a\sin(\omega t + \phi_1)$

$x_2 = a\sin(\omega t + \phi_2)$

$x' = x_1 + x_2$

$= a[\sin(\omega t + \phi_1) + \sin(\omega t + \phi_2)]$

$$= 2a\sin\left(\omega t + \frac{\phi_1+\phi_2}{2}\right)\cos\left(\frac{\phi_1-\phi_2}{2}\right)$$

Now as given in question

$$2a\cos\frac{\phi_1-\phi_2}{2}=a$$

$$\cos\left(\frac{\phi_1-\phi_2}{2}\right)=\frac{1}{2}$$

$$\frac{\phi_1-\phi_2}{2}=\frac{\pi}{3}$$

$$\phi_1-\phi_2=\frac{2\pi}{3}$$

24. The standing wave in a medium is expressed as $y = 0.2 \sin(0.8x)\cos(3000t)$ m. The distance between any two consecutive points of minimum or maximum displacement is

(1) $\frac{\pi}{2}$m (2) $\frac{\pi}{4}$m (3) $\frac{\pi}{6}$m (4) None of these

Sol. Answer (4)

$$y = 0.2\sin 0.8x\cos 3000t$$

The distance between any two points of minimum or maximum displacement is simply wavelength $\left(\frac{\lambda}{4}\right)$ of the wave.

$$k=\frac{2\pi}{\lambda}=0.8$$

or $\lambda=\frac{2\pi}{0.8}$

$\therefore\ \lambda=\frac{5\pi}{2}\text{m}\Rightarrow\frac{\lambda}{4}=\frac{5\pi}{8}\text{m}$

Hence answer must be (4).

25. The equation of a standing wave in a string fixed at both ends is given as $y = 2A\sin kx\cos\omega t$

The amplitude and frequency of a particle vibrating at the mid of an antinode and a node are respectively

(1) $A,\frac{\omega}{2\pi}$ (2) $\frac{A}{\sqrt{2}},\frac{\omega}{2\pi}$ (3) $A,\frac{\omega}{\pi}$ (4) $\sqrt{2}A,\frac{\omega}{2\pi}$

Sol. Answer (4)

$$y = 2A\sin kx\,.\cos\omega t$$

In a standing waves the function of amplitude (A_y) is given by

$$A_y = 2A\sin kx$$

At mid-point of node and antinode $x=\frac{\lambda}{8}$

$$A_y = 2A\sin\frac{2\pi}{\lambda}\times\frac{\lambda}{8}\quad\left[k=\frac{2\pi}{\lambda}\right]$$

or $A_y = \dfrac{2A}{\sqrt{2}}$

$\therefore$ $A_y = \sqrt{2}A$

Frequency is same at all points = $\dfrac{\omega}{2\pi}$

26. Two sinusoidal waves given below are superposed

$$y_1 = A\sin\left(kx - \omega t + \frac{\pi}{6}\right) \quad , \quad y_2 = A\sin\left(kx - \omega t - \frac{\pi}{6}\right)$$

The equation of resultant wave is

(1) $y = \dfrac{A}{\sqrt{3}}\sin(kx - \omega t)$ (2) $y = A\sqrt{3}\sin(kx - \omega t)$

(3) $y = A\sqrt{3}\sin\left(kx - \omega t - \dfrac{\pi}{3}\right)$ (4) $y = \dfrac{A}{\sqrt{3}}\sin\left(kx - \omega t - \dfrac{\pi}{3}\right)$

Sol. Answer (2)

$y' = y_1 + y_2$

or $y' = A\sin\left(kx - \omega t + \dfrac{\pi}{6}\right) + A\sin\left(kx - \omega t - \dfrac{\pi}{6}\right)$

or $y' = 2A\sin(kx - \omega t)\,.\,\cos\left(\dfrac{\left(\dfrac{\pi}{6} + \dfrac{\pi}{6}\right)}{2}\right)$

or $y' = 2A\dfrac{\sqrt{3}}{2}\sin(kx - \omega t)$

$\therefore$ $y' = A\sqrt{3}\sin(kx - \omega t)$

27. For a particular resonance tube, following are four of the six harmonics below 1000 Hz;

300, 600, 750 and 900 Hz

The two missing harmonics are

(1) 75, 150 (2) 150, 450 (3) 400, 800 (4) 250, 400

Sol. Answer (2)

The 6th harmonic (f_6) = $\dfrac{6v}{2l} = 900$

or $\dfrac{v}{2l} = 150$

Hence fundamental frequency of string $\dfrac{v}{2l}$ or 150 Hz is missing.

3rd multiple of 150 which is 450 is also missing.

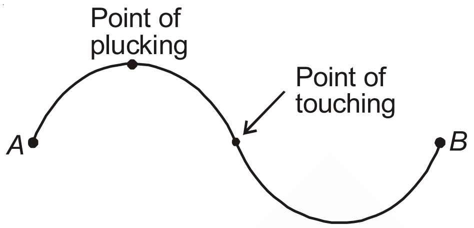
Hence required frequencies are 150, 450.

28. A second harmonic has to be generated in a string of length l stretched between two rigid supports. The points where the string has to be plucked and touched are respectively

(1) $\frac{l}{4}, \frac{l}{2}$ (2) $\frac{l}{4}, \frac{3l}{4}$ (3) $\frac{l}{2}, \frac{l}{2}$ (4) $\frac{l}{2}, \frac{3l}{4}$

Sol. Answer (1)

In the 2nd harmonic the shape of wave looks like.



The point of touching forms a node point of plucking forms an antinode. Hence, for 2nd harmonic, we need to need wire touched at $\frac{l}{2}$ and pluck it at $\frac{l}{4}$.

29. In a standing wave, all particles of the medium cross the mean position with

(1) Different speeds at different instants (2) Different speeds at same instant

(3) Same speed at different instants (4) Same speed at same instant

Sol. Answer (2)

In a standing waves all particles of same wave have same v and hence vibrate in phase passing the mean point at same time. The amplitude of the waves is different at different points hence the speed is different.

30. Two waves are represented by

$y_1 = 5 \sin 2\pi(75t - 0.25x)$

$y_2 = 10 \sin 2\pi(150t - 0.50x)$

The intensity ratio $\frac{I_1}{I_2}$ of the two waves is

(1) 1 : 2 (2) 1 : 4 (3) 1 : 8 (4) 1 : 16

Sol. Answer (4)

$A_1 = 5,$ $A_2 = 10$

$$\frac{I_1}{I_2} = \frac{kA_1^2}{kA_2^2} = \left(\frac{5}{10}\right)^2 = 1:4$$

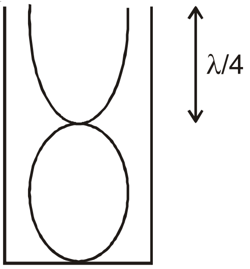
31. In a closed organ pipe of length 105 cm, standing waves are set up corresponding to third overtone. What distance from the closed end, a pressure node is formed?

(1) 5 cm (2) 15 cm (3) 25 cm (4) 30 cm

Sol. Answer (2)

In a closed pipe $f = \dfrac{(2P+1)}{4l}v$

For third overtone (f) = $\dfrac{7v}{4l}$



$$\lambda = \frac{v}{f} = \frac{v}{7v} \times 4l$$

$$\lambda = \frac{4l}{7}$$

$$\lambda = \frac{4 \times 105}{7}$$

$$\lambda = 60 \text{ cm}$$

First pressure node will be formed $\dfrac{\lambda}{4}$

32. A uniform string resonates with a tuning fork, at a maximum tension of 32 N. If it is divided into two segments by placing a wedge at a distance one-fourth of length from one end, then to resonance with same frequency the maximum value of tension for string will be

(1) 2 N (2) 4 N (3) 8 N (4) 16 N

Sol. Answer (1)

Let length be l.

$$f = \sqrt{\frac{T}{\mu}} \times \frac{1}{2l} \text{ ... (i)} \qquad f = \sqrt{\frac{T}{\mu}} \times \frac{4}{2l} \text{ ... (ii)} \qquad \text{or } f = \sqrt{\frac{T}{\mu}} \times \frac{4}{6l} \text{ ... (iii)}$$

Equating (i) & (ii) and (i) & (iii)

$$\sqrt{\frac{T}{T_1}} = 4 \quad \& \quad \sqrt{\frac{T}{T_2}} = \frac{4}{3}$$

Put T = 32 N

$$\frac{32}{16} = T_1 \qquad \frac{9}{16} \times 32 = T_2$$

$$T_1 = 2 \text{ N} \qquad T_2 = 18 \text{ N}$$

of the options on T_1 is right.

33. If in a stationary wave the amplitude corresponding to antinode is 4 cm, then the amplitude corresponding to a particle of medium located exactly midway between a node and an antinode is

(1) 2 cm (2) $2\sqrt{2}$ cm (3) $\sqrt{2}$ cm (4) 1.5 cm

Sol. Answer (2)

$y = A_0 \sin(kx) \cos \omega t$

Mid way between a node and antinode is $\frac{\lambda}{8}$ from origin.

Function for amplitude is $A = A_0 \sin(kx)$

$$A = 4 \sin\left(\frac{2\pi}{\lambda} \times \frac{\lambda}{8}\right)$$

$$A = 2\sqrt{2} \text{ cm}$$

34. A uniform string of fundamental frequency of vibration f is divided into two segments by means of a bridge. If f_1 and f_2 are fundamental frequencies of these segments then

(1) $f_1 f_2 = f[f_1 + f_2]$ (2) $2f = f_1 + f_2$ (3) $\sqrt{f} = \sqrt{f_1} + \sqrt{f_2}$ (4) $\sqrt{f_1 f_2} = 2f$

Sol. Answer (1)

$l = l_1 + l_2$

$$f_1 = \frac{v}{2l_1}$$

or $l_1 = \frac{v}{2f_1}$

Similarly,

$l_2 = \frac{v}{2f_2}$ $l = \frac{v}{2f}$

$$\frac{v}{2f} = \frac{v}{2f_1} + \frac{v}{2f_2}$$

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$f = \frac{f_1 f_2}{f_1 + f_2}$$

$$f[f_1 + f_2] = f_1 f_2$$

35. Two sound waves of intensity 2 W/m^2 and 3 W/m^2 meet at a point to produce a resultant intensity 5 W/m^2. The phase difference between two waves is

(1) π (2) $\frac{\pi}{4}$ (3) $\frac{\pi}{2}$ (4) Zero

Sol. Answer (3)

$$I = I_1 + I_2 + 2\sqrt{T_1}\sqrt{T_2}\cos\phi$$

$$5 = 3 + 2 + 2\sqrt{6}\cos\phi$$

$\therefore$ $\cos\phi = 0$

or $\phi = \frac{\pi}{2}$

36. The two waves of the same frequency moving in the same direction give rise to

(1) Beats (2) Interference (3) Stationary waves (4) None of these

Sol. Answer (2)

The two waves of same frequency moving in the same direction give rise to interference.

37. The string of a violin emits a note of 205 Hz at its correct tension. The string is tightened slightly and then it produces six beats in two seconds with a tuning fork of frequency 205 Hz. The frequency of the note emitted by the taut string is

(1) 211 Hz (2) 199 Hz (3) 208 Hz (4) 202 Hz

Sol. Answer (3)

Initial frequency = 205 Hz

String tightned so frequency is increased = 205 + f

Final frequency of string – frequency of tuning fork = 3 beats

$205 + f - 205 = 3$

$\therefore$ $f = 3$

$\therefore$ Final frequency = 205 + 3 = 208 Hz

38. When two tuning forks (fork 1 and fork 2) are sounded together, 4 beats per second are heard. Now some tape is attached on the prong of the fork 2. When the tuning forks are sounded again, 6 beats per second are heard. If the frequency of fork 1 is 200 Hz, then what was the original frequency of fork 2?

(1) 204 Hz (2) 196 Hz (3) 202 Hz (4) 200 Hz

Sol. Answer (2)

Frequency of fork 1 = 200 Hz

Frequency of fork 2 = 200 ± 4

When tape is added frequency of fork 2 decreases.

When frequency of fork 2 decreases number of beats increases.

Hence we know frequency of fork 2 is

$f_2 = 200 - 4 = 196$ Hz

39. A train moving at a speed of 220 ms^{-1} towards a stationary object, emits a sound of frequency 1000 Hz. Some of the sound reaching the object gets reflected back to the train as echo. The frequency of the echo as detected by the driver of the train is (Speed of sound in air is 330 ms^{-1})

(1) 3500 Hz (2) 4000 Hz (3) 5000 Hz (4) 3000 Hz

Sol. Answer (3)

$v = 220\ \text{ms}^{-1}$

$f = 1000$ Hz

Frequency of echo = $\dfrac{300+220}{330-220}\times f$

$f_e = \dfrac{550}{110}\times f$

or $f_e = 5f$

or $f_e = 5000$ Hz

40. A source of frequency ν gives 5 beats/second when sounded with a source of frequency 200 Hz. The second harmonic of frequency 2ν of source gives 10 beats/second when sounded with a source of frequency 420 Hz. The value of ν is

(1) 205 Hz (2) 195 Hz (3) 200 Hz (4) 210 Hz

Sol. Answer (1)

$\nu = 200 \pm 5$ ... (i)

$2\nu = 420 \pm 10$

$\nu = 210 \pm 5$ ... (ii)

Common value for (i) & (ii) is 205 Hz.

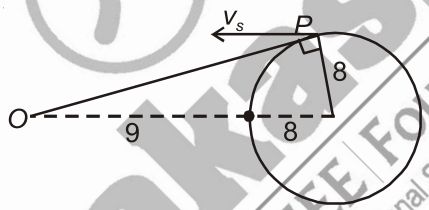
Hence ν = 205 Hz

41. A vibrating tuning fork is moving slowly and uniformly in a horizontal circular path of radius 8 m. The shortest distance of an observer in same plane from the tuning fork is 9 m. The distance between the tuning fork and observer at the instant when apparent frequency becomes maximum is

(1) 9 m (2) 25 m (3) 15 m (4) $\sqrt{353}$ m

Sol. Answer (3)

The apparent frequency is maximum when relative velocity of approach of tuning fork with respect to observer is maximum.



$OP = \sqrt{17^2 - 8^2} = 15$ m

42. The frequency changes by 10% as a sound source approaches a stationary observer with constant speed V_s. What would be percentage change in the frequency as the source recedes the observer with same speed ($V_s < V$)?

(1) 10.5% (2) 8.5% (3) 4.5% (4) 1.5%

Sol. Answer (2)

$$f' = \frac{v}{v - v_s} f_0$$

f is such that $f = \dfrac{110}{100} f_0$

When $\dfrac{v}{v - v_s} = \dfrac{110}{100}$

$100\,v = 110\,v - 110\,v_s$

$v = 11\,v_s$

When source is received

$$\frac{v}{v+v_s} f_0 = \frac{x}{100} f_0$$

Putting $v = 11\ v_s$

$$\frac{11}{12} \times 100 = x$$

$$x = 91.66\%$$

% change = 100 – 91.66 ≈ 8.5%

43. A train blowing its whistle moves with constant speed on a straight track towards observer and then crosses him. If the ratio of difference between the actual and apparent frequencies be 3 : 2 in the two cases, then the speed of train is [v is speed of sound]

(1) $\frac{2v}{3}$

(2) $\frac{v}{5}$

(3) $\frac{v}{3}$

(4) $\frac{3v}{2}$

Sol. Answer (2)

$$f_A = \frac{v}{v-v_s} f_0 \qquad \text{(Frequency of approach)}$$

$$f_R = \frac{v}{v+v_s} f_0 \qquad \text{(Frequency of departing)}$$

$$\Delta f_A = \left(\frac{v}{v-v_s} - 1\right) f_0$$

$$\Delta f_A = \frac{v}{v-v_s} f_0$$

$$\Delta f_R = \left(1 - \frac{v}{v+v_s}\right) f_0$$

$$\Delta f_R = \frac{v}{v+v_s} f_0$$

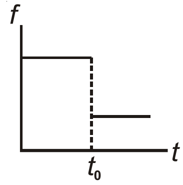
$$\frac{\Delta f_A}{\Delta f_R} = \frac{v+v_s}{v-v_s} = \frac{3}{2}$$

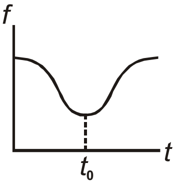
$$2\ v = 2\ v_s = 3\ v - 3\ v_s$$

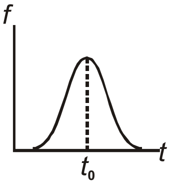
$$5\ v_s = v$$

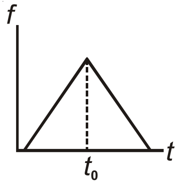
$$v_s = \frac{v}{5}$$

44. A man is standing on a railway platform listening to the whistle of an engine that passes the man at constant speed without stopping. If the engine passes the man at time instant t_0, how does the frequency f of the whistle as heard by the man changes with time?

(1) 

(2) 

(3) 

(4) 

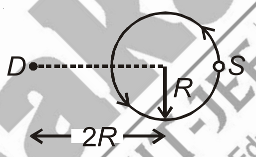
Sol. Answer (1)

When the train is approaching with speed v_s. The apparent frequency is constant and $f_A = \frac{v}{v - v_s} f_0$

When it is departing it is again constant, suddenly changing after t_0 to $f_0 = \frac{v}{v + v_s} f_0$.

Hence graph will be that of option (1).

45. A whistle '*S*' of frequency *f* revolves in a circle of radius *R* at a constant speed *v*. What is the ratio of maximum and minimum frequency detected by a detector *D* at rest at a distance *2R* from the center of circle as shown in figure? (take '*c*' as speed of sound)



(1) $\left(\frac{c+v}{c-v}\right)$

(2) $\sqrt{2}\left(\frac{c+v}{c-v}\right)$

(3) $\sqrt{2}$

(4) $\frac{(c+v)}{c\sqrt{2}}$

Sol. Answer (1)

c = Speed of sound

At maximum frequency sources directly approaches observes with speed v_s.

$$\therefore \quad f_A = \frac{c}{c-v} f_0$$

At minimum frequency sources recedes with v_s

$$f_R = \frac{c}{c+v} f_0$$

$$\frac{f_A}{f_R} = \frac{c+v}{c-v}$$

SECTION - C

Previous Years Questions

1. Two waves are represented by the equations

$y_1 = a\sin(\omega t + kx + 0.57)$m and $y_2 = a\cos(\omega t + kx)$ m,

where x is in metre and t in second. The phase difference between them is

(1) 0.57 radian (2) 1.0 radian

(3) 1.25 radian (4) 1.57 radian

Sol. Answer (2)

Phase difference is simply difference in the argument in sine function.

We can write $y_2 = a \sin [\omega t + kx + \pi/2]$

$\therefore \quad \Delta\phi = \omega t + kx + \pi/2 - (\omega t + kx + 0.57)$

$= 1.57 - 0.57 = 1$ radian

2. A hospital uses an ultrasonic scanner to locate tumours in a tissue. The operating frequency of the scanner is 4.2 MHz. The speed of sound in a tissue is 1.7 km/s. The wavelength of sound in the tissue is close to

(1) 4×10^{-3} m (2) 8×10^{-3} m

(3) 4×10^{-4} m (4) 8×10^{-4} m

Sol. Answer (3)

$f = 4.2 \times 10^6$ Hz

$v = 1700$ m/s

$$\lambda = \frac{v}{f}$$

$$= \frac{1700}{42\times10^5} = 0.404 \times 10^{-3}$$

$= 4 \times 10^{-4}$

3. Sound waves travel at 350 m/s through a warm air and at 3500 m/s through brass. The wavelength of a 700 Hz acoustic wave as it enters brass from warm air

(1) Decreases by a factor 20 (2) Decreases by a factor 10

(3) Increases by a factor 20 (4) Increases by a factor 10

Sol. Answer (4)

Frequency will remain constant

v_a = Velocity in air

v_b = Velocity in brass

$v_a = 700 \times \lambda_a$

$v_b = 700 \times \lambda_b$

$$\lambda_a = \frac{350}{700} \qquad \lambda_b = \frac{3500}{700}$$

$\lambda_a = 0.5$ m/s $\qquad \lambda_b = 50$ m

$\therefore \quad \lambda_b = 10\,\lambda_a$

4. The wave described by $y = 0.25 \sin(10\pi x - 2\pi t)$, where x and y are in meter and t in second, is a wave travelling along the

   (1) –ve x direction with amplitude 0.25 m and wavelength $\lambda = 0.2$ m

   (2) –ve x direction with frequency 1 Hz

   (3) +ve x direction with frequency π Hz and wavelength $\lambda = 0.2$ m

   (4) +ve x direction with frequency 1 Hz and wavelength $\lambda = 0.2$ m

Sol. Answer (4)

$y = 0.25 \sin(10\pi x - 2\pi t)$ ... (i)

Frequency $(f) = \dfrac{\omega}{2\pi} = 1$ Hz

Wavelength $(\lambda) = \dfrac{2\pi}{k} = \dfrac{1}{5}$ m

Equation (i) is the equation of wave travelling in +ve x-direction.

Hence answer is (0.2) option (4)

5. Two points are located at a distance of 10 m and 15 m from the source of oscillation. The period of oscillation is 0.05 s and the velocity of the wave is 300 m/s. What is the phase difference between the oscillations of two points?

   (1) $\dfrac{\pi}{6}$ (2) $\dfrac{\pi}{3}$ (3) $\dfrac{2\pi}{3}$ (4) π

Sol. Answer (3)

$T = 0.05$ s Velocity $(v) = 300$ m/s

$\therefore\ f = \dfrac{1}{T} = 20$ Hz

$\omega = 2\pi f = 40\pi$

Since velocity $= \dfrac{\omega}{k}$

$300 = \dfrac{40\pi}{k}$

$k = \dfrac{2\pi}{15}$

$\lambda = 15$ m

Put $x = 10$ and $x = 15$ in equation

$y = A \sin(kx - \omega t)$

$= A \sin\left(\dfrac{2\pi}{15}x - 40\pi t\right)$

Time (t) is same.

$$y_1 = A\sin\left(\frac{2\pi}{15}10-\omega t\right)$$

$$y_2 = A\sin(2\pi - \omega t)$$

$$\Delta\phi = (2\pi - \omega t) - \left(\frac{4\pi}{3}-\omega t\right)$$

or $\Delta\phi = 2\pi - \dfrac{4\pi}{3}$

or $\Delta\phi = \dfrac{2\pi}{3}$

6. Two sound waves having a phase difference of 60° have path difference of

(1) $\dfrac{\lambda}{6}$ (2) $\dfrac{\lambda}{3}$ (3) 2λ (4) $\dfrac{\lambda}{2}$

Sol. Answer (1)

Path difference = $\dfrac{\lambda}{2\pi}$ × Phase difference.

$\therefore$ Path difference = $\dfrac{\lambda}{6}$ m

7. A transverse wave is represented by the equation $y = y_0\sin\dfrac{2\pi}{\lambda}(vt - x)$. For what value of λ the maximum particle velocity is equal to two times the wave velocity?

(1) $\lambda = \dfrac{\pi y_0}{2}$ (2) $\lambda = \dfrac{\pi y_0}{3}$ (3) $\lambda = 2\pi y_0$ (4) $\lambda = \pi y_0$

Sol. Answer (4)

$$y = y_0\sin\frac{2\pi}{\lambda}(vt - x)$$

$$\frac{dy}{dt} = y_0\frac{v}{\lambda}2\pi\cos\frac{2\pi}{\lambda}(vt - x)$$

Maximum particle velocity = $y_0\dfrac{2\pi v}{\lambda}$

Wave velocity = v

$$\frac{y_0 2\pi v}{\lambda} = 2\ v$$

$$\pi_{y_0} = \lambda$$

8. A wave travelling in positive x-direction with A = 0.2 m, velocity = 360 m/s and λ = 60 m, then correct expression for the wave is

(1) $y = 0.2\sin\left[2\pi\left(6t + \frac{x}{60}\right)\right]$ (2) $y = 0.2\sin\left[\pi\left(6t + \frac{x}{60}\right)\right]$

(3) $y = 0.2\sin\left[2\pi\left(6t - \frac{x}{60}\right)\right]$ (4) $y = 0.2\sin\left[\pi\left(6t - \frac{x}{60}\right)\right]$

Sol. Answer (3)

A = 0.2 m Velocity = 360 m/s and λ = 60 m

We are looking for a waves of the form $y = A \sin \omega t - kx$

$$\omega = \frac{2\pi v}{\lambda} = \frac{2\pi\times 360}{60} = 12\pi$$

$$k = \frac{2\pi}{\lambda} = \frac{2\pi}{60}$$

Correct value of ω and k are found in option (3).

9. The phase difference between two waves, represented by $y_1 = 10^{-6}\sin[100t + (x/50) + 0.5]$ m and $y_2 = 10^{-6}\cos[100t + (x/50]$ m, where x is expressed in metre and t is expressed in second, is approximately

(1) 1.07 radian (2) 2.07 radian (3) 0.5 radian (4) 1.5 radian

Sol. Answer (1)

$$y_1 = 10^{-6}\sin\left(100t + \frac{x}{50} + 0.5\right)$$

$$y_2 = 10^{-6}\cos\left(100t + \frac{x}{50}\right)$$

$$y_2 = 10^{-6}\sin\left(100t + \frac{x}{50} + \frac{\pi}{2}\right)$$

Phase differences

$$\left(100t + \frac{x}{50} + \frac{\pi}{2}\right) - \left(100t + \frac{x}{50} + 0.5\right)$$

$$= \frac{3.14}{2} - \frac{1}{2} = 1.07 \text{ radian}$$

10. A transverse wave propagating along x-axis is represented by $y(x, t) = 8.0 \sin (0.5\,\pi x - 4\pi t - \pi/4)$

where x is in metres and t is in seconds. The speed of the wave is

(1) 8 m/s (2) 4π m/s (3) 0.5π m/s (4) $\frac{\pi}{4}$ m/s

Sol. Answer (1)

$$v = \frac{\omega}{k}$$

$$v = \frac{4\pi}{\pi/2}$$

$$v = 8 \text{ m/s}$$

11. A point source emits sound equally in all directions in a non-absorbing medium. Two points *P* and *Q* are at distances of 2 m and 3 m respectively from the source. The ratio of the intensities of the waves at *P* and *Q* is

(1) 3 : 2 (2) 2 : 3 (3) 9 : 4 (4) 4 : 9

Sol. Answer (3)

$$I \propto \frac{1}{r^2}$$

$$I_P = \frac{k}{2^2} \qquad I_Q = \frac{k}{3^2}$$

$$I_P = I_Q = 9 : 4$$

12. The time of reverberation of a room *A* is one second. What will be the time (in second) of reverberation of a room, having all the dimensions double of those of room *A*?

(1) 1 (2) 2 (3) 4 (4) $\frac{1}{2}$

Sol. Answer (2)

Sabini's formula for reverberation time is

$$T = \frac{0.16V}{\Sigma as}$$

Where *V* is volume of hall in m^3

$$\frac{T'}{T} = \frac{V'}{s'} \times \frac{s}{V}$$

$$\frac{T'}{T} = \frac{2^3}{2^2} \text{ or } T = 2 \text{ s}$$

13. When a string is divided into three segments of length l_1, l_2 and l_3, the fundamental frequencies of these three segments are ν_1, ν_2 and ν_3 respectively. The original fundamental frequency (ν) of the string is

(1) $\frac{1}{\nu} = \frac{1}{\nu_1} + \frac{1}{\nu_2} + \frac{1}{\nu_3}$ (2) $\frac{1}{\sqrt{\nu}} = \frac{1}{\sqrt{\nu_1}} + \frac{1}{\sqrt{\nu_2}} + \frac{1}{\sqrt{\nu_3}}$

(3) $\sqrt{\nu} = \sqrt{\nu_1} + \sqrt{\nu_2} + \sqrt{\nu_3}$ (4) $\nu = \nu_1 + \nu_2 + \nu_3$

Sol. Answer (1)

Let original fundamental frequency be = $\frac{v}{2l}$

$l = l_1 + l_2 + l_3$ ... (i)

$f_1 = \frac{\nu}{2l_1}$ or $l_1 = \frac{\nu}{2f_1}$

Similarly, $l_2 = \frac{v}{2f_2}$ $l_3 = \frac{v}{2f_3}$ $l = \frac{v}{2f}$

Putting values for l, l_1, l_2, l_3 in (i)

$$\frac{v}{2f} = \frac{v}{2f_1} + \frac{v}{2f_2} + \frac{v}{2f_3}$$

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3}$$

14. Two identical piano wires, kept under the same tension T have a fundamental frequency of 600 Hz. The fractional increase in the tension of one of the wires which will lead to occurrence of 6 beats per second when both the wires oscillate together would be

(1) 0.04 (2) 0.01 (3) 0.02 (4) 0.03

Sol. Answer (3)

Beats = 6 Hz

New frequency of one of the wires = 600 + 6 = 606

$$f = \frac{v}{2l} = \sqrt{\frac{T}{\mu}} \times \frac{1}{2l}$$

$$\left(\frac{606}{600}\right)^2 = \frac{T + \Delta T}{T} \text{ or } \frac{\Delta T}{T} = 0.0201 \simeq 0.02$$

15. A wave of frequency 100 Hz travels along a string towards its fixed end. When this wave travels back, after reflection, a node is formed at a distance of 10 cm from the fixed end. The speed of the wave (incident and reflected) is

(1) 20 m/s (2) 40 m/s (3) 5 m/s (4) 10 m/s

Sol. Answer (1)

Node is formed at 10 cm

∴ Wavelength = 2 × 10 = 20 cm

$\lambda = 0.2$ cm

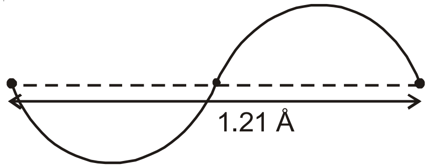
$v = f\lambda = 0.2 \times 100 = 20$ m/s

16. A standing wave having 3 nodes and 2 antinodes is formed between two atoms having a distance 1.21 Å between them. The wavelength of the standing wave is

(1) 6.05 Å (2) 2.42 Å (3) 1.21 Å (4) 3.63 Å

Sol. Answer (3)

Total distance 1.21 Å



According to description the wave must like above diagram wavelength (λ) = 1.21 Å

17. A wave in a string has an amplitude of 2 cm. The wave travels in the +ve direction of x axis with a speed of 128 m/s and it is noted that 5 complete waves fit in 4 m length of the string. The equation describing the wave is

(1) $y = (0.02)$ m $\sin(7.85x - 1005t)$
(2) $y = (0.02)$ m $\sin(7.85x + 1005t)$
(3) $y = (0.02)$ m $\sin(15.7x - 2010t)$
(4) $y = (0.02)$ m $\sin(15.7x + 2010t)$

Sol. Answer (1)

$$\lambda = \frac{4}{5} = 0.8 \text{ m}$$

Velocity = 128 m/s

$$\omega = \frac{2\pi v}{\lambda} = \frac{2\pi \times 128}{0.8} = 320\ \pi = 1005$$

$$k = \frac{2\pi}{0.8} = 7.85$$

∴ Equation of the form $y = A \sin(kx - \omega t)$ is the first option.

18. Two sources of sound placed close to each other, are emitting progressive waves given by $y_1 = 4\sin 600\pi t$ and $y_2 = 5\sin 608\pi t$. An observer located near these two sources of sound will hear

(1) 8 beats per second with intensity ratio 81 : 1 between waxing and waning
(2) 4 beats per second with intensity ratio 81 : 1 between waxing and waning
(3) 4 beats per second with intensity ratio 25 : 16 between waxing and waning
(4) 8 beats per second with intensity ratio 25 : 16 between waxing and waning

Sol. Answer (2)

$\omega_1 = 600\ \pi = 2\pi f_1$

$\omega_2 = 608\ \pi = 2\pi f_2$

$f_1 = 300$ Hz

$f_2 = 304$ Hz

∴ Beats heard will be 304 – 300 = 4 beats / s

$$\frac{I_{\max}}{I_{\min}} = \frac{(A_1 + A_2)^2}{(A_1 - A_2)^2} \text{ or } \frac{I_{\max}}{I_{\min}} = \frac{81}{1}$$

19. Two waves of wavelengths 50 cm and 51 cm produced 12 beats per second. The velocity of sound is

(1) 340 m/s (2) 331 m/s (3) 306 m/s (4) 360 m/s

Sol. Answer (3)

$$f_1 = \frac{v}{\lambda_1} \qquad f_2 = \frac{v}{\lambda_2}$$

$$f_1 - f_2 = 12$$

$$\frac{v}{0.5} - \frac{v}{0.51} = 12$$

Solving for v, we get v = 306 m/s.

20. Two stationary sources each emit waves of wavelength λ. An observer moves from one source to another with velocity u. Then number of beats heard by him

(1) $\frac{2u}{\lambda}$ (2) $\frac{u}{\lambda}$ (3) $\sqrt{u\lambda}$ (4) $\frac{u}{2\lambda}$

Sol. Answer (1)

Let both have the same frequencies ρ_0.

Let the initial source be s_1 and the source is approaching be s_2.

$$f_0 = \frac{v}{\lambda}$$

$$f_{s_1} = \frac{v - v_0}{v} \times f_0 = \frac{1}{\lambda}(v - v_0)$$

$$f_{s_2} = \frac{v + v_0}{v} \times f_0 = \frac{1}{\lambda}(v + v_0)$$

$v_0 = u$ and $f_{s_2} - f_{s_1} = ?$

$$\left[\frac{(v+u)}{\lambda} - \frac{(v-u)}{\lambda}\right] = \text{number of beats.}$$

$$\left[\frac{v+u-v+u}{\lambda}\right] = \text{number of beats.}$$

$$\frac{2u}{\lambda} = \text{number of beats.}$$

21. Two vibrating tuning forks produce progressive waves given by $Y_1 = 4 \sin 500\,\pi t$ and $Y_2 = 2 \sin 506\,\pi t$. Number of beats produced per minute is

(1) 360 (2) 180 (3) 60 (4) 3

Sol. Answer (2)

$y_1 = 4 \sin 500\,\pi t$ and $y_2 = 2 \sin 506\,\pi t$

$\omega_1 = 2\pi f_1 = 500\,\pi$

f_1 = 250 Hz

Similarly, $2\pi f_2 = 506\ \pi$

$f_2 = 253$ Hz

Beats = $f_2 - f_1 = 3$ Hz

3 beats in 1 second then number of beats in 1 minute = 3 × 60 = 180

22. Two sound waves with wavelengths 5.0 m and 5.5 m respectively, each propagate in a gas with velocity 330 m/s. We expect the following number of beats per second

(1) 6 (2) 12 (3) Zero (4) 1

Sol. Answer (1)

$$f_1 = \frac{v}{\lambda_1} = \frac{330}{5} = 66\,\text{Hz}$$

$$f_2 = \frac{v}{\lambda_2} = \frac{330}{5.5} = 60\,\text{Hz}$$

Beats = $f_2 - f_1 = 6$ beats/s

23. Each of the two strings of length 51.6 cm and 49.1 cm are tensioned separately by 20 N force. Mass per unit length of both the strings is same and equal to 1 g/m. When both the strings vibrate simultaneously the number of beats is

(1) 3 (2) 5 (3) 7 (4) 8

Sol. Answer (3)

$l_1 = 51.6$ cm $l_2 = 49.1$ cm $T = 20$ N

$\mu = 1$ g/m = 0.001 kg/m

$$\frac{v}{2l_1} = \sqrt{\frac{20}{0.001}} \times \frac{1}{2 \times 0.516} \quad \left[v = \sqrt{\frac{T}{\mu}}\right]$$

≈ 137 Hz

Similarly,

$$\frac{v}{2l_2} = 144\,\text{Hz}$$

Number of beats = 144 – 137 = 7 Hz

24. A tuning fork of frequency 512 Hz makes 4 beats per second with the vibrating string of a piano. The beat frequency decreases to 2 beats per second when the tension in the piano string is slightly increased. The frequency of the piano string before increasing the tension was

(1) 508 Hz (2) 510 Hz (3) 514 Hz (4) 516 Hz

Sol. Answer (1)

Tuning fork of frequency = 512 Hz

Frequency of wire = 512 ± 4

Since frequency beats decrease when tension is increased, frequency of tuning fork must be greater than string initially.

$\therefore$ Frequency of piano = 508 Hz

25. A vehicle, with a horn of frequency n is moving with a velocity of 30 m/s in a direction perpendicular to the straight line joining the observer and the vehicle. The observer perceives the sound to have a frequency $n + n_1$. Then (if the sound velocity in air is 300 m/s)

(1) $n_1 = 0.1\,n$ (2) $n_1 = 0$ (3) $n_1 = 10\,n$ (4) $n_1 = -0.1\,n$

Sol. Answer (2)

If the object and source are not approaching each other in any direction there is no change in frequency due to Doppler effect.

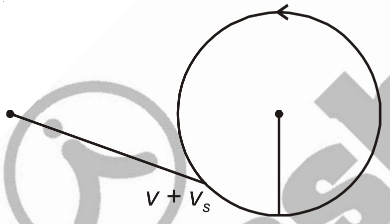
Length = 50 cm

26. A whistle revolves in a circle with angular speed $\omega = 20$ rad/s using a string of length 50 cm. If the frequency of sound from the whistle is 385 Hz, then what is the minimum frequency heard by an observer who is far away from the centre ($v_{\text{sound}} = 340$ m/s)?

(1) 385 Hz (2) 374 Hz (3) 394 Hz (4) 333 Hz

Sol. Answer (2)

$$v_s = r_\omega = 20 \times 0.5 = 10 \text{ m/s}$$



Observed frequency is minimum when source moves from observer.

$$\text{Apparent frequency} = \frac{v}{v+v_s}\times f_0$$

$$= \frac{340}{340+10}\times 385$$

$$= \frac{340}{350}\times 385$$

$$= 34 \times 11 = 374 \text{ Hz}$$

27. An observer moves towards a stationary source of sound with a speed 1/5th of the speed of sound. The wavelength and frequency of the source emitted are λ and f respectively. The apparent frequency and wavelength recorded by the observer are respectively

(1) $1.2f$, $1.2\,\lambda$ (2) $1.2f$, λ (3) f, $1.2\,\lambda$ (4) $0.8f$, $0.8\,\lambda$

Sol. Answer (2)

Wavelength of wave does not change due to the Doppler effect.

$$\text{Apparent frequency} = \frac{v+v_s}{v}\times f$$

$$= \frac{6}{5}\times f \text{ or } 12\,f$$

Wavelength = λ

28. A car is moving towards a high cliff. The driver sounds a horn of frequency *f*. The reflected sound heard by the driver has frequency 2*f* if *v* the velocity of sound, then the velocity of the car, in the same velocity units, will be

(1) $\frac{v}{\sqrt{2}}$ (2) $\frac{v}{3}$ (3) $\frac{v}{4}$ (4) $\frac{v}{2}$

Sol. Answer (2)

Frequency with which sound hits the wall $(f_1) = \frac{v}{v - v_c} \times f$

Frequency with which man hears the sound again $(f_2) = \frac{v + v_c}{v} \times f_1$

or $f_2 = \frac{v + v_c}{v - v_c} \times f$ or $2f = \frac{v + v_c}{v - v_c} \times f$ or $2v - 2v_c = v + v_c$

$v_c = \frac{v}{3}$

29. The equation of a simple harmonic wave is given by $y = 3\sin\frac{\pi}{2}(50t - x)$, where *x* and *y* are in metres and *t* is in seconds. The ratio of maximum particle velocity to the wave velocity is

(1) 2π (2) $\frac{3}{2}\pi$ (3) 3π (4) $\frac{2}{3}\pi$

Sol. Answer (2)

$y = 3\sin\frac{\pi}{2}(50t - x)$

Maximum particle velocity = $A\omega$

or $3 \times 25\pi = 75\pi$

Wave velocity = $\frac{\omega}{k} = \frac{50}{1} = 50\,\text{m/s}$

Ratio = $\frac{75\pi}{50} = \frac{3\pi}{2}$

30. Which one of the following statements is true?

(1) The sound waves in air are longitudinal while the light waves are transverse

(2) Both light and sound waves in air are longitudinal

(3) Both light and sound waves can travel in vacuum

(4) Both light and sound waves in air are transverse

Sol. Answer (1)

Sound is a mechanical wave and travels longitudinally in air.

Light being electromagnetic will be all transversely irrespective of the medium.

SECTION - D

Assertion-Reason Type Questions

1. A : Doppler's effect in sound is asymmetric but in light, it is symmetric.

   R : In sound, change in frequency depends on the individual velocity of both the source as well as the observer. In light, change in frequency depends on the relative velocity between source and observer.

Sol. Answer (2)

Doppler's effect in sound is different when the object is moving towards source and when source moves towards observer.

Hence it is asymmetric. Light is symmetric as it just depends on relative motion between the source and the object.

2. A : The propagation of sound in air should be an isothermal process.

   R : As air is bad conductor of heat, its temperature does not change by compression or expansion.

Sol. Answer (4)

The propagation of sound in air is an adiabatic process as very little sound energy get dissipated as heat.

Air may be a bad conductor of heat but its temperature does change when work is performed on it.

3. A : Velocity of sound in air increases with increase in humidity.

   R : Velocity of sound doesn't depend upon medium.

Sol. Answer (3)

$$v = \sqrt{\frac{\gamma P}{\rho}}$$

The ρ or density reduces because of presence of water vapour as both N_2 and O_2 are heavier than H_2O.

Velocity of sound, thus, depends largely on the medium.

4. A : Intensity of sound wave does not change when the listener moves towards or away from the stationary source.

   R : The motion of listener towards a stationary source causes an apparent change in wavelength of sound.

Sol. Answer (4)

Intensity of sound changes when observer moves towards are away from source because of change in frequency.

Motion of observers only causes change in frequency of sound and not the wavelength.

5. A : A vibrating tuning fork sounds louder when its stem is pressed against desk top.

   R : When a wave reaches another denser medium, part of the wave is reflected.

Sol. Answer (2)

When a vibrating tuning fork is held in hand only air is set into vibration. When its stem is placed in contact with the labels the entire labels is set into forced vibrations.

6. A : Longitudinal waves do not exhibit the phenomenon of polarisation.

   R : In longitudinal waves medium particle vibrate in direction normal to the wave propagation.

Sol. Answer (3)

Polarisation means redirecting a wave to propagate in only one plane.

The molecules in a longitudinal wave vibrate along the direction of propagation of wave and hence cannot be redirected by any material.

7. A : If a wave moving in a rarer medium, gets reflected at the boundary of a denser medium, then it encounters a sudden change in phase of π.

   R : If a wave propagating in a denser medium, gets reflected from rarer medium, then there will be no abrupt phase change.

Sol. Answer (2)

Both the statements are true but (2) does not give the correct explanation for (1).

8. A : Speed of sound in moist air is more than its speed in dry air.

   R : Dry air is denser than moist air at atmospheric pressure.

Sol. Answer (1)

Speed of sound in air is $v = \sqrt{\frac{\gamma P}{\rho}}$

When the air is humid, the density of air reduces as O_2 and N_2 are heavier than H_2O.

Hence speed of sound decreases.

9. A : Sound travels faster in solids as compared to liquids and gases.

   R : Solids are more elastic than liquids and gases.

Sol. Answer (1)

$$v = \sqrt{\frac{B}{\rho}}$$

Hence since the Bulk molecules of solids is higher the speed of sound is higher in solids.

Since 'B' is refer to bulk molecule.

Speed depends on elasticity and reason is correct explanation of assertion.

10. A : There is no energy transferred by standing waves.

    R : The total energy of standing waves is twice the energy of each of incident and reflected wave.

Sol. Answer (2)

Both statements are true but reason is not the correct explanation of each other.

11. A : In Doppler's effect the value of apparent frequency depends on the relative motion between source and observer.

R : The change in frequency in Doppler effect is independent from the distance between source and observer.

Sol. Answer (2)

Both the statements are true but reason does not explain the cause for assertion.

12. A : The pitch of female voice is higher than the pitch of male voice.

R : Pitch distinguishes between a shrill and a grave sound.

Sol. Answer (2)

The assertion is a true fact and so is the reason. But the reason offers no explanation for the assertion.

❑ ❑ ❑

Chapter 1

Electric Charges and Fields

Solutions

SECTION - A

Objective Type Questions

1. If a body has positive charge on it, then it means it has

(1) Gained some protons	(2) Lost some protons
(3) Gained some electrons	(4) Lost some electrons

Sol. Answer (4)

Due to lack of electron body get positive charge.

2. Sure check for presence of electric charge is

(1) Process of induction	(2) Repulsion between bodies
(3) Attraction between bodies	(4) Frictional force between bodies

Sol. Answer (2)

Due to similar (like charge), repulsion force is possible but attraction force may be due to uncharged body.

3. If a solid and a hollow conducting sphere have same radius then

(1) Hollow sphere will hold more maximum charge

(2) Solid sphere will hold more maximum charge

(3) Both the spheres will hold same maximum charge

(4) Both the sphere can’t hold charge

Sol. Answer (3)

Excess charge spread on outer surface only from their property.

4. When a conducting soap bubble is negatively charged then

(1) Its size starts varying arbitrarily	(2) It expands
(3) It contracts	(4) No change in its size takes place

Sol. Answer (2)

Due to repulsion force between diametrically opposite wall, it expands.

5. Five balls marked *a* to *e* are suspended using separate threads. Pairs (*b, c*) and (*d, e*) show electrostatic repulsion while pairs (*a, b*), (*c, e*) and (*a, e*) show electrostatic attraction. The ball marked *a* must be

(1) Negatively charged (2) Positively charged

(3) Uncharged (4) Any of the above is possible

Sol. Answer (3)

6. When a plastic rod rubbed with wool is brought near the knob of a negatively charged gold leaf electroscope, the gold leaves

(1) Contract (2) Dilate

(3) Start oscillating (4) Collapse completely

Sol. Answer (2)

7. Coulomb's law is analogous to

(1) Charge conservation law (2) Newton's second law of motion

(3) Law of conservation of energy (4) Newton's law of gravitation

Sol. Answer (4)

Coulomb's law and Newton's law of gravitation are inverse square law.

8. Two point charges Q_1 and Q_2 exert a force *F* on each other when kept certain distance apart. If the charge on each particle is halved and the distance between the two particles is doubled, then the new force between the two particles would be

(1) $\frac{F}{2}$ (2) $\frac{F}{4}$ (3) $\frac{F}{8}$ (4) $\frac{F}{16}$

Sol. Answer (4)

Given

$$F = \frac{KQ_1Q_2}{r^2} \quad \ldots\text{(i)}$$

if, $Q_1' = \frac{Q_1}{2}$

$Q_2' = \frac{Q_2}{2}$

& $r = 2r$

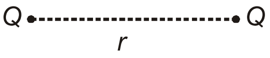
Then = $F_1' = \frac{F}{16}$

9. Two equally charged identical small balls kept some fixed distance apart exert a repulsive force *F* on each other. A similar uncharged ball, after touching one of them is placed at the mid-point of line joining the two balls. Force experienced by the third ball is

(1) $4F$ (2) $2F$ (3) F (4) $\frac{F}{2}$

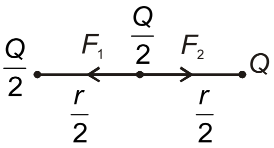
Sol. Answer (3)

First case :



$$F_1 = F = \frac{KQ^2}{r^2} \qquad \ldots\text{(i)}$$

Second case :



$$|F_{Net}| = |F_2 - F_1|$$

$$= \frac{K\,Q^2 4}{4.r^2} - \frac{K\,Q^2\ 4}{2r^2}$$

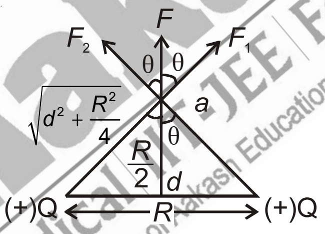
$$\frac{KQ^2}{r^2} = F$$

Force remain's constant

10. Two equal point charges *A* and *B* are *R* distance apart. A third point charge placed on the perpendicular bisector at a distance '*d*' from the centre will experience maximum electrostatic force when

(1) $d = \frac{R}{2\sqrt{2}}$ (2) $d = \frac{R}{\sqrt{2}}$ (3) $d = R\sqrt{2}$ (4) $d = 2\sqrt{2}R$

Sol. Answer (1)



$$F_1 = F_2 = \frac{KQ^2}{\left[d^2 + \frac{R^2}{4}\right]}$$

$F_N = F_1 \cos\theta + F_2 \cos\theta$

$= 2F_1 \cos\theta =$

$$F_N = 2.\frac{KQ^2}{\left(d^2 + \frac{R^2}{4}\right)}.\frac{d}{\left[d^2 + \frac{R^2}{4}\right]}\frac{1}{2}$$

If F = Maximum than $\frac{dF}{d\text{”}d'} = 0$

So we get $\alpha = \frac{R}{2\sqrt{2}}$

11. A charged gold leaf electroscope has its leaves apart by certain amount having enclosed air. When the electroscope is subjected to X-rays, then the leaves

(1) Further dilate (2) Start oscillating (3) Collapse (4) Remain unaltered

Sol. Answer (3)

12. Two equal positive charges Q are fixed at points $(a, 0)$ and $(-a, 0)$ on the x-axis. An opposite charge $-q$ at rest is released from point $(0, a)$ on the y-axis. The charge $-q$ will

(1) Move to infinity
(2) Move to origin and rest there
(3) Undergo SHM about the origin
(4) Execute oscillatory periodic motion but not SHM

Sol. Answer (4)

In question

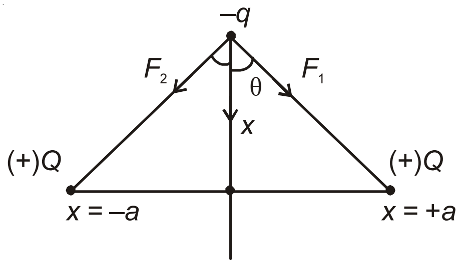
Net force on q is not proportional to (x)

as $F \propto (-x)$ [For SHM]

but Net force on q is

$$F = -\frac{K\, q.Q\, x}{\left(x^2+a^2\right)^{\frac{1}{2}}}$$

This is condition for periodic motion



13. Four charges each equal to Q are placed at the four corners of a square and a charge q is placed at the centre of the square. If the system is in equilibrium then the value of q is

(1) $\frac{Q}{2}(1+2\sqrt{2})$
(2) $\frac{-Q}{4}(1+2\sqrt{2})$
(3) $\frac{Q}{4}(1+2\sqrt{2})$
(4) $\frac{-Q}{2}(1+2\sqrt{2})$

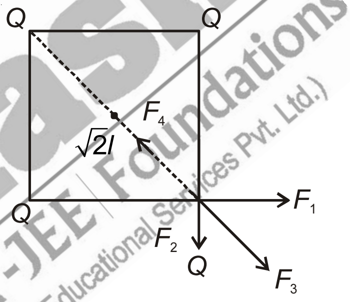
Sol. Answer (2)

Net force on Q due to other corner charge is

$$F_{123} = F_3 + \sqrt{F_1^2+F_2^2}$$

$$= F_3 + \sqrt{2}\, F_1$$

$$= \frac{KQ^2}{2l^2} + \frac{\sqrt{2}KQ^2}{l^2}$$



Force on Q_1 due to centre charge $-q$

$$F_4 = \frac{K\,Q\,q}{l^2}.2$$

If net force on corner charge Q is zero

Then

$$F_{123} + F_4 = 0$$

So $q = -\frac{Q}{4}\left[1+2\sqrt{2}\right]$

14. Which of the following is not true about electric charge?

(1) Charge on a body is always integral multiple of certain charge known as charge of electron
(2) Charge is a scalar quantity
(3) Net charge on an isolated system is always conserved
(4) Charge can be converted into energy and energy can be converted into charge

Sol. Answer (4)

A rest charge cannot be converted into energy.

15. What is the amount of charge possessed by 1 kg of electrons?

(1) 1.76×10^{11} C (2) 1.76×10^{-9} C (3) 1.76×10^{-7} C (4) 1.76×10^{-5} C

Sol. Answer (1)

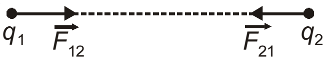
$\because m_e = 9.1 \times 10^{-31}\text{kg}$

$q_e = 1.6 \times 10^{-19}\text{C}$

So charge due to 1 kg electron

$$Q = \frac{1.6 \times 10^{-19}}{9.1 \times 10^{-31}} = 1.76 \times 10^{11} C$$

16. According to Coulomb's Law, which is correct relation for the following diagram?



(1) $q_1 q_2 < 0$ (2) $q_1 q_2 > 0$ (3) $q_1 q_2 = 0$ (4) $q_1 q_2 >> 100$ C

Sol. Answer (1)

Both charge should be unlike charge

$q_1 = +Q$, $q_2 = -Q$

So $q_1 q_2 = -Q^2$

So $q_1 q_2$ = Negative

So $q_1 q_2 < 0$

17. A charge q is to be distributed on two conducting spheres. What should be the value of the charges on the spheres so that the repulsive force between them is maximum when they are placed at a fixed distance from each other in air?

(1) $\frac{q}{2}$ and $\frac{q}{2}$ (2) $\frac{q}{4}$ and $\frac{3q}{4}$ (3) $\frac{q}{3}$ and $\frac{2q}{3}$ (4) $\frac{q}{5}$ and $\frac{4q}{5}$

Sol. Answer (1)

Force between both is

$$F = \frac{K\,Q(q-Q)}{r^2}$$

If F = maximum then

$$\frac{dF}{dQ} = 0$$

So $Q = \frac{q}{2}$

So both charge be $\frac{q}{2}, \frac{q}{2}$

18. A point charge q_1 exerts an electric force on a second point charge q_2. If third charge q_3 is brought near, the electric force of q_1 exerted on q_2

(1) Decreases

(2) Increases

(3) Remains unchanged

(4) Increases if q_3 is of same sign as q_1 and decreases if q_3 is of opposite sign

Sol. Answer (3)

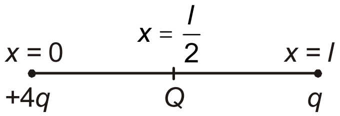
Electric force between '2' charge do not depend on the '3'rd charge.

19. Three charges +4q, Q and q are placed in a straight line of length l at points 0, $\frac{\ell}{2}$ and ℓ distance away from one end respectively. What should be Q in order to make the net force on q to be zero?

(1) $-q$ (2) $4q$ (3) $-\frac{q}{2}$ (4) $-2q$

Sol. Answer (1)

F_{Net} on q is



$$F = \frac{K.4q^3}{l^2} + \frac{KQq.4}{l^2}$$

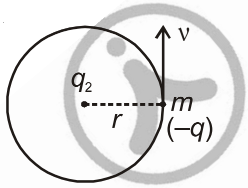
If $F = 0$ then

$Q = -q$

20. A particle of mass m and carrying charge $-q_1$ is moving around a charge $+q_2$ along a circular path of radius r. Find period of revolution of the charge $-q_1$

(1) $\sqrt{\frac{16\pi^3\varepsilon_0 mr^3}{q_1q_2}}$ (2) $\sqrt{\frac{8\pi^3\varepsilon_0 mr^3}{q_1q_2}}$ (3) $\sqrt{\frac{q_1q_2}{16\pi^3\varepsilon_0 mr^3}}$ (4) Zero

Sol. Answer (1)



$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}.\frac{q_1\,q_2}{r^2}$$

$$v = \left[\frac{1}{4\pi\varepsilon_0}\frac{q_1\,q_2}{rm}\right]^{\frac{1}{2}}$$

For 1 trip

$$T = \frac{2\pi r}{v} = 2\pi r\left[4\pi\varepsilon_0 mr\right]\left[q_1\,q_2\right]^{\frac{1}{2}}$$

$$T = \sqrt{\frac{16\pi^3\varepsilon_0 mr^3}{q_1\,q_2}}$$

21. Consider three point objects P, Q and R. P and Q repel each other, while P and R attract. What is the nature of force between Q and R?

(1) Repulsive force (2) Attractive force (3) No force (4) None of these

Sol. Answer (2)

22. Which of the following processes involves the principle of electrostatic induction?

(1) Pollination (2) Chocolate making (3) Xerox copying (4) All of these

Sol. Answer (4)

These are properties of electrostatic induction.

23. The electric field intensity at a point in vacuum is equal to

(1) Zero

(2) Force a proton would experience there

(3) Force an electron would experience there

(4) Force a unit positive charge would experience there

Sol. Answer (4)

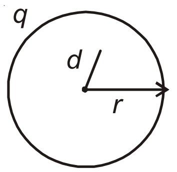
This is defination of electric field.

24. A sphere of radius r has electric charge uniformly distributed in its entire volume. At a distance d from the centre inside the sphere ($d < r$) the electric field intensity is directly proportional to

(1) $\frac{1}{d}$ (2) $\frac{1}{d^2}$ (3) d (4) d^2

Sol. Answer (3)

Electric field inside volume charge is given by



$$E = \frac{1}{4\pi\varepsilon_0}\ \frac{q\,d}{r^3}$$

$E \propto d$

25. The electric field at $2R$ from the centre of a uniformly charged non-conducting sphere of radius R is E. The electric field at a distance $\frac{R}{2}$ from the centre will be

(1) Zero (2) $2E$ (3) $4E$ (4) $16E$

Sol. Answer (2)

Given $E = \frac{Kq}{(2R)^2}$ …(i)

Then $E' = \frac{Kq.\frac{R}{2}}{R^3}$ …(ii)

Find $E^{'} = 2E$

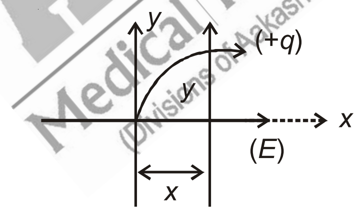
26. In a uniform electric field if a charge is fired in a direction different from the line of electric field then the trajectory of the charge will be a

(1) Straight line (2) Circle (3) Parabola (4) Ellipse

Sol. Answer (3)

$F = qE = m\ a_x$

$a_x = \left[\frac{qE}{m}\right]$



Then, $x = 0 + \frac{1}{2}a_x\ t^2$ …(i)

But $y = u_x t$ then $t = \frac{y}{ux}$

So, $x = \frac{1}{2}\frac{qE}{m}.\frac{y^2}{u^2}$

so $x \propto y^2$ for parabola

27. A positively charged pendulum is oscillating in a uniform electric field pointing upwards. Its time period as compared to that when it oscillates without electric field

(1) Is less (2) Is more (3) Remains unchanged (4) Starts fluctuating

Sol. Answer (2)

Effective g decreases.

28. How many electrons should be removed from a coin of mas 1.6 g, so that it may float in an electric field of intensity 10^9 N/C directed upward?

(1) 9.8×10^7 (2) 9.8×10^5 (3) 9.8×10^3 (4) 9.8×10^1

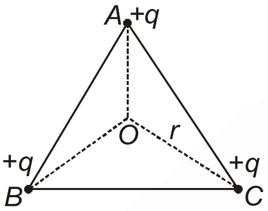
Sol. Answer (1)

$qE = mg$

$neE = mg$

Use $n = \dfrac{mq}{eE}$

29. *ABC* is an equilateral triangle. Charges +*q* are placed at each corner. The electric field intensity at the centroid of triangle will be



(1) $\dfrac{1}{4\pi\varepsilon_0}\times\dfrac{q}{r^2}$ (2) $\dfrac{1}{4\pi\varepsilon_0}\times\dfrac{3q}{r^2}$ (3) $\dfrac{1}{4\pi\varepsilon_0}\times\dfrac{q}{r}$ (4) Zero

Sol. Answer (4)

$F_N = 0$

30. A charge *Q* is placed at the centre of a square. If electric field intensity due to the charge at the corners of the square is E_1 and the intensity at the mid point of the side of square is E_2, then the ratio of $\dfrac{E_1}{E_2}$ will be

(1) $\dfrac{1}{2\sqrt{2}}$ (2) $\sqrt{2}$ (3) $\dfrac{1}{2}$ (4) 2

Sol. Answer (3)

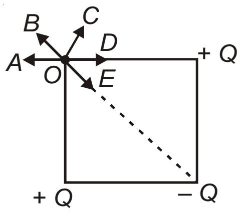
$$E_1 = \frac{1}{4\pi\varepsilon_0}\,\frac{Q^2}{l^2} \qquad \ldots\text{(i)}$$

$$E_2 = \frac{1}{4\pi\varepsilon_0}\,\frac{Q^4}{l^2}$$

$E_2 = 2E_1$

$$\frac{E_1}{E_2} = \frac{1}{2}$$

31. Point charges each of magnitude *Q* are placed at three corners of a square as shown in the diagram. What is the direction of the resultant electric field at the fourth corner?



(1) *OC* (2) *OE* (3) *OD* (4) *OB*

Sol. Answer (4)

Resultant force act along *OB*

32. Two charges e and $3e$ are placed at a distance r. The distance of the point where the electric field intensity will be zero is

(1) $\dfrac{r}{(1+\sqrt{3})}$ from $3e$ charge

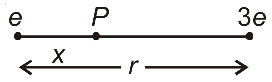
(2) $\dfrac{r}{(1+\sqrt{3})}$ from e charge

(3) $\dfrac{r}{(1-\sqrt{3})}$ from $3e$ charge

(4) $\dfrac{r}{1+\sqrt{\dfrac{1}{3}}}$ from e charge

Sol. Answer (2)

Net electric field at P is zero then



$O = E_1 - E_2$

$E_1 = E_2$

$$\frac{k\,e}{x^2} = \frac{k\,3e}{(r-x)^2}$$

so, $\dfrac{1}{x} = \dfrac{\sqrt{3}}{r-x}$

$r - x = \sqrt{3}x$

$r = x\left[1+\sqrt{3}\right]$

$x = \dfrac{r}{\left(1+\sqrt{3}\right)}$

33. If electric lines of force in a region are represented as shown in the figure, then one can conclude that, electric field is

(1) Non-uniform

(2) Uniform

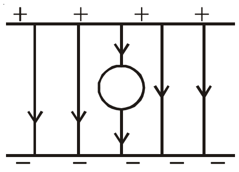
(3) Both uniform and non-uniform

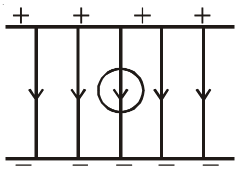
(4) Zero everywhere

Sol. Answer (1)

Diverging electric line of force denote non-uniform electric field.

34. An uncharged sphere of metal is placed in a uniform electric field produced by two oppositely charged plates. The lines of force will appear as

(1)


(2)


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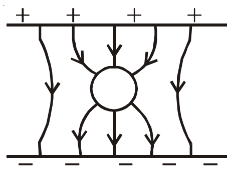
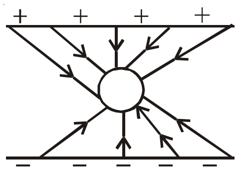


(4)


Sol. Answer (3)

35. An electron released on the axis of a positively charged ring at a large distance from the centre will

(1) Not move (2) Do oscillatory motion (3) Do SHM (4) Do non periodic motion

Sol. Answer (2)

$$F_N = -q.\frac{k\ Q\ x}{\left(x^2+r^2\right)^{\frac{3}{2}}}$$

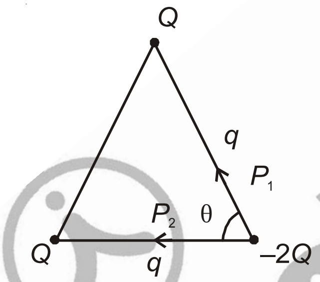
For SHM

F ∝ $(-x)$

36. Electric charge Q, Q and $-2Q$ respectively are placed at the three corners of an equilateral triangle of side a. Magnitude of the electric dipole moment of the system is

(1) $\sqrt{2}Qa$ (2) $\sqrt{3}Qa$ (3) Qa (4) $2Qa$

Sol. Answer (2)



$P_1 = Q.a$

$P_2 = Q.a$

$$P = \sqrt{P_1^2 + P_2^2 + 2P_1P_2\cos\theta}$$

$$P_N = \sqrt{3}\ Q.a$$

37. An electric dipole placed in a uniform electric field experiences maximum moment of couple when the dipole is placed

(1) Against the direction of the field (2) Towards the electric field

(3) Perpendicular to the direction of the field (4) At 135° to the direction of the field

Sol. Answer (3)

$\tau = PE\sin\theta$

For $\theta = 90°$

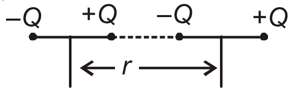
τ = Max.

38. Force of interaction between two co-axial short electric dipoles whose centres are R distance apart varies as

(1) $\frac{1}{R}$ (2) $\frac{1}{R^2}$ (3) $\frac{1}{R^3}$ (4) $\frac{1}{R^4}$

Sol. Answer (4)

$$F = \frac{K\ 6P_1P_2}{r^4}$$



39. Two charges of $+25 \times 10^{-9}$ coulomb and -25×10^{-9} coulomb are placed 6 m apart. Find the electric field intensity ratio at points 4 m from the centre of the electric dipole (i) on axial line (ii) on equatorial line

(1) $\frac{1000}{49}$ (2) $\frac{49}{1000}$ (3) $\frac{500}{49}$ (4) $\frac{49}{500}$

Sol. Answer (1)

$$E_{\text{axial}} = \frac{k.2Pr}{\left(r^2 - l^2\right)^2} \quad \text{...(i)}$$

$$E_{\text{eq.}} = \frac{k.p}{\left(r^2 + l^2\right)^{\frac{3}{2}}} \quad \text{...(ii)}$$

Find $\frac{E_{\text{axial}}}{E_{eq}} = \frac{1000}{49}$

40. The electric force on a point charge situated on the axis of a short dipole is F. If the charge is shifted along the axis to double the distance, the electric force acting will be

(1) $4F$ (2) $\frac{F}{2}$ (3) $\frac{F}{4}$ (4) $\frac{F}{8}$

Sol. Answer (4)

$F \propto \frac{1}{r^3}\left[F \propto \frac{1}{r^3}\right]$

If $r_1 = 2r$

Then force become $\frac{F}{8}$

41. An electric dipole is placed at an angle 60° with an electric field of strength 4×10^5 N/C. It experiences a torque equal to $8\sqrt{3}$ Nm. Calculate the charge on the dipole, if dipole is of length 4 cm

(1) 10^{-1} C (2) 10^{-2} C (3) 10^{-3} C (4) 10^{-4} C

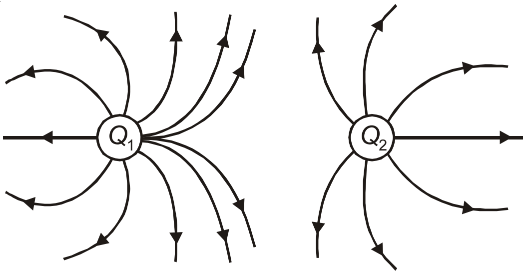
Sol. Answer (3)

$\tau = PE \sin\theta$

$8\sqrt{3} = \left[q \times 4 \times 10^{-2}\right].\, 4 \times 10^5 \sin 60°$

find $q = 10^{-3}$

42. Figure shows electric lines of forces due to charges Q_1 and Q_2. Hence

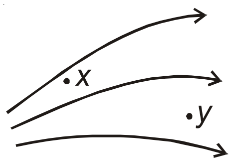


(1) Q_1 and Q_2 both are negative (2) Q_1 and Q_2 both are positive

(3) $Q_1 > Q_2$ (4) Both (2) & (3)

Sol. Answer (4)

43. Figure shows electric lines of force. If E_x and E_y are the magnitudes of electric field at points x and y respectively, then



(1) $E_x > E_y$ (2) $E_x = E_y$ (3) $E_x < E_y$ (4) Any of these

Sol. Answer (1)

44. A charge q is situated at the centre of a cube. Electric flux through one of the faces of the cube is

(1) $\frac{q}{\varepsilon_0}$ (2) $\frac{q}{3\varepsilon_0}$ (3) $\frac{q}{6\varepsilon_0}$ (4) Zero

Sol. Answer (3)

$$\phi_{\text{Total}}\left[\text{of 6 surface}\right]=\frac{q}{\varepsilon_0}$$

$$\phi_{\text{One surface}}=\frac{q}{6\varepsilon_0}$$

45. A charge Q is placed at the centre of the open end of a cylindrical vessel. Electric flux through the surface of the vessel is

(1) $\frac{q}{2\varepsilon_0}$ (2) $\frac{q}{\varepsilon_0}$ (3) $\frac{2q}{\varepsilon_0}$ (4) Zero

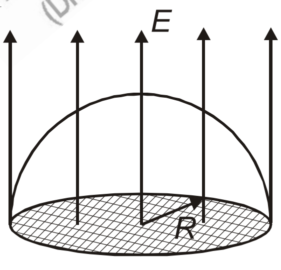
Sol. Answer (1)

If charge Q is surrounded with two cylinder then flux of '2' cylinder is

$$\phi=\frac{q}{\varepsilon_0}$$

Flux of one cylinder = $\frac{q}{2\varepsilon_0}$

46. A hemispherical surface of radius R is kept in a uniform electric field E as shown in figure. The flux through the curved surface is



(1) $E2\pi R^2$ (2) $E\pi R^2$ (3) $E4\pi R^2$ (4) Zero

Sol. Answer (2)

$q_{\text{Net}} = 0$ So $\phi_{\text{Net}} = 0$

$\phi_{\text{in}} + \phi_{\text{out}} = 0$

$\phi_{\text{out}} = -\phi_{\text{in}} = -[E.\pi R^2\cos 180°]$

$= E.\pi R^2$

47. Total electric flux associated with unit positive charge in vacuum is

(1) $4\pi\varepsilon_0$ (2) $\dfrac{1}{4\pi\varepsilon_0}$ (3) $\dfrac{1}{\varepsilon_0}$ (4) ε_0

Sol. Answer (3)

$\phi = \dfrac{q}{\varepsilon_0}$ for $q = 1$

$\phi = \dfrac{1}{\varepsilon_0}$

48. A charged body has an electric flux F associated with it. Now if the body is placed inside a conducting shell then the electric flux outside the shell is

(1) Zero (2) Greater than F (3) Less than F (4) Equal to F

Sol. Answer (4)

Charge remains constant so flux remains constant.

49. A cylinder of radius R and length L is placed in a uniform electric field E parallel to the cylinder axis. The outward flux over the surface of the cylinder is given by

(1) $2\pi R^2E$ (2) $\dfrac{\pi R^2E}{2}$ (3) $2\pi RLE$ (4) πR^2E

Sol. Answer (4)

Not net flux only outward flux

$\phi = E\pi R^2$

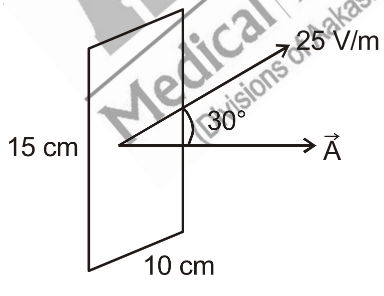
50. A rectangular surface of sides 10 cm and 15 cm is placed inside a uniform electric field of 25 V/m, such that the surface makes an angle of 30° with the direction of electric field. Find the flux of the electric field through the rectangular surface

(1) 0.1675 N/m^{2}C (2) 0.1875 Nm^2/C (3) Zero (4) 0.1075 Nm^2/C

Sol. Answer (2)

$\phi = EA\cos 30°$

$= 0.1875$ Nm^2/C



51. If an electric field is given by $10\hat{i} + 3\hat{j} + 4\hat{k}$, calculate the electric flux through a surface of area 10 units lying in yz plane

(1) 100 units (2) 10 units (3) 30 units (4) 40 units

Sol. Answer (1)

$\vec{E} = 10\hat{i} + 3\hat{j} + 4\hat{k}$

$\vec{A} = 10\hat{i}$

So, $\phi = \vec{E}.\vec{A} = 100$ unit

52. The electric field in a region is radially outward and at a point is given by $E = 250\ r$ V/m (where r is the distance of the point from origin). Calculate the charge contained in a sphere of radius 20 cm centred at the origin

(1) 2.22×10^{-6} C (2) 2.22×10^{-8} C (3) 2.22×10^{-10} C (4) Zero

Sol. Answer (3)

$$E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q}{r^2}$$

$$250r = \frac{9 \times 10^9 . Q}{r^2}$$

Use $r = 20 \times 10^{-2}$ m

Find Q = ?

$Q = 2.22 \times 10^{-10}$ C

53. There is uniform electric field of $8 \times 10^3 \hat{i}$ N/C. What is the net flux (in SI units) of the uniform electric field through a cube of side 0.3 m oriented so that its faces are parallel to the coordinate plane?

(1) $2 \times 8 \times 10^3$ (2) $0.3 \times 8 \times 10^3$ (3) Zero (4) $8 \times 10^6 \times 6$

Sol. Answer (3)

$\vec{E} = 8 \times 10^3\ \hat{i}$ N/C (Uniform)

here $q = 0$

So $\phi = 0$

54. A charge Q is kept at the corner of a cube. Electric flux passing through one of those faces not touching that charge is

(1) $\frac{Q}{24\varepsilon_0}$ (2) $\frac{Q}{3\varepsilon_0}$ (3) $\frac{Q}{8\varepsilon_0}$ (4) $\frac{Q}{6\varepsilon_0}$

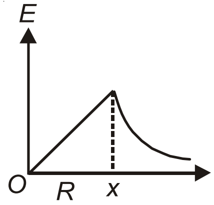
Sol. Answer (1)

$$\phi_{\text{Net}} = \frac{q}{8\varepsilon_0} \text{ (Of 3 surface)}$$

$$\phi_{\text{One surface}} = \frac{q}{24\varepsilon_0}$$

55. An isolated solid metal sphere of radius R is given an electric charge. Which of the graphs below best shows the way in which the electric field E varies with distance x from the centre of the sphere?

(1)



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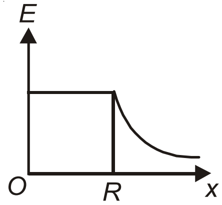

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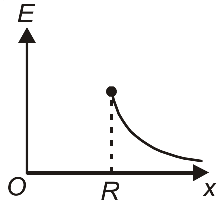

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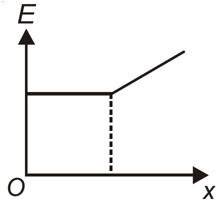


Sol. Answer (3)

$$E_{\text{outside}} = \frac{k\,q}{r^2}$$

$E_{\text{inside}} = 0$

56. The electric field intensity at P and Q, in the shown arrangement, are in the ratio

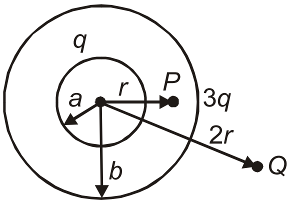


Fig.: Hollow concentric shell

(1) 1 : 2 (2) 2 : 1 (3) 1 : 1 (4) 4 : 3

Sol. Answer (3)

$$E_P = \frac{k\,q}{r^2} \qquad \ldots\text{(i)}$$

$$E_Q = \frac{k\,q}{(2r)^2} + \frac{k.3q}{(2r)^2}$$

$$= \frac{k\,q}{4r^2} + \frac{k.3q}{4r^2}$$

$$= \frac{k\,q}{r^2} \qquad \ldots\text{(ii)}$$

$E_P : E_Q = 1 : 1$

57. Consider an atom with atomic number Z as consisting of a positive point charge at the centre and surrounded by a distribution of negative electricity uniformly distributed within a sphere of radius R. The electric field at a point inside the atom at a distance r from the centre is

(1) $\frac{Ze}{4\pi\varepsilon_0}\left[\frac{1}{r^2} - \frac{r}{R^3}\right]$ (2) $\frac{Ze}{4\pi\varepsilon_0}\left[\frac{1}{r^2} + \frac{1}{R^3}\right]$ (3) $\frac{2Ze}{4\pi\varepsilon_0 r^2}$ (4) Zero

Sol. Answer (1)

$E = E_1 - E_2$

$$E = \frac{k.ze}{r^2} - \frac{k\,zer}{R^3}$$

58. An electron is rotating around an infinite positive linear charge in a circle of radius 0.1 m, if the linear charge density is 1 μC/m, then the velocity of electron in m/s will be

(1) 0.562×10^7 (2) 5.62×10^7 (3) 562×10^7 (4) 0.0562×10^7

Sol. Answer (2)

$$\frac{mv^2}{r} = q\,E$$

$$\frac{mv^2}{r} = e.\frac{\lambda}{2\pi\varepsilon_0 r}$$

$$v = 5.62 \times 10^7 \text{ m/s}$$

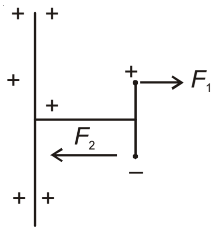
59. A dipole with an electric moment $\vec{p}$ is located at a distance r from a long thread charged uniformly with a linear charge density λ. Find the force F acting on the dipole if the vector $\vec{p}$ is oriented along the thread

(1) $\frac{p\lambda}{2\pi\varepsilon_0 r^2}$ (2) $\frac{p\lambda}{2\pi\varepsilon_0 r}$ (3) $\frac{p}{2\pi\varepsilon_0 r\lambda}$ (4) Zero

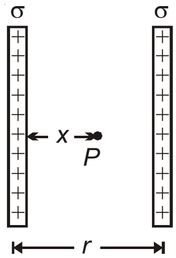
Sol. Answer (4)

$F_1 = F_2$

So, $F_N = 0$



60. For two infinitely long charged parallel sheets, the electric field at P will be



(1) $\frac{\sigma}{2x} - \frac{\sigma}{2(r-x)}$ (2) $\frac{\sigma}{2\varepsilon_0 x} + \frac{\sigma}{2\pi(r-x)\varepsilon_0}$

(3) $\frac{\sigma}{\varepsilon_0}$ (4) Zero

Sol. Answer (4)

$$E_N = E_1 - E_2 = \frac{\sigma}{2\varepsilon_0} - \frac{\sigma}{2\varepsilon_0} = 0$$

SECTION - B

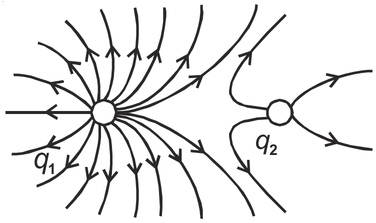
Objective Type Questions

1. Select the correct statement about electric charge
   (1) Charge can be converted into energy and energy can be converted into charge
   (2) Charge of a particle increases with increase in its velocity
   (3) Charge on a body is always integral multiple of a certain charge called charge of electron
   (4) Charge on a body is always positive or zero

Sol. Answer (3)

Quantization of charge.

2. Figure shows electric field lines due to a charge configuration, from this we conclude that



(1) q_1 and q_2 are positive and $q_2 > q_1$ (2) q_1 and q_2 are positive and $q_1 > q_2$

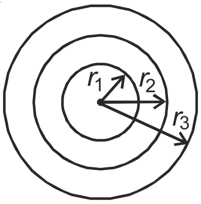
(3) q_1 and q_2 are negative and $|q_1| > |q_2|$ (4) q_1 and q_2 are negative and $|q_2| > |q_1|$

Sol. Answer (2)

(i) Electric field lines originates from positive charge.

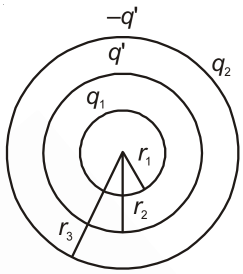
(ii) Higher the number of field lines originating from positive charge, greater is magnitude of charge.

3. Figure shows three concentric metallic spherical shells. The outermost shell has charge q_2, the inner most shell has charge q_1, and the middle shell is uncharged. The charge appearing on the inner surface of outermost shell is



(1) $q_1 + q_2$ (2) $\frac{q_2}{2}$ (3) $-q_1$ (4) Zero

Sol. Answer (3)



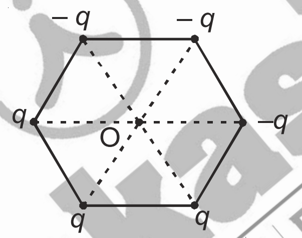
Suppose a guassian surface passes through conducting shell with radius (r_3)

Flux through it well be zero. So, net charge enclosed must be zero.

$\therefore q_1 + q' = 0$

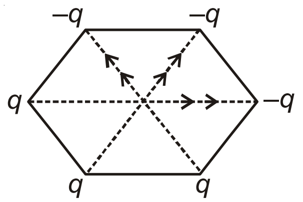
$q' = -q_1$

4. Six point charges are placed at the vertices of a hexagon of side 1m as shown in figure. Net electric field at the centre of the hexagon is



(1) Zero (2) $\frac{6q}{4\pi\varepsilon_0}$ (3) $\frac{q}{\pi\varepsilon_0}$ (4) $\frac{q}{4\pi\varepsilon_0}$

Sol. Answer (3)



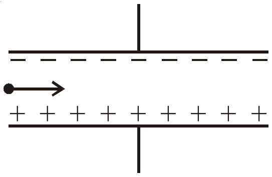
Electric field at O due to each charge is $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{(1)^2}$

So, net electric field (E_{net}) is,

$$\Rightarrow E_{net} = \sqrt{E^2 + E^2 + 2E^2\cos 120^\circ} + 2E$$

$$\Rightarrow E_{net} = 4E = \frac{q}{\pi\varepsilon_0}$$

5. A proton and an α-particle having equal kinetic energy are projected in a uniform transverse electric field as shown in figure



(1) Proton trajectory is more curved

(2) α-particle trajectory is more curved

(3) Both trajectories are equally curved but in opposite direction

(4) Both trajectories are equally curved and in same direction

Sol. Answer (2)

α-particle has more charge than proton

$\therefore$ Strong electric force on α-particle and more curved path.

6. Electric field in a region is uniform and is given by $\vec{E} = a\hat{i} + b\hat{j} + c\hat{k}$. Electric flux associated with a surface of area $\vec{A} = \pi R^2 \hat{i}$ is

(1) $a\pi R^2$ (2) $3a\pi R^2$ (3) $2abR$ (4) acR

Sol. Answer (1)

$$\phi = \vec{E}.\vec{A} = a\pi R^2$$

7. Which of the following is not true about electric charge?

(1) Charge is a scalar quantity

(2) Charge on an isolated system is always conserved

(3) A particle having nonzero rest mass can have zero charge

(4) A particle having zero rest mass can have non zero charge

Sol. Answer (4)

Charge is always associated with mass

∴ particle with zero rest mass can never have a charge.

8. If ε_0 is permittivity of free space, e is charge of proton, G is universal gravitational constant and m_p is mass of a proton then the dimensional formula for $\dfrac{e^2}{4\pi\varepsilon_0 G m_p^2}$ is

(1) $[M^1L^1T^{-3}A^{-1}]$ (2) $[M^0L^0T^0A^0]$ (3) $[M^1L^3T^{-3}A^{-1}]$ (4) $[M^{-1}L^{-3}T^4A^2]$

Sol. Answer (2)

Gravitational force $F_1 = \dfrac{GM_P^2}{r^2}$

Electrostatic force $F_2 = \dfrac{1}{4\pi\varepsilon_0}\dfrac{e^2}{r^2}$

$$\frac{F_2}{F_1} = \frac{e^2}{4\pi\varepsilon_0 G M_P^2}$$

∴ Dimension less $[M^\circ L^\circ T^\circ A^\circ]$

9. Two positive point charges of unequal magnitude are placed at a certain distance apart. A small positive test charge is placed at null point, then

(1) The test charge is in unstable equilibrium (2) The test charge is in stable equilibrium

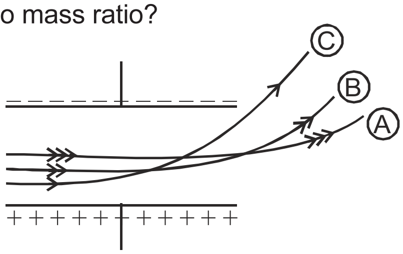
(3) The test charge is in neutral equilibrium (4) The test charge is not in equilibrium

Sol. Answer (1)

When charge is displaced above, it gets repelled and move away from null point.

Hence, unstable equilibrium.

10. Three particles are projected in a uniform electric field with same velocity perpendicular to the field as shown. Which particle has highest charge to mass ratio?



(1) A (2) B

(3) C (4) All have same charge to mass ratio

Sol. Answer (3)

Charge with maximum curved path has highest charge to mass ratio.

11. An infinite line charge is at the axis of a cylinder of length 1 m and radius 7 cm. If electric field at any point on the curved surface of cylinder is 250 NC^{-1}, then net electric flux through the cylinder is

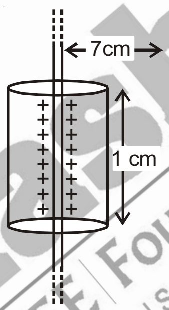
(1) 1.1×10^2 Nm^2 C^{-1} (2) 9.74×10^{-6} Nm^2 C^{-1} (3) 5.5×10^6 Nm^2 C^{-1} (4) 2.5×10^2 Nm^2 C^{-1}

Sol. Answer (1)

Charge enclosed is $(q) = \lambda(1)$

$$E = \frac{\lambda}{2\pi\varepsilon_0(0.07)} = 250$$

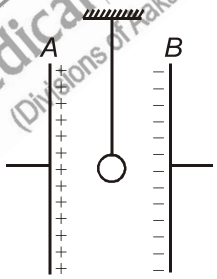
So, $\lambda = 500(0.07)\pi\varepsilon_0$



Electric flux through cylinder = $\dfrac{q}{\varepsilon_0}$ = 500 (0.07)ε_0

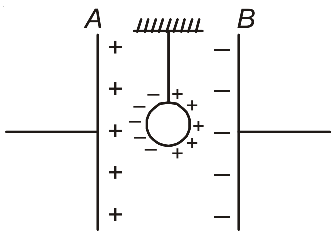
$\simeq 1.1 \times 10^2$ Nm^2 C^{-1}

12. A small conducting sphere is hanged by an insulating thread between the plates of a parallel plate capacitor as shown in figure. The net force on the sphere is



(1) Towards plate *A* (2) Towards plate *B* (3) Upwards (4) Zero

Sol. Answer (4)



Net force on sphere will be zero.

13. Which of the following is not the unit of charge?

(1) Farad (2) Coulomb (3) Stat coulomb (4) Faraday

Sol. Answer (1)

Farad is not a unit of charge

14. If two charges of 1 coulomb each are placed 1 km apart, then the force between them will be

(1) 9×10^3 N (2) 9×10^{-3} N (3) 9×10^{-4} N (4) 10^{-6} N

Sol. Answer (1)

$$F = \frac{9\times10^9(1)(1)}{(1000)^2} = 9\times10^3\text{N}$$

15. The magnitude of electric field strength *E* such that an electron placed in it would experience an electrical force equal to its weight is given by

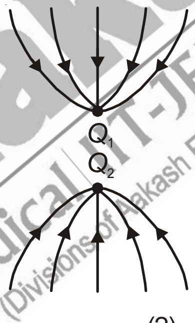
(1) mge (2) $\frac{mg}{e}$ (3) $\frac{e}{mg}$ (4) $\frac{e^2g}{2m}$

Sol. Answer (2)

$mg = eE$

$$E = \frac{mg}{e}$$

16. The figure shown is a plot of electric field lines due to two charges Q_1 and Q_2. The sign of charges is



(1) Both negative (2) Q_1 positive and Q_2 negative

(3) Both positive (4) Q_1 negative and Q_2 positive

Sol. Answer (1)

Electric field lines terminates at negative charge

17. The figure shows electric field lines. If E_A and E_B are electric fields at *A* and *B* and distance *AB* is *r*, then

(1) $E_A > E_B$ (2) $E_A = E_B/r$ (3) $E_A < E_B$ (4) $E_A = E_B/r^2$

Sol. Answer (1)

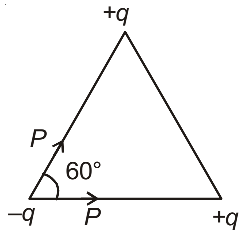
$E_A > E_B$

→ Closes the electric field lines, stronger is electric field.

18. Electric charge q, q and $-2q$ are placed at the corners of an equilateral triangle ABC of side L. The magnitude of electric dipole moment of the system is

(1) qL (2) $2qL$ (3) $\sqrt{3}qL$ (4) $4qL$

Sol. Answer (3)



$P = qL$

$$P_{net} = \sqrt{P^2 + P^2 + 2P^2 \cos 60°}$$

$$P_{net} = \sqrt{3}P = \sqrt{3}qL$$

19. A given charge situated at a certain distance from a short electric dipole in the end on position experience a force F. If the distance of the charge is doubled, the force acting on the charge will be

(1) $2F$ (2) $\frac{F}{2}$ (3) $\frac{F}{4}$ (4) $\frac{F}{8}$

Sol. Answer (4)

$F = qE$ and $E \propto \frac{1}{r^3}$

on doubling the distance

$$E' = \frac{E}{8}$$

So, $F' = \frac{F}{8}$

20. The torque τ acting on an electric dipole of dipole moment $\vec{p}$ in an electric field $\vec{E}$ is

(1) $\vec{\tau} = \vec{p} \cdot \vec{E}$ (2) $\vec{\tau} = \vec{p} \times \vec{E}$ (3) $\vec{\tau} = p\vec{E}$ (4) $\vec{\tau} = \vec{p}E$

Sol. Answer (2)

$$\vec{\tau} = \vec{P} \times \vec{E}$$

21. An electric dipole consists of two opposite charges each of magnitude 1μC separated by a distance of 2 cm. The dipole is placed in an external field of 10^5 N/C. The maximum torque on the dipole is

(1) 2×10^{-4} N m (2) 2×10^{-3} N m (3) 4×10^{-3} N m (4) 10^{-3} N m

Sol. Answer (2)

Max. torque $\tau_{max} = pE \sin 90°$

$= (1 \times 10^{-6})(2 \times 10^{-2})(10^5)$

$= 2 \times 10^{-3}$ Nm

22. A charge Q is situated at the centre of a cube. The electric flux through one of the faces of the cube is

(1) $\frac{Q}{\varepsilon_0}$ (2) $\frac{Q}{2\varepsilon_0}$ (3) $\frac{Q}{4\varepsilon_0}$ (4) $\frac{Q}{6\varepsilon_0}$

Sol. Answer (4)

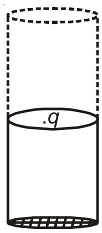
Total flux through cube $(\phi) = \frac{Q}{\varepsilon_0}$ (Six surfaces)

Flux through each face = $\frac{Q}{6\varepsilon_0}$

23. A charge q is placed at the centre of the open end of a cylindrical vessel. The flux of the electric field through the surface of the vessel is

(1) Zero (2) $\frac{q}{\varepsilon_0}$ (3) $\frac{q}{2\varepsilon_0}$ (4) $\frac{2q}{\varepsilon_0}$

Sol. Answer (3)



Total flux through the cylindrical gaussian surface = $\frac{q}{\varepsilon_0}$

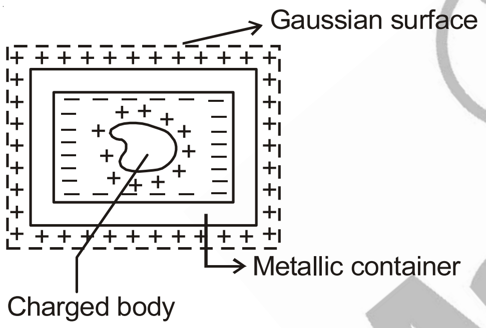
Flux through open cylinder = $\frac{1}{2}$(Total flux)

$= \frac{q}{2\varepsilon_0}$

24. A charged body has an electric flux ϕ associated with it. The body is now placed inside a metallic container. The flux ϕ, outside the container will be

(1) Zero (2) Equal to ϕ (3) Greater than ϕ (4) Less than ϕ

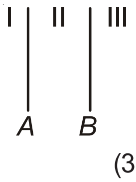
Sol. Answer (2)



As same charge is enclosed

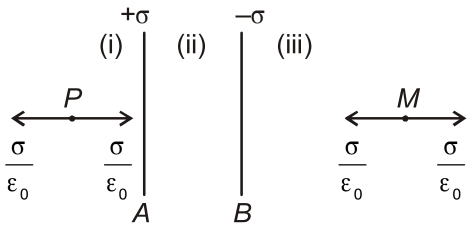
→ Same flux outside the container

25. The given figure shows, two parallel plates A and B of charge densities $+\sigma$ and $-\sigma$ respectively. Electric intensity will be zero in region



(1) I only (2) II only (3) III only (4) Both (1) & (3)

Sol. Answer (4)



At points P and M is zero.

26. If the electric field intensity in a fair weather atmosphere is 100 V/m, then the total charge on the earth's surface is (radius of the earth is 6400 km)

(1) 4.55×10^7 C (2) 4.55×10^8 C (3) 4.55×10^5 C (4) 4.55×10^6 C

Sol. Answer (3)

$$E = 100\frac{\text{V}}{\text{m}} \quad R = 6400 \text{ km}$$

By Gauss law

$$EA = \frac{q}{\varepsilon_0} \Rightarrow q = EA\varepsilon_0$$

$$\Rightarrow q = 200\left(4\pi\left(6400\times10^3\right)^2\right)\times 8.85\times10^{-12}$$

$\Rightarrow q = 4.55 \times 10^5$ C

27. A sphere of radius R has a uniform distribution of electric charge in its volume. At a distance x from its centre for $x < R$, the electric field is directly proportional to

(1) $\frac{1}{x^2}$ (2) $\frac{1}{x}$ (3) x (4) x^2

Sol. Answer (3)

In non-conducting sphere,

If $x < R$ (radius)

then $E = \frac{kQx}{R^3}$

Or $E \propto x$

28. The electric field at 20 cm from the centre of a uniformly charged non-conducting sphere of radius 10 cm is E. Then at a distance 5 cm from the centre it will be

(1) 16 E (2) 4 E (3) 2 E (4) Zero

Sol. Answer (3)

R = 10 cm, r = 20 cm

$$E = \frac{kQ}{(0.2)^2}$$

Now at r = 5 cm

$$E' = \frac{kQ(0.05)}{(0.1)^3}$$

Now, $\frac{E'}{E} = \frac{(0.05)}{(0.1)^3}(0.2)^2 = 2$

$E' = 2E$

29. When two particles having charges q_1 and q_2 are kept at a certain distance, they exert a force F on each other. If the distance between the particles is reduced to half and the charge on each particle is doubled then the force between the particles would be

(1) $2F$ (2) $4F$ (3) $8F$ (4) $16F$

Sol. Answer (4)

$$F = \frac{kq_1q_2}{r^2}$$

Now, $F' = \dfrac{k(2q_1)(2q_2)}{\left(\dfrac{r}{2}\right)^2}$

$$F' = 8\left[\frac{kq_1\,q_2}{r^2}\right] = 8\text{ F}$$

30. Charge $2Q$ and $-Q$ are placed as shown in figure. The point at which electric field intensity is zero will be somewhere

(1) Between $-Q$ and $2Q$

(2) On the left of $-Q$

(3) On the right of 2Q

(4) On the perpendicular bisector of line joining the charges

Sol. Answer (2)

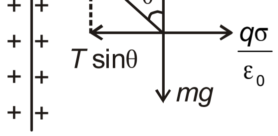
In case of two charges of opposite polarity, neutral point always lies outside the line joining charges and closes to smaller magnitude charge.

31. If a small sphere of mass m and charge q is hung from a silk thread at an angle θ with the surface of a vertical charged conducting plate, then for equilibrium of sphere, the surface charge density of the plate is

(1) $\varepsilon_0\left(\dfrac{mg}{q}\right)\tan\theta$ (2) $\varepsilon_0\left(\dfrac{2mg}{q}\right)\tan\theta$ (3) $\varepsilon_0(mgq)\tan\theta$ (4) $\varepsilon_0\left(\dfrac{mg}{3q}\right)\tan\theta$

Sol. Answer (1)

$$\frac{T\sin\theta}{T\cos\theta} = \frac{q\sigma/\varepsilon_0}{mg}$$



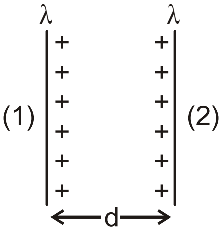
$$\tan\theta = \frac{q\sigma}{\varepsilon_0 mg}$$

$$\sigma = \frac{\varepsilon_0 mg\tan\theta}{q}$$

32. Two long thin charged rods with charge density λ each are placed parallel to each other at a distance *d* apart. The force per unit length exerted on one rod by the other will be $\left(\text{where } k = \frac{1}{4\pi\varepsilon_0}\right)$

(1) $\frac{k2\lambda}{d}$ (2) $\frac{k2\lambda^2}{d}$ (3) $\frac{k2\lambda}{d^2}$ (4) $\frac{k2\lambda^2}{d^2}$

Sol. Answer (2)



Electric field due to rod (1) at distance '*d*' = $\frac{\lambda}{2\pi\varepsilon_0 d}$

So, force per unit length $\frac{F}{l} = \frac{qE}{l} = \lambda\left[\frac{\lambda}{2\pi\varepsilon_0 d}\right]$

$$= \frac{k2\lambda^2}{d}$$

33. The dimensional formula of linear charge density λ is

(1) $[\mathrm{M^{-1}L^{-1}T^{+1}A}]$ (2) $[\mathrm{M^{0}L^{-1}T^{+1}A}]$ (3) $[\mathrm{M^{-1}L^{-1}T^{+1}A^{-1}}]$ (4) $[\mathrm{M^{0}L^{-1}T^{+1}A^{-1}}]$

Sol. Answer (2)

Linear charge density (λ) = $\frac{Q}{L}$

$$\lambda = \frac{[AT]}{[L]} = \left[\mathrm{M^0L^{-1}\ T^1A^1}\right]$$

34. Two isolated metallic spheres of radii 2 cm and 4 cm are given equal charge, then the ratio of charge density on the surfaces of the spheres will be

(1) 1 : 2 (2) 4 : 1 (3) 8 : 1 (4) 1 : 4

Sol. Answer (2)

Surface charge density (σ) = $\frac{Q}{4\pi r^2}$

$$\sigma \propto \frac{1}{r^2}$$

$$\therefore\ \frac{\sigma_1}{\sigma_2} = \frac{r_2^2}{r_1^2} = \frac{4^2}{2^2} = \frac{4}{1}$$

35. If the number of electric lines of force emerging out of a closed surface is 1000, then the charge enclosed by the surface is

(1) 8.854×10^{-9} C (2) 8.854×10^{-4} C (3) 8.854×10^{-1} C (4) 8.854 C

Sol. Answer (1)

$$\phi = 1000 = \frac{q}{\varepsilon_0}$$

$q = 8.854 \times 10^{-12} \times 1000$

$q = 8.854 \times 10^{-9}$C

36. A charge of 1 coulomb is located at the centre of a sphere of radius 10 cm and a cube of side 20 cm. The ratio of outgoing flux from the sphere and cube will be

(1) More than one (2) Less than one

(3) One (4) Nothing certain can be said

Sol. Answer (3)

If charge inclosed same, electric flux will be same.

37. Gauss's law can help in easy calculation of electric field due to

(1) Moving charge only (2) Any charge configuration

(3) Any symmetrical charge configuration (4) Some special symmetric charge configuration

Sol. Answer (4)

For easy calculation of electric field using Gauss' law, gaussian surfaces having some special symmetry with respect to charge configuration is used.

38. An electric dipole when placed in a uniform electric field E will have minimum potential energy, when the angle made by dipole moment with field E is

(1) π (2) $\frac{3\pi}{2}$ (3) Zero (4) $\frac{\pi}{2}$

Sol. Answer (3)

$U = -pE\cos\theta$

For $U_{\min}$ $\theta = 0°$ So, $U_{\min} = -pE$

39. An electric dipole is placed in non-uniform electric field. It may experience

(1) Resultant force and couple (2) Only resultant force

(3) Only couple (4) All of these

Sol. Answer (4)

Electric dipole in non uniform $\vec{E}$ may experience force, or couple.

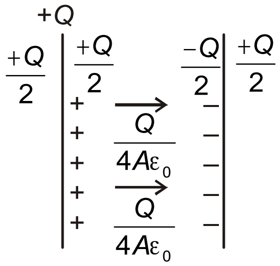
40. Each of two large conducting parallel plates has one sided surface area A. If one of the plates is given a charge Q whereas the other is neutral, then the electric field at a point in between the plates is given by

(1) $\frac{Q}{A\varepsilon_0}$ (2) $\frac{Q}{2A\varepsilon_0}$ (3) $\frac{Q}{4A\varepsilon_0}$ (4) Zero

Sol. Answer (2)

$$E_{net} = \frac{Q}{4A\varepsilon_0} \times 2$$

$$= \frac{Q}{4A\varepsilon_0}$$



41. If atmospheric electric field is approximately 150 volt/m and radius of the earth is 6400 km, then the total charge on the earth's surface is

(1) 6.8×10^5 coulomb (2) 6.8×10^6 coulomb (3) 6.8×10^4 coulomb (4) 6.8×10^9 coulomb

Sol. Answer (1)

$E = 150$ V/m

$R = 6400$ km

Using Gauss' Law

$$\Rightarrow EA = \frac{q}{\varepsilon_0}$$

$$\Rightarrow 150\left(4\pi\left(6400 \times 10^3\right)^2\right) = \frac{q}{\varepsilon_0}$$

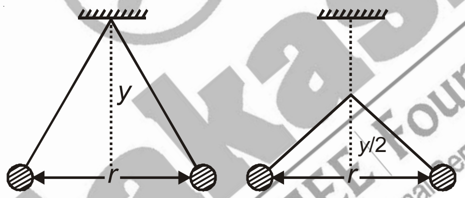
$q = 150 \times 4\pi \times (6400 \times 10^3)^2 \times 8.854 \times 10^{-12}$

$q = 6.8 \times 10^5$ C

SECTION - C

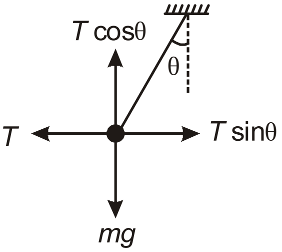
Previous Years Questions

1. Two pith balls carrying equal charges are suspended from a common point by strings of equal length, the equilibrium separation between them is *r*. Now the strings are rigidly clamped at half the height. The equilibrium separation between the balls now become



(1) $\left(\frac{r}{\sqrt[3]{2}}\right)$ (2) $\left(\frac{2r}{\sqrt{3}}\right)$ (3) $\left(\frac{2r}{3}\right)$ (4) $\left(\frac{1}{\sqrt{2}}\right)^2$

Sol. Answer (1)



$$T\sin\theta = \frac{K.Q^2}{r^2} \quad \ldots\text{(i)}$$

$$T\cos\theta = mg \quad \ldots\text{(ii)}$$

$$\frac{(i)}{(ii)} \quad \tan\theta = \frac{K.Q^2}{mg.r^2}$$

$$\Rightarrow r_1^2.\tan\theta_1 = r_2^2.\tan\theta_2$$

$$\Rightarrow r^2.\frac{r}{2y} = r_2^2.\frac{r^2.2}{2.y}$$

$$\Rightarrow \frac{r^3}{2y} = \frac{r_2^3}{y}$$

$$\Rightarrow r_2 = \frac{r}{2^{\frac{1}{3}}}$$

2. What is the flux through a cube of side *a* if a point charge of *q* is at one of its corner?

(1) $\frac{q}{\varepsilon_0}$ (2) $\frac{q}{2\varepsilon_0}6a^2$ (3) $\frac{2q}{\varepsilon_0}$ (4) $\frac{q}{8\varepsilon_0}$

Sol. Answer (4)

$\phi_{net} = \frac{Q_{inc.}}{\varepsilon_0} = \frac{Q}{\varepsilon_0}$ (through eight cubes)

Flux through one cube = $\frac{a}{8\varepsilon_0}$

3. A charge *Q* is enclosed by a Gaussian spherical surface of radius *R*. If the radius is doubled, then the outward electric flux will

(1) Be doubled (2) Increase four times (3) Be reduced to half (4) Remain the same

Sol. Answer (4)

Flux does not depend upon size of surface.

4. A charged cloud system produces an electric field in the air near the earth's surface. A particle of charge -2×10^{-9} C is acted on by a downward electrostatic force of 3×10^{-6} N when placed in this field. The gravitational and electrostatic force, respectively, exerted on a proton placed in this field are

(1) 1.64×10^{-26} N, 2.4×10^{-16} N (2) 1.64×10^{-26} N, 1.5×10^{3} N

(3) 1.56×10^{-18} N, 2.4×10^{-16} N (4) 1.5×10^{3} N, 2.4×10^{-16} N

Sol. Answer (1)

$F = Q.E$

$\Rightarrow E = \frac{F}{q} = \frac{3 \times 10^{-6}}{2 \times 10^{-9}} = 1.5 \times 10^{3}$

Hence force on proton = $F_P = Q_P.E$

$= (1.6 \times 10^{-19}) \times (1.5 \times 10^{3})$

$= 2.4 \times 10^{-16}$ N

Gravity force on proton = $F_G = mg$

$= 1.6 \times 10^{-27} \times 10$

$= 1.64 \times 10^{-26}$ N

5. The frequency of oscillation of an electric dipole moment having dipole moment *p* and rotational inertia *I*, oscillating in a uniform electric field *E* is given

(1) $(1/2\pi)\sqrt{I/pE}$ (2) $(1/2\pi)\sqrt{pE/I}$ (3) $(2\pi)\sqrt{pE/I}$ (4) $(2\pi)\sqrt{I/pE}$

Sol. Answer (2)

$$n = \frac{1}{T} = \frac{w}{2\pi} = \sqrt{\frac{PE/I}{2\pi}} = \frac{1}{2\pi}.\sqrt{\frac{P.E}{I}}$$

6. What is the net charge on a conducting sphere of radius 10 cm? Given that the electric field 15 cm from the center of the sphere is equal to 3×10^3 N/C and is directed inward

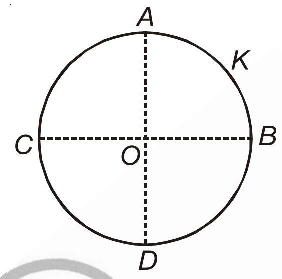
(1) -7.5×10^{-5} C (2) -7.5×10^{-9} C (3) 7.5×10^{-5} C (4) 7.5×10^{-9} C

Sol. Answer (2)

$$E.A. = \frac{Q_{\text{inc.}}}{\varepsilon_0} \Rightarrow 3\times 10^3 \times \left(4\pi r^2\right) = \frac{Q_{\text{inc.}}}{\varepsilon_0}$$

$$\Rightarrow Q_{\text{inc.}} = \frac{3\times 10^3 \times 15^2}{9\times 10^9 \times 100} = \frac{75\times 10}{10^9} = -7.5\times 10^{-9}\text{ C}$$

7. A thin conducting ring of radius *R* is given a charge +*Q*. The electric field at the centre *O* of the ring due to the charge on the part *AKB* of the ring is *E*. The electric field at the centre due to the charge on the part *ACDB* of the ring is

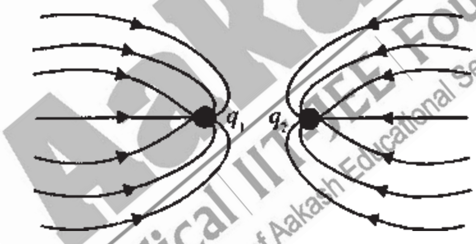


(1) 3 *E* along *OK* (2) 3 *E* along *KO* (3) *E* along *OK* (4) *E* along *KO*

Sol. Answer (3)

E along *OK*, Since *E* at the centre must be zero.

8. The given figure gives electric lines of force due to two charges q_1 and q_2. What are the signs of the two charges?



(1) q_1 is positive but q_2 is negative (2) q_1 is negative but q_2 is positive

(3) Both are negative (4) Both are positive

Sol. Answer (3)

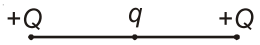
Electric field is directed from positive to negative charge.

9. A charge *q* is placed at the centre of the line joining two exactly equal positive charges *Q*. The system of three charges will be in equilibrium, if *q* is equal to

(1) $-Q$ (2) $\frac{Q}{2}$ (3) $-\frac{Q}{4}$ (4) $+Q$

Sol. Answer (3)

Net force on *Q* due to other charges



$$\frac{K.Q.q}{r^2} = \frac{K.Q.Q}{4r^2}$$

$$\Rightarrow Q = \frac{-Q}{4}$$

10. A point charge $+q$ is placed at the mid-point of a cube of side l. The electric flux emerging from the cube is

(1) $\frac{6ql^2}{\varepsilon_0}$ (2) $\frac{q}{6l^2\varepsilon_0}$ (3) Zero (4) $\frac{q}{\varepsilon_0}$

Sol. Answer (4)

$$\phi = E.A. = \frac{Q_{inc.}}{\varepsilon_0}$$

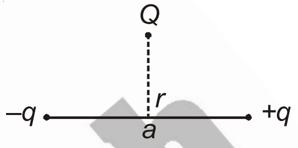
$$\Rightarrow \phi_{net} = \frac{Q}{\varepsilon_0}$$

11. A point Q lies on the perpendicular bisector of an electrical dipole of dipole moment p. If the distance of Q from the dipole is r (much larger than the size of the dipole), then the electric field at Q is proportional to

(1) p^2 & r^{-3} (2) p & r^{-2} (3) p^{-1} & r^{-2} (4) p & r^{-3}

Sol. Answer (4)

$$E = \frac{p}{4\pi\varepsilon_0.\left(r^2 + a^2\right)^{\frac{3}{2}}} \qquad \because r >> a$$



$$= \frac{p}{4\pi\varepsilon_0.r^3}$$

$$\Rightarrow E \propto p,\ E \propto r^{-3}$$

12. A particle of mass m and charge q is placed at rest in a uniform electric field E and then released. The kinetic energy attained by the particle after moving a distance y is

(1) qEy (2) qE^2y (3) qEy^2 (4) q^2Ey

Sol. Answer (1)

$$F = QE$$

$$a = \frac{F}{m} = \frac{qE}{m}$$

Hence, $K.E. = \frac{1}{2}mv^2$

$$= \frac{1}{2} \times m \times \left(\frac{2qEy}{m}\right)$$

$$= qEy$$

13. A hollow insulated conducting sphere is given a positive charge of 10 μC. What will be the electric field at the centre of the sphere if its radius is 2 metre?

(1) 20 μC m^{-2} (2) 5 μC m^{-2} (3) Zero (4) 8 μC m^{-2}

Sol. Answer (3)

Electric field at the centre is zero.

14. When air is replaced by a dielectric medium of constant K, the maximum force of attraction between two charges separated by a distance

(1) Increases K times (2) Remains unchanged (3) Decreases K times (4) Increases K^{-2} times

Sol. Answer (3)

$$F_{\text{air}} = \frac{1}{4\pi\varepsilon_0}.\frac{Q_1.Q_2}{r^2}$$

$$F_{\text{medium}} = \frac{F_{\text{air}}}{k} \Rightarrow \text{ decreases by } k \text{ times}$$

15. A charge Q is situated at the corner of a cube, the electric flux passed through all the six faces of the cube is

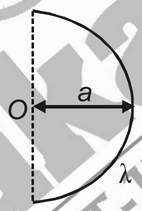
(1) $\frac{Q}{6\varepsilon_0}$ (2) $\frac{Q}{8\varepsilon_0}$ (3) $\frac{Q}{\varepsilon_0}$ (4) $\frac{Q}{2\varepsilon_0}$

Sol. Answer (2)

$$\phi = E.A. = \frac{Q_{inc.}}{\varepsilon_0} = \frac{Q}{\varepsilon_0}$$

$\Rightarrow \phi_{net}$ through the cube $= \frac{1}{8}\left(\frac{Q}{\varepsilon_0}\right)$

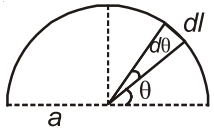
16. Electric field at centre O of semicircle of radius a having linear charge density λ is given as



(1) $\frac{2\lambda}{\varepsilon_0 a}$ (2) $\frac{\lambda\pi}{\varepsilon_0 a}$ (3) $\frac{\lambda}{2\pi\varepsilon_0 a}$ (4) $\frac{\lambda}{\pi\varepsilon_0 a}$

Sol. Answer (3)

$$dE = \frac{k.d\theta}{a^2} = \frac{k.(\lambda.dl)}{a^2} = \frac{k.\lambda.(a.d\theta)}{a^2} = \frac{k.\lambda}{a}.\int_0^{2\pi} d\theta = \frac{1}{2\pi\varepsilon_0}.\left(\frac{\lambda}{a}\right)$$



17. A charge Q μC is placed at the centre of a cube, the flux coming out from any face of the cube will be

(1) $\frac{Q}{6\varepsilon_0}\times 10^{-6}$ (2) $\frac{Q}{6\varepsilon_0}\times 10^{-3}$ (3) $\frac{Q}{24\varepsilon_0}$ (4) $\frac{Q}{8\varepsilon_0}$

Sol. Answer (1)

Flux through total surface $= \left(\frac{Q}{\varepsilon_0}\right)\mu\text{C}$

Flux through any one surface $= \frac{Q}{6.\varepsilon_0}\times 10^{-6}$ $\quad \Big| \because 1\,\mu\text{C} = 10^{-6}\,\text{C}$

$$= \frac{Q}{6\varepsilon_0}\times 10^{-6}$$

18. A dipole of dipole moment $\vec{P}$ is placed in uniform electric field $\vec{E}$, then torque acting on it is given by

(1) $\vec{\tau} = \vec{P} \cdot \vec{E}$ (2) $\vec{\tau} = \vec{P} \times \vec{E}$ (3) $\vec{\tau} = \vec{P} + \vec{E}$ (4) $\vec{\tau} = \vec{P} - \vec{E}$

Sol. Answer (2)

$\vec{\tau} = \vec{P} \times \vec{E}$

from formula

19. A charge q is located at the centre of a cube. The electric flux through any face of the cube is

(1) $\dfrac{2\pi q}{6(4\pi\varepsilon_0)}$ (2) $\dfrac{4\pi q}{6(4\pi\varepsilon_0)}$ (3) $\dfrac{\pi q}{6(4\pi\varepsilon_0)}$ (4) $\dfrac{q}{6(4\pi\varepsilon_0)}$

Sol. Answer (2)

$$\phi = \frac{q_{\text{inc.}}}{\varepsilon_0} = \frac{Q}{\varepsilon_0}$$

Flux through any one surface of the cube = $\dfrac{1}{6}\left(\dfrac{Q}{\varepsilon_0}\right)$

20. The unit of permittivity of free space, ε_0, is

(1) coulomb/newton-metre (2) newton-metre^2/coulomb^2

(3) coulomb^2/(newton-metre^2) (4) coulomb^2/(newton-metre)^2

Sol. Answer (3)

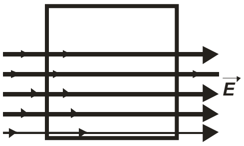
From formula

$$F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q^2}{r^2}$$

$$\Rightarrow \varepsilon_0 = \frac{Q^2}{Fr^2}$$

$$\Rightarrow \frac{\text{C}^2}{\text{Nm}^2}$$

21. A square surface of side L metres is in the plane of the paper. A uniform electric field $\vec{E}$ (volt/m), also in the plane of the paper, is limited only to the lower half of the square surface (see figure). The electric flux in SI units associated with the surface is



(1) EL^2 (2) $\dfrac{EL^2}{2\varepsilon_0}$ (3) $\dfrac{EL^2}{2}$ (4) Zero

Sol. Answer (4)

$$\phi_{net} = \vec{E}.\vec{A} = EA\cos\theta \qquad |\because \theta = 90^\circ$$

$$= 0$$

22. Three point charges $+q$, $-2q$ and $+q$ are placed at points ($x = 0$, $y = a$, $z = 0$), ($x = 0$, $y = 0$, $z = 0$) and ($x = a$, $y = 0$, $z = 0$) respectively. The magnitude and direction of the electric dipole moment vector of this charge assembly are

(1) $\sqrt{2}qa$ along the line joining points ($x = 0$, $y = 0$, $z = 0$) and ($x = a$, $y = a$, $z = 0$)

(2) qa along the line joining points ($x = 0$, $y = 0$, $z = 0$) and ($x = a$, $y = a$, $z = 0$)

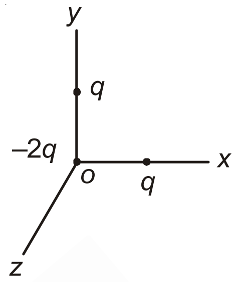
(3) $\sqrt{2}qa$ along +x direction

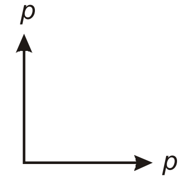
(4) $\sqrt{2}qa$ along +y direction

Sol. Answer (1)

$$p_{net} = \sqrt{2}p$$

$$= \sqrt{2}qa$$





23. A hollow cylinder has a charge q coulomb within it. If ϕ is the electric flux in units of voltmeter associated with the curved surface B, the flux linked with the plane surface A in units of voltmeter will be

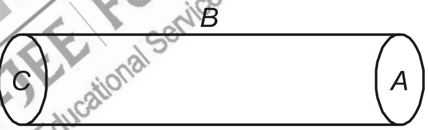
(1) $\frac{q}{2\varepsilon_0}$ (2) $\frac{\phi}{3}$ (3) $\frac{q}{\varepsilon_0} - \phi$ (4) $\frac{1}{2}\left(\frac{q}{\varepsilon_0} - \phi\right)$

Sol. Answer (4)

Net flux through the all surface = $\frac{Q}{\varepsilon_0}$

Flux through curved surface = ϕ

Hence, flux through plane surface $= \frac{1}{2}\left(\frac{Q}{\varepsilon_0} - \phi\right)$



24. Two positive ions, each carrying a charge q, are separated by a distance d. If F is the force of repulsion between the ions, the number of electrons missing from each ion will be (e being the charge on an electron)

(1) $\frac{4\pi\varepsilon_0 Fd^2}{q^2}$ (2) $\frac{4\pi\varepsilon_0 Fd^2}{e^2}$ (3) $\sqrt{\frac{4\pi\varepsilon_0 Fe^2}{d^2}}$ (4) $\sqrt{\frac{4\pi\varepsilon_0 Fd^2}{e^2}}$

Sol. Answer (4)

Force between two ions

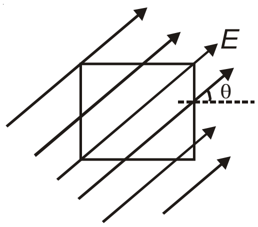
$$\frac{K.Q_1.Q_2}{d^2} = F$$

$$\Rightarrow \frac{1}{4\pi\varepsilon_0}.\frac{(ne)^2}{d^2} = F$$

$$\Rightarrow n^2.e^2 = Fd^2.4\pi\varepsilon_0$$

$$\Rightarrow n = \sqrt{Fd^2.4\pi\varepsilon_0 \big/ e^2}$$

25. A square surface of side L meter in the plane of the paper is placed in a uniform electric field E (volt/m) acting along the same plane at an angle θ with the horizontal side of the square as shown in figure. The electric flux linked to the surface, in units of volt-m, is



(1) Zero (2) EL^2 (3) $EL^2 \cos\theta$ (4) $EL^2 \sin\theta$

Sol. Answer (1)

$$\text{Flux} = \phi = \vec{E}.\vec{A} = EA\cos\theta = 0 \qquad |\because \theta = 0^\circ$$

26. The electric field at a distance $\frac{3R}{2}$ from the centre of a charged conducting spherical shell of radius R is E. The electric field at a distance $\frac{R}{2}$ from the centre of the sphere is

(1) Zero (2) E (3) $\frac{E}{2}$ (4) $\frac{E}{3}$

Sol. Answer (1)

Electric field inside the shell is zero.

SECTION - D

Assertion-Reason Type Questions

1. A : A negatively charged body means that the body has gained electrons while a positively charged body means the body has lost some of its electrons.

   R : Charging process involves transfer of electrons.

Sol. Answer (1)

2. A : Particles such as *photon* or *neutrino* which have no rest mass are uncharged.

   R : Charge cannot exist without mass.

Sol. Answer (1)

3. A : When a body is charged, its mass changes.

   R : Charge is quantized.

Sol. Answer (2)

4. A : Though quark particles have fractional electronic charges, the quantum of charge is still electronic charge (e).

   R : Quark particles do not exist in free state.

Sol. Answer (1)

5. A : An electron has negative charge by definition.

   R : Charge of a body depends on its velocity.

Sol. Answer (3)

6. A : A point charge cannot exert force on itself.

   R : Coulomb force is a central force.

Sol. Answer (2)

7. A : Since matter cannot be concentrated at a point, therefore point charge is not possible.

   R : An electron is a point charge.

Sol. Answer (3)

8. A : A finite size charged body may behave like a point charge if it produces an inverse square electric field.

   R : Two charged bodies may be considered as point charges if their distance of separation is very large compared to their dimensions.

Sol. Answer (2)

9. A : The path traced by a positive charge is a field line.

   R : A field line can intersect itself.

Sol. Answer (4)

10. A : If electric flux over a closed surface is negative then the surface encloses net negative charge.

    R : Electric flux is independent of the charge distribution inside the surface.

Sol. Answer (2)

11. A : We may have a Gaussian surface in which less number of field lines enter and more field lines come out.

    R : The electric field *E* in the Gauss's law is only due to the enclosed charges.

Sol. Answer (3)

12. A : The equilibrium of a charged particle under the action of electrostatic force alone can never be stable.

    R : Coulombian force is an action-reaction pair.

Sol. Answer (2)

13. A : The field in a cavity inside a conductor is zero which causes electrostatic shielding.

    R : Dielectric constant of conductors in electrostatics is infinite.

Sol. Answer (2)

14. A : If dipole moment of water molecules were zero, then microwave cooking would not be possible.

    R : In a microwave oven the water molecules vibrate due to oscillating electric field in microwave and heat the food.

Sol. Answer (1)

15. A : Electric field lines are continuous curves in free space.

    R : Electric field lines start from negative charge and terminate at positive charge.

Sol. Answer (3)

16. A : When an electric dipole is placed in uniform electric field, net force on it will be zero.

R : Force on the constituent charges of the dipole will be equal and opposite when it is in uniform electric field.

Sol. Answer (1)

17. A : Gauss' theorem is applicable on any closed surface.

R : In order to find the value of electric field due to a charge distribution, Gauss' theorem should be applied on a symmetrical closed surface.

Sol. Answer (2)

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Chapter 2

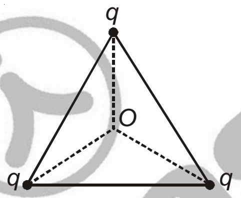
Electrostatic Potential and Capacitance

Solutions

SECTION - A

Objective Type Questions

1. Three isolated equal charges are placed at the three corners of an equilateral triangle as shown in figure. The statement which is true for net electric potential V and net electric field intensity E at the centre of the triangle is

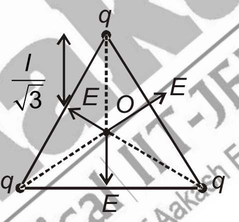


(1) $E = 0,\ V = 0$ (2) $V = 0,\ E \neq 0$ (3) $V \neq 0,\ E = 0$ (4) $V \neq 0,\ E \neq 0$

Sol. Answer (3)

$E_{net} = 0$

$$V_{net} = 3\left(\frac{k\,q\sqrt{3}}{l}\right) = 3\sqrt{3}\,\frac{kq}{l}$$



2. The potential at a point 0.1 m from an isolated point charge is + 100 volt. The nature of the point charge is

(1) Positive (2) Negative (3) Zero (4) Either positive or zero

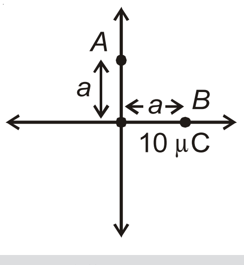
Sol. Answer (1)

As potential is +ve, so point charge is also +ve.

3. A charge of 10μC is placed at the origin of x-y coordinate system. The potential difference between two points (0, a) and (a, 0) in volt will be

(1) $\frac{9\times10^4}{a}$ (2) $\frac{9\times10^4}{a\sqrt{2}}$ (3) $\frac{9\times10^4}{2a}$ (4) Zero

Sol. Answer (4)



$$V_A = \frac{kq}{a}$$

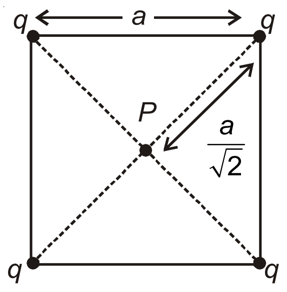
$$V_B = \frac{kq}{a}$$

$\Delta V = V_A - V_B = 0$

4. Four charges of same magnitude q are placed at four corners of a square of side a. The value of electric potential at the centre of the square will be (Where $k = \frac{1}{4\pi\varepsilon_0}$)

(1) $\frac{4kq}{a}$ (2) $4\sqrt{2}\frac{kq}{a}$ (3) $\frac{4kq}{\sqrt{2}a}$ (4) $\frac{kq}{a\sqrt{2}}$

Sol. Answer (2)



$$V_P = 4\left(\frac{kq\sqrt{2}}{a}\right) = 4\sqrt{2}\frac{kq}{a}$$

5. Two identical positive charges are placed on the y-axis at $y = -a$ and $y = +a$. The variation of V (electric potential) along x-axis is shown by graph

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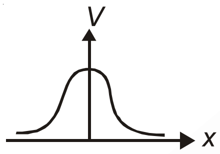

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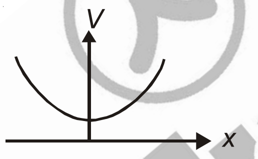

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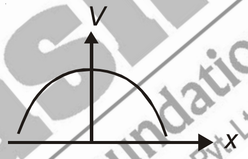
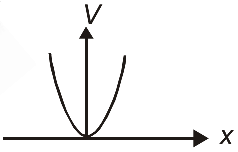
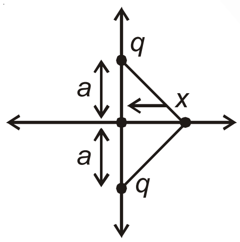
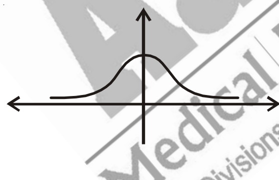


(4)


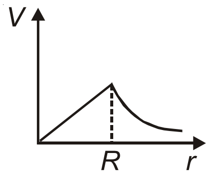
Sol. Answer (1)





$$V = \frac{2kq}{\sqrt{a^2 + x^2}}$$

6. Which graph best represents the variation of electric potential as a function of distance from the centre of a uniformly charged solid sphere of charge of radius R?

(1)


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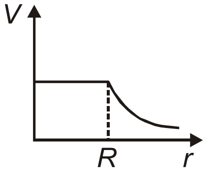

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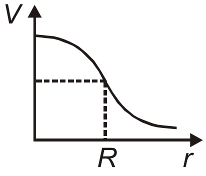

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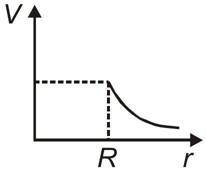


Sol. Answer (3)

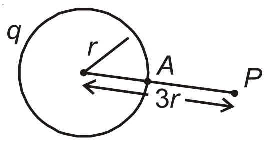
$$\left[V = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Q}{2R^3}\left(3R^2 - r^2\right)\right]$$

7. A hollow charged metal sphere has radius r. If the potential difference between its surface and a point at a distance $3r$ from the centre is V, then the electric field intensity at distance $3r$ from the centre is

(1) $\frac{V}{3r}$ (2) $\frac{V}{4r}$ (3) $\frac{V}{6r}$ (4) $\frac{V}{2r}$

Sol. Answer (3)

$V_A = \frac{kq}{r}$ $V_P = \frac{kq}{3r}$

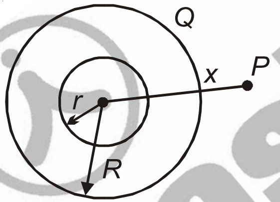


$V = V_A - V_P = \frac{2kq}{3r}$

$kq = \frac{3Vr}{2}$

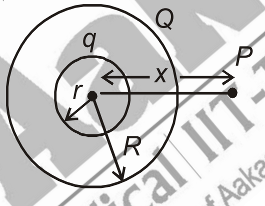
$E = \frac{kq}{9r^2} = \frac{3Vr}{2(9r^2)} = \frac{V}{6r}$

8. Two concentric hollow conducting spheres of radius r and R are shown. The charge on outer shell is Q. What charge should be given to inner sphere so that the potential at any point P outside the outer sphere is zero?



(1) $-\frac{Qr}{R}$ (2) $-\frac{QR}{r}$ (3) $-Q$ (4) $-\frac{2QR}{r}$

Sol. Answer (3)



$V_P = \frac{kq}{x} + \frac{KQ}{x} = 0$

$q = -Q$

9. The potential gradient is a

(1) Vector quantity (2) Scalar quantity (3) Conversion factor (4) Constant

Sol. Answer(1)

Potential gradient = $\frac{dV}{dr} = -E$ (Vector)

10. The electric potential V at a point $P(x, y, z)$ in space is given by $V = 4x^2$ volt. Electric field at a point (1m, 0, 2m) in V/m is

(1) 8 along –ve x-axis (2) 8 along +ve x-axis (3) 16 along –ve x-axis (4) 16 along +ve x-axis

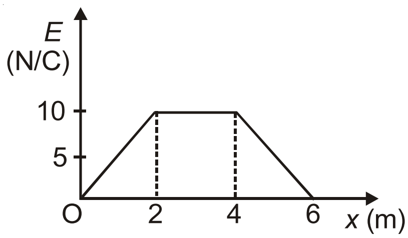
Sol. Answer (1)

$V = 4x^2$

$E_x = \frac{-dV}{dx} = -8x$

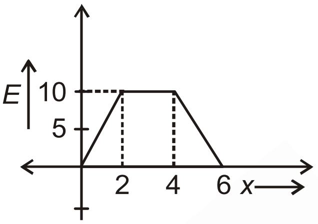
$E_x = -8$

11. Figure shows the variation of electric field intensity E versus distance x. What is the potential difference between the points at x = 2 m and at x = 6 m from O?



(1) 30 V
(2) 60 V
(3) 40 V
(4) 80 V

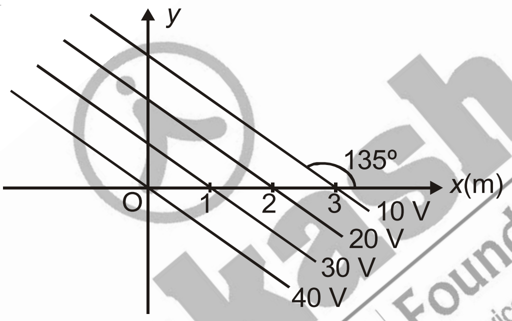
Sol. Answer(1)



$$V_2 - V_6 = -\int E dr$$

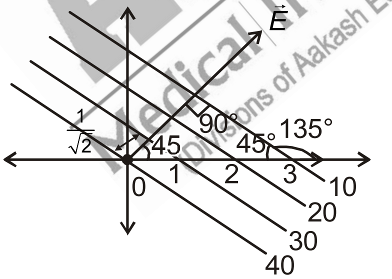
$$V_2 - V_6 = (10)(2) + \frac{1}{2}(10)(2) = 30$$

12. Figure shows a set of equipotential surfaces. The magnitude and direction of electric field that exists in the region is



(1) $10\sqrt{2}$ V/m at 45º with x-axis
(2) $10\sqrt{2}$ V/m at –45º with x-axis
(3) $5\sqrt{2}$ V/m at 45º with x-axis
(4) $5\sqrt{2}$ V/m at –45º with x-axis

Sol. Answer (1)



$$E = \frac{10\sqrt{2}}{1}$$

$E = 10\sqrt{2}$ at 45° with x-axis

13. Determine the electric field strength vector if the potential of this field depends on x, y coordinates as $V = 10\,axy$

(1) $10\,a(y\hat{i} + x\hat{j})$
(2) $-10\,a[y\hat{i} + x\hat{j}]$
(3) $-a[y\hat{i} + x\hat{j}]$
(4) $-10a[x\hat{i} + y\hat{k}]$

Sol. Answer (2)

$V = 10axy$

$$E_x = \frac{-dV}{dx} = -10ay, E_y = \frac{-dV}{dy} = -10ax$$

$$\vec{E} = -10a\left(y\hat{i} + x\hat{j}\right)$$

14. If on the x-axis electric potential decreases uniformly from 60 V to 20 V between x = –2 m to x = +2 m, then the magnitude of electric field at the origin

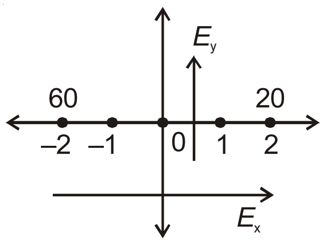
(1) Must be 10 V/m
(2) May be greater than 10 V/m
(3) Is zero
(4) Is 5 V/m

Sol. Answer (2)

$$E_x = \frac{40}{4} = 10\,\frac{\text{V}}{\text{m}}$$

$$E_y \neq 0$$

$$E = \sqrt{E_x^2 + E_y^2} > 10$$



15. An infinite conducting sheet has surface charge density σ. The distance between two equipotential surfaces is *r*. The potential difference between these two surfaces is

(1) $\frac{\sigma r}{2\varepsilon_0}$
(2) $\frac{\sigma r}{\varepsilon_0}$
(3) $\frac{\sigma}{\varepsilon_0 r}$
(4) $\frac{\sigma}{2\varepsilon_0 r}$

Sol. Answer (2)

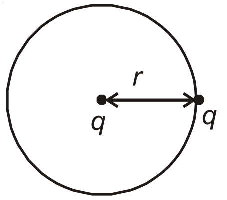
$$\Delta V = Ed = \frac{\sigma r}{\varepsilon_0}$$

$$\Delta V = \frac{\sigma r}{\varepsilon_0}$$

16. Two small spheres each carrying a charge *q* are placed, distance *r* apart. If one of the spheres is taken around the other in a circular path, the work done will be equal to

(1) Force between them × *r*
(2) $\frac{\text{Force between them}}{2\pi r}$
(3) Force between them × 2π*r*
(4) Zero

Sol. Answer (4)



W = 0 as whole path is equipotential.

17. Work done in moving a charge *q* coulomb on the surface of a given charged conductor of potential *V* is

(1) $\frac{V}{q}$ joule
(2) *Vq* joule
(3) $\frac{q}{V}$ joule
(4) Zero

Sol. Answer (4)

As the surface of a conductor is equipotential, So *w* = 0.

18. If an α-particle and a proton are accelerated from rest by a potential difference of 1 megavolt then the ratio of their kinetic energy will be

(1) $\frac{1}{2}$ (2) 1 (3) 2 (4) 4

Sol. Answer (3)

$\Delta KE = qV$

$$\frac{\Delta KE_\alpha}{\Delta KE_P} = \frac{q_\alpha V}{q_p V} = \frac{q_\alpha}{q_p} = 2$$

19. When a test charge is brought in from infinity along the perpendicular bisector of an electric dipole, the work done is

(1) Positive (2) Zero (3) Negative (4) None of these

Sol. Answer (2)

$W = q(V_f - V_i) = q(0 - 0) = 0$

20. The work done in moving an electric charge q in an electric field does not depend upon

(1) Mass of the particle (2) Potential difference between two points

(3) Magnitude of charge (4) All of these

Sol. Answer (1)

Work done does not depend on mass of the particle.

21. A particle A has charge $+q$ and particle B has charge $+4q$ with each of them having the same mass m. When allowed to fall from rest through the same electric potential difference, the ratio of their speeds $\frac{V_A}{V_B}$ will become

(1) 1 : 2 (2) 2 : 1 (3) 1 : 4 (4) 4 : 1

Sol. Answer (1)

$$qV = \frac{1}{2}mV_A^2 \qquad V_B = \sqrt{\frac{8qV}{m}}$$

$$V_A = \sqrt{\frac{2qV}{m}}$$

$$\frac{V_A}{V_B} = \frac{1}{2}$$

22. If 50 joule of work must be done to move an electric charge of 2 C from a point, where potential is –10 volt to another point, where potential is V volt, the value of V is

(1) 5 V (2) – 15 V (3) + 15 V (4) + 10 V

Sol. Answer (3)

$50 = 2(V - (-10))$

$25 = V + 10$

$V = 15$ V

23. A proton has a mass 1.67×10^{-27} kg and charge $+1.6 \times 10^{-19}$ C. If the proton is accelerated through a potential difference of million volts, then the kinetic energy is

(1) 1.6×10^{-15} J (2) 1.6×10^{-13} J (3) 1.6×10^{-21} J (4) 3.2×10^{-13} J

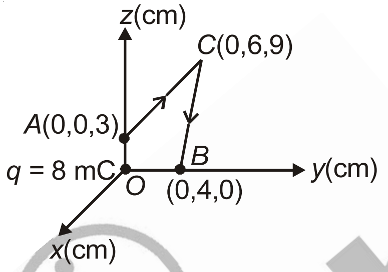
Sol. Answer (2)

$$(1.6 \times 10^{-19})(10^{6}) = \frac{1}{2}(1.67 \times 10^{-27})\, v^2$$

$$1.6 \times 10^{-13} = \frac{1.67}{2} \times 10^{-27} v^2 = \text{KE}$$

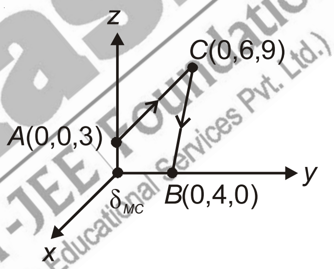
KE = 1.6×10^{-13} J

24. Calculate the work done in taking a charge -2×10^{-9} C from *A* to *B* via *C* (in diagram)



(1) 0.2 joule (2) 1.2 joule (3) 2.2 joule (4) Zero

Sol. Answer (2)



$$V_A = \frac{9 \times 10^9 \times 8 \times 10^{-3}}{3 \times 10^{-2}} = 24 \times 10^8\,\text{V}$$

$$V_B = \frac{9 \times 10^9 \times 8 \times 10^{-3}}{4 \times 10^{-2}} = 18 \times 10^8\,\text{V}$$

$\Delta W = -2 \times 10^{-9}(-6 \times 10^{8})$

$\Delta W = 12 \times 10^{-1}$ J

$\Delta W = 1.2$ J

25. The electric potential at a distance of 3 m on the axis of a short dipole of dipole moment 4×10^{-12} coulomb-meter is

(1) 1.33×10^{-3} V (2) 4 mV (3) 12 mV (4) 27 mV

Sol. Answer (2)

$$V = \frac{9 \times 10^9 \times 4 \times 10^{-12}}{9} = 4 \times 10^{-3}\,\text{V} = 4\,\text{mV}$$

26. The electric potential in volts due to an electric dipole of dipole moment 2×10^{-8} coulomb-metre at a distance of 3m on a line making an angle of 60° with the axis of the dipole is

(1) Zero (2) 10 (3) 20 (4) 40

Sol. Answer (2)

$$V = \frac{9 \times 10^9 \times 2 \times 10^{-8} \times \frac{1}{2}}{9} = 10\,\text{V}$$

27. An electric dipole of length 2 cm is placed with its axis making an angle of 30° to a uniform electric field 10^5 N/C. If it experiences a torque of $10\sqrt{3}$ Nm, then potential energy of the dipole

(1) – 10 J (2) – 20 J (3) – 30 J (4) – 40 J

Sol. Answer (3)

$$10\sqrt{3} = P10^5\frac{1}{2}$$

$$2\sqrt{3}\times10^{-4} = P$$

$$U = -2\sqrt{3}\times10^{-4}\times10^5\times\frac{\sqrt{3}}{2}$$

$U = -3 \times 10$

$U = -30$ J

28. Two electrons are moving towards each other, each with a velocity of 10^6 m/s. What will be closest distance of approach between them?

(1) 1.53×10^{-8} m (2) 2.53×10^{-10} m (3) 2.53×10^{-6} m (4) Zero

Sol. Answer (2)

$$2.\frac{1}{2}\left(9.1\times10^{-31}\right)\left(10^6\right)^2 = \frac{9\times10^9\times\left(1.6\times10^{-19}\right)^2}{r}$$

$$9.1\times10^{-19} = \frac{9\times10^9\times2.56\times10^{-38}}{r}$$

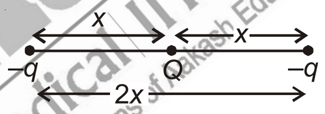
$r = 2.56 \times 10^{-10}$ m

29. Three charges –*q*, *Q* and –*q* are placed respectively at equal distances on a straight line. If the potential energy of the system of three charges is zero, then what is the ratio of *Q* : *q* ?

(1) 1 : 1 (2) 1 : 2 (3) 1 : 3 (4) 1 : 4

Sol. Answer (4)

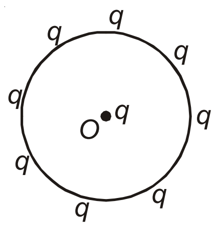
$$U = \frac{-kqQ}{x} - \frac{kqQ}{x} + \frac{kq^2}{2x} = 0$$



$$\frac{kq^2}{2x} = \frac{2kqQ}{x}$$

$q = 4Q,$ $\quad \frac{Q}{q} = \frac{1}{4}$

30. A point charge *q* is surrounded by eight identical charges at distance *r* as shown in figure. How much work is done by the forces of electrostatic repulsion when the point charge at the centre is removed to infinity?



(1) Zero (2) $\frac{8q^2}{4\pi\varepsilon_0 r}$ (3) $\frac{8q}{4\pi\varepsilon_0 r}$ (4) $\frac{64q^2}{4\pi\varepsilon_0 r}$

Sol. Answer (2)

$$W = -q\,(V_f - V_i) = -q(V_\infty - V_i) = +qV_i$$

$$V_i = 8.\frac{kq^2}{r} = \frac{8q^2}{4\pi\varepsilon_0 r}$$

$$W = \frac{+8q^2}{4\pi\varepsilon_0 r}$$

31. 1000 small water drops each of capacitance C join together to form one large spherical drop. The capacitance of bigger sphere is

(1) C (2) $10\,C$ (3) $100\,C$ (4) $1000\,C$

Sol. Answer (2)

$$C = 4\pi\varepsilon_0 r$$

$$1000.\frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3$$

$$R = 10r$$

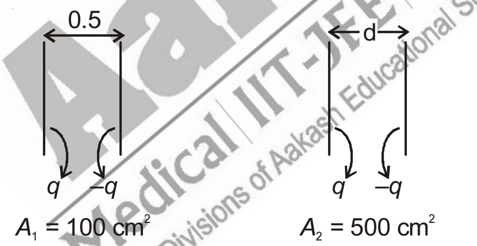
$$C' = 4\pi\varepsilon_0 R = 10\,(4\pi\varepsilon_0 r)$$

$$C' = 10C$$

32. Two parallel plate capacitors have their plate areas 100 cm^2 and 500 cm^2 respectively. If they have the same charge and potential and the distance between the plates of the first capacitor is 0.5 mm, then the distance between the plates of the second capacitor is

(1) 0.10 cm (2) 0.15 cm (3) 0.20 cm (4) 0.25 cm

Sol. Answer (4)



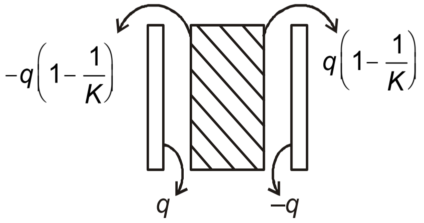
$$\frac{100\varepsilon_0}{0.5} = \frac{500\varepsilon_0}{d}$$

d = 2.5 cm = 0.25 cm

33. A dielectric slab of dielectric constant K is placed between the plates of a parallel plate capacitor carrying charge q. The induced charge q' on the surface of slab is given by

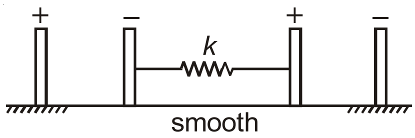
(1) $q' = q - \frac{q}{K}$ (2) $q' = -q + \frac{q}{K}$ (3) $q' = q\left[\frac{1}{K}+1\right]$ (4) $q' = -q\left(1+\frac{1}{K}\right)$

Sol. Answer (2)



$$q' = -q\left(1-\frac{1}{K}\right)$$

34. Two charged capacitors have their outer plates fixed and inner plates connected by a spring of force constant 'k'. The charge on each capacitor is q. Find the extension in the spring at equilibrium



(1) $\frac{q^2}{2A\varepsilon_0 k}$ (2) $\frac{q^2}{4A\varepsilon_0 k}$ (3) $\frac{q^2}{A\varepsilon_0 k}$ (4) Zero

Sol. Answer (1)

$$F = kx = \frac{q^2}{2A\varepsilon_0}$$

$$x = \frac{q^2}{2A\varepsilon_0 k}$$

35. A battery does 200 J of work in charging a capacitor. The energy stored in the capacitor is

(1) 200 J (2) 100 J (3) 50 J (4) 400 J

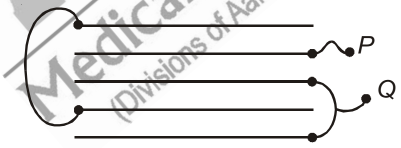
Sol. Answer (2)

$$U = \frac{1}{2}Cv^2$$

$$W = Cv^2$$

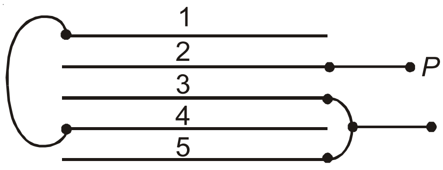
$U = \frac{W}{2} = 100$ J (half of work is lost in heat)

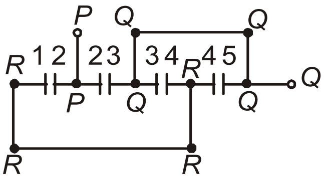
36. The following arrangement consists of five identical metal plates parallel to each other. Area of each plate is A and separation between the successive plates is d. The capacitance between P and Q is

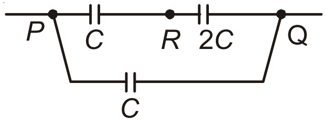


(1) $\frac{5\varepsilon_0 A}{d}$ (2) $\frac{7}{3}\varepsilon_0\frac{A}{d}$ (3) $\frac{4}{3}\frac{\varepsilon_0 A}{d}$ (4) $\frac{5}{3}\frac{\varepsilon_0 A}{d}$

Sol. Answer (4)

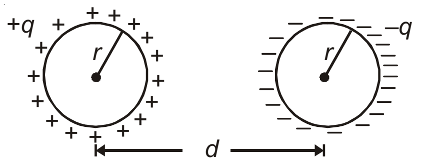






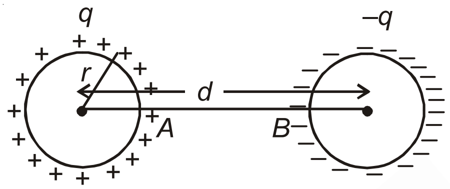
$$C_{\text{net}} = \frac{5C}{3}$$

37. Two similar conducting balls having charges +*q* and –*q* are placed at a separation *d* from each other in air. The radius of each ball is *r* and the separation between their centres is *d*(*d* >>*r*). Calculate the capacitance of the two ball system



(1) $4\pi\varepsilon_0 r$ (2) $2\pi\varepsilon_0 r$ (3) $4\pi\log_e\dfrac{\varepsilon_0 r}{d}$ (4) $4\pi\log_e\dfrac{r}{d}$

Sol. Answer (2)



$$V_A = \frac{kq}{r} + \frac{k(-q)}{d-r}$$

$$V_B = \frac{-kq}{r} + \frac{kq}{d-r}$$

$$V = V_A - V_B = \frac{2kq}{r} - \frac{2kq}{d-r} = \frac{2q}{4\pi\varepsilon_0}\left[\frac{1}{r} - \frac{1}{d-r}\right]$$

$$V = \frac{q}{2\pi\varepsilon_0}\left[\frac{d-2r}{(r)(d-r)}\right]$$

$d >> r$

$$V = \frac{q}{2\pi\varepsilon_0}$$

$$\frac{q}{V} = 2\pi\varepsilon_0 r = C$$

38. A capacitor is half filled with a dielectric (*K* = 2) as shown in figure A. If the same capacitor is to be filled with same dielectric as shown, what would be the thickness of dielectric so that capacitor still has same capacity?

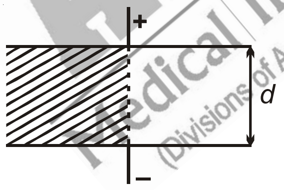


Fig. A

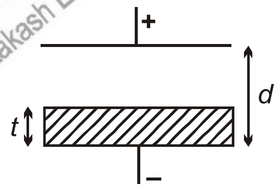
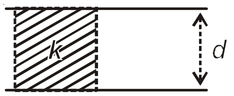


Fig. B

(1) 2*d*/3 (2) 3*d*/2 (3) 3*d*/4 (4) 4*d*/3

Sol. Answer (1)

$$C_{\text{net}} = \frac{k+1}{2}\frac{A\varepsilon_0}{d} \qquad C_{\text{net}} = \frac{A\varepsilon_0}{d - t\left(1-\frac{1}{2}\right)} = \frac{A\varepsilon_0}{d-\frac{t}{2}}$$



$$C_{\text{net}} = \frac{3A\varepsilon_0}{2d}$$

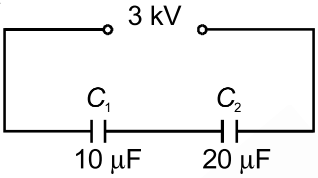
$$\frac{3A\varepsilon_0}{2d} = \frac{A\varepsilon_0}{d-\frac{t}{2}}$$

$$3d - \frac{3t}{2} = 2d$$

$$\frac{3t}{2} = d$$

$$t = \frac{2d}{3}$$

39. Capacitors C_1(10 μF) and C_2(20 μF) are connected in series across a 3 kV supply, as shown. What is the charge on the capacitor C_1?



(1) 45000 μC (2) 20000 μC (3) 15000 μC (4) 10000 μC

Sol. Answer (2)

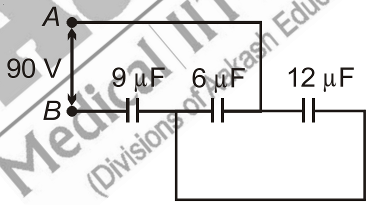
$$\frac{1}{C} = \frac{1}{10} + \frac{1}{20} = \frac{3}{20}$$

$$C = \frac{20}{3}\mu F$$

$$q = \frac{20}{3}.3000 = 20000 \times 10^{-6}$$

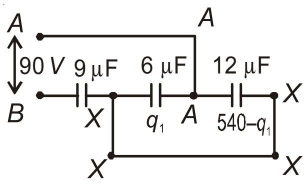
$q = 2 \times 10^{-4}$ C

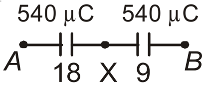
40. The charge on the 6 μF capacitor in the circuit shown is



(1) 540 μC (2) 270 μC (3) 180 μC (4) 90 μC

Sol. Answer (3)





$$\frac{1}{C} = \frac{1}{18} + \frac{1}{9} = \frac{3}{18}$$

$C = 6$ μF

$q = 6 \times 90 = 540$ μC

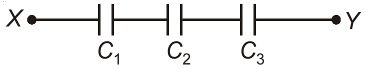
$$\frac{q_1}{540 - q_1} = \frac{6}{12}$$

$2q_1 = 540 - q_1$

$3q_1 = 540$

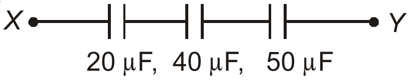
$q_1 = 180$ μC

41. In the circuit below $C_1 = 20\,\mu\text{F}$, $C_2 = 40\,\mu\text{F}$ and $C_3 = 50\,\mu\text{F}$. If no capacitor can sustain more than 50 V, then maximum potential difference between *X* and *Y* is



(1) 95 V (2) 75 V (3) 150 V (4) 65 V

Sol. Answer (1)



$q_{\text{max}} = 1000\ \mu\text{C},\ 2000\ \mu\text{C},\ 2500\ \mu\text{C}$

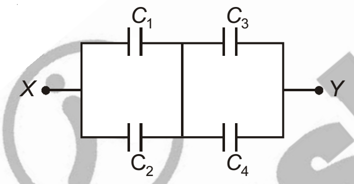
$q = 1000\ \mu\text{C},\ 1000\ \mu\text{C},\ 1000\ \mu\text{C}$

$V = 50\text{ V},\ 25\text{ V},\ 20\text{ V}$

$V_{\text{net}} = 50 + 20 + 25$

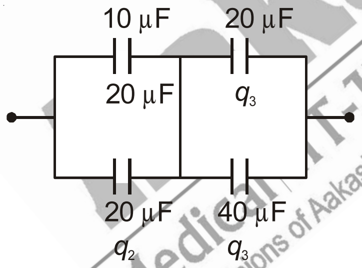
$V_{\text{net}} = 95\text{ V}$

42. In the circuit shown below $C_1 = 10\ \mu\text{F}$, $C_2 = C_3 = 20\ \mu\text{F}$, and $C_4 = 40\ \mu\text{F}$. If the charge on C_1 is 20 μC then potential difference between *X* and *Y* is



(1) 2 V (2) 3 V (3) 6 V (4) 3.5 V

Sol. Answer (2)



$q_3 = 20\ \mu\text{C}$

$q_4 = q_4 = 40\ \mu\text{C}$

$$\Delta V = \frac{20}{10} + \frac{20}{20} = 3\text{ V}$$

43. A parallel plate capacitor after charging is kept connected to a battery and the plates are pulled apart with the help of insulating handles. Now which of the following quantities will decrease ?

(1) Charge (2) Capacitance (3) Energy stored (4) All of these

Sol. Answer (4)

V remains constant

$C = \dfrac{A\varepsilon_0}{d} \Rightarrow d$ increases

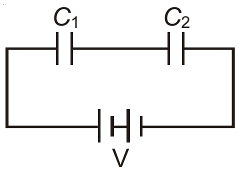
C decreases

$q = CV$

q decreases $U = \dfrac{1}{2}CV^2$

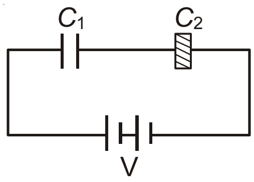
U decreases

44. In the circuit below, if a dielectric is inserted into C_2 then the charge on C_1 will



(1) Increase (2) Decrease (3) Remain same (4) Be halved

Sol. Answer (1)



$$q_1 = \frac{C_1C_2V}{C_1+C_2} \qquad q_1' = \frac{KC_1C_2V}{C_1+KC_2}$$

$q_1' > q_1$, so charge increases.

45. A capacitor with plate separation d is charged to V volts. The battery is disconnected and a dielectric slab of thickness $\frac{d}{2}$ and dielectric constant '2' is inserted between the plates. The potential difference across its terminals becomes

(1) V (2) $2V$ (3) $\frac{4V}{3}$ (4) $\frac{3V}{4}$

Sol. Answer (4)

$q = CV$

$$C' = \frac{A\varepsilon_0}{d - \frac{d}{2}\left(1-\frac{1}{2}\right)} = \frac{4A\varepsilon_0}{3d} = \frac{4C}{3}$$

$$q = \frac{4CV'}{3}$$

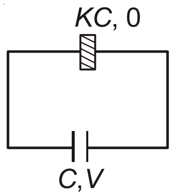
$$CV = \frac{4CV'}{3}$$

$$V' = \frac{3V}{4}$$

46. An uncharged parallel plate capacitor having a dielectric of constant K is connected to a similar air cored parallel capacitor charged to a potential V. The two capacitors share charges and the common potential is V'. The dielectric constant K is

(1) $\frac{V'-V}{V'+V}$ (2) $\frac{V'-V}{V'}$ (3) $\frac{V'-V}{V}$ (4) $\frac{V-V'}{V'}$

Sol. Answer (4)



$$V' = \frac{(KC)(0)+(C)(V)}{KC+C}$$

$$V' = \frac{CV}{KC+C}$$

$KV' + V' = V$

$KV' = V' - V'$

$$K = \frac{V-V'}{V'}$$

47. Two identical capacitors are connected in parallel across a potenial difference V. After they are fully charged, the positive plate of first capacitor is connected to negative plate of second and negative plate of first is connected to positive plate of other. The loss of energy will be

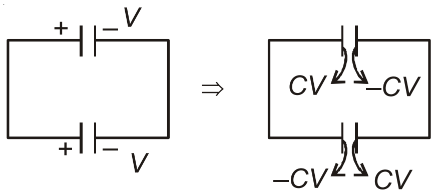
(1) $\frac{1}{2}CV^2$ (2) CV^2 (3) $\frac{1}{4}CV^2$ (4) Zero

Sol. Answer (2)

$$U_i = \frac{1}{2}CV^2 + \frac{1}{2}CV^2 = CV^2$$

$U_f = 0$

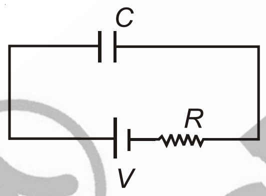
$\Delta U = CV^2$



SECTION - B

Objective Type Questions

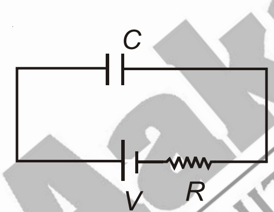
1. As in the figure, if a capacitor of capacitance *'C'* is charged by connecting it with resistance R, then energy given by the battery will be



(1) $\frac{1}{2}CV^2$ (2) Less than $\frac{1}{2}CV^2$ (3) CV^2 (4) More than CV^2

Sol. Answer (3)

$$q = CV\left(1 - e^{\frac{-t}{RC}}\right)$$

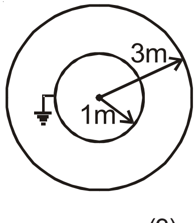


$t = \infty$ $q = CV$

Battery gives CV charge

$W = CV^2$

2. Figure shows a solid conducting sphere of radius 1 m, enclosed by a metallic shell of radius 3 m such that their centres coincide. If outer shell is given a charge of 6 μC and inner sphere is earthed, find magnitude charge on the surface of inner shell

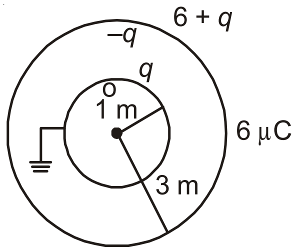


(1) 1 μC (2) 2 μC (3) 4 μC (4) 6 μC

Sol. Answer (2)

$$V = \frac{kq}{1} + \frac{k6}{3} = 0$$

$q = -2$ μC



3. A positively charged ring is in $y - z$ plane with its centre at origin. A positive test charge q_0, held at origin is released along x-axis, then its speed

(1) Increases continuously
(2) Decreases continuously
(3) First increases then decreases
(4) First decreases then increases

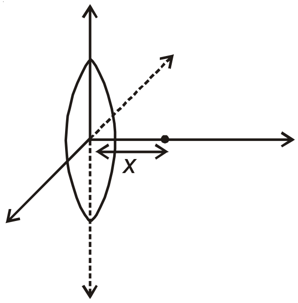
Sol. Answer (1)

$$V = \frac{kq}{\sqrt{x^2 + a^2}}$$

V decreases

So, U decreases

So, K increases



4. Three point charges q, q and $-2q$ are placed at the corners of an equilateral triangle of side 'L'. Calculate work done by external force in moving all the charges far apart without acceleration

(1) $\frac{1}{4\pi\varepsilon_0}\frac{3q^2}{L}$
(2) $-\frac{1}{4\pi\varepsilon_0}\frac{3q^2}{L}$
(3) $\frac{1}{4\pi\varepsilon_0}\frac{5q^2}{L}$
(4) $-\frac{1}{4\pi\varepsilon_0}\frac{5q^2}{L}$

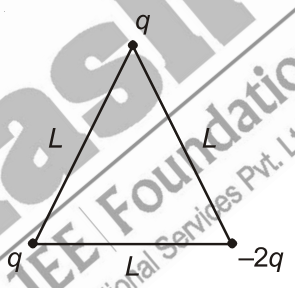
Sol. Answer (1)

$$U = \frac{k(q)(-2q)}{L} + \frac{k(q)(q)}{L} + \frac{k(q)(-2q)}{L}$$

$$U = \frac{-3kq^2}{L}$$

$$U_\infty = 0$$

$$W_{\text{ext}} = U_\infty - U = \frac{3kq^2}{L}$$



5. There is a uniformly charged non conducting solid sphere made of material of dielectric constant one. If electric potential at infinity be zero, then the potential at its surface is V. If we take electric potential at its surface to be zero, then the potential at the centre will be

(1) $\frac{3V}{2}$
(2) $\frac{V}{2}$
(3) V
(4) Zero

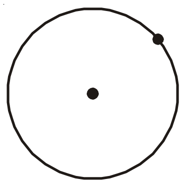
Sol. Answer (2)

$V_{\text{surface}} = V + V_\infty$

If $V_\infty = 0$, $V_{\text{surface}} = V$

If $V_\infty = -V$, $V_{\text{surface}} = 0$

$$V_{\text{cen}} = \frac{3V}{2} + V_\infty = \frac{3V}{2} - V = \frac{V}{2}$$



6. Electric potential in a region is varying according to the relation $V = \frac{3x^2}{2} - \frac{y^2}{4}$, where x and y are in metre and V is in volt. Electric field intensity (in N/C) at a point (1 m, 2 m) is

(1) $3\hat{i} - \hat{j}$
(2) $-3\hat{i} + \hat{j}$
(3) $6\hat{i} - 2\hat{j}$
(4) $-6\hat{i} + 2\hat{j}$

Sol. Answer (2)

$$V = \frac{3x^2}{2} - \frac{y^2}{4}$$

$$E_x = \frac{-dV}{dx} = -3x = -3$$

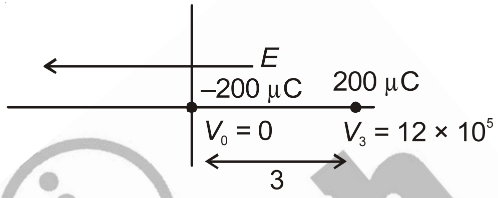
$$E_y = \frac{-dV}{dy} = +\frac{y}{2} = 1$$

$$\vec{E} = -3\hat{i} + \hat{j}$$

7. There exists a uniform electric field $E = 4 \times 10^5\ \text{Vm}^{-1}$ directed along negative x-axis such that electric potential at origin is zero. A charge of –200 μC is placed at origin, and a charge of +200 μC is placed at (3 m, 0). The electrostatic potential energy of the system is

(1) 120 J (2) – 120 J (3) – 240 J (4) Zero

Sol. Answer (1)



$$V_3 = 4 \times 10^5 \times 3 = 12 \times 10^5$$

$$U = \frac{kq_1\,q_2}{r} + q_1V_2 + q_2V_2$$

$$U = \frac{-9 \times 10^9 \times 200 \times 200 \times 10^{-12}}{3} + (-200)(0) + 200\,(12 \times 10^5) \times 10^{-6}$$

$U = -120 + 240$

$U = 120$ J

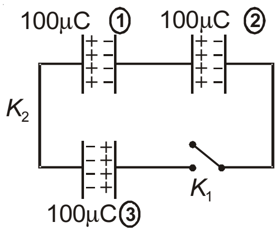
8. If the electric potential on the axis of an electric dipole at a distance 'r' from it is V, then the potential at a point on its equatorial line at the same distance away from it will be

(1) 2 V (2) $\frac{V}{2}$ (3) 0 (4) – V

Sol. Answer (3)

Potential at any point on the equatorial line due to an electric dipole is 0.

9. Three identical charged capacitors each of capacitance 5 μF are connected as shown in figure. Potential difference across capacitor (3), long time after the switches K_1 and K_2 are is closed, is

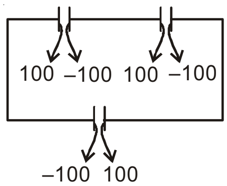


(1) 20 V (2) 10 V (3) 5 V (4) Zero

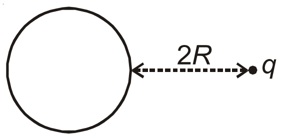
Sol. Answer (4)

In the wires, the charge is 0, Thus final charge = 0

Thus $\Delta V = 0$



10. A positive point charge q is placed at a distance $2R$ from the surface of a metallic shell of radius R. The electric field at centre of shell due to induced charge has magnitude



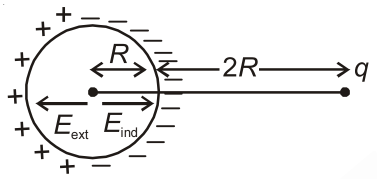
(1) Zero (2) $\frac{1}{4\pi\varepsilon_0}\frac{q}{9R^2}$ (3) $\frac{1}{4\pi\varepsilon_0}\frac{q}{4R^2}$ (4) $\frac{1}{4\pi\varepsilon_0}\frac{q}{R^2}$

Sol. Answer (2)

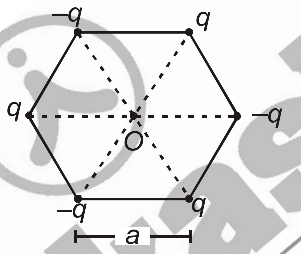
$$\vec{E}_{\text{int}} + \vec{E}_{\text{ext}} = 0$$

$$\vec{E}_{\text{int}} = \vec{E}_{\text{ext}}$$

$$\vec{E}_{\text{int}} = \frac{kq}{9R^2}$$



11. Six point charges are placed at the vertices of a regular hexagon of side a as shown. If E represents electric field and V represents electric potential at O, then

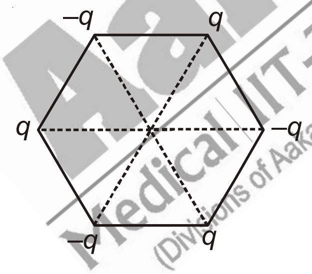


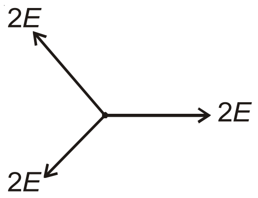
(1) $E = 0$ but $V \neq 0$ (2) $E \neq 0$ but $V = 0$ (3) $E = 0$ and $V = 0$ (4) $E \neq 0$ and $V \neq 0$

Sol. Answer (3)

$$V = \frac{3kq}{r} - \frac{3kq}{r} = 0$$

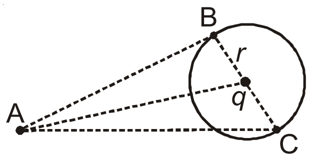
from the figure





$E_{\text{net}} = 0$

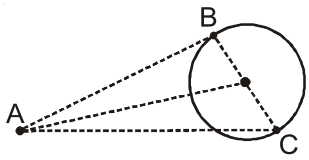
12. A point charge q is held at the centre of a circle of radius r. B, C are two points on the circumference of the circle and A is a point outside the circle. If W_{AB} represents work done by electric field in taking a charge q_0 from A to B and W_{AC} represents the workdone from A to C, then



(1) $W_{AB} > W_{AC}$ (2) $W_{AB} < W_{AC}$ (3) $W_{AB} = W_{AC} \neq 0$ (4) $W_{AB} = W_{AC} = 0$

Sol. Answer (3)

$$W_{AB} = U_B - U_A = q_0\left(V_B - V_A\right)$$



$$W_{AC} = U_C - U_A = q_0\left(V_C - V_A\right)$$

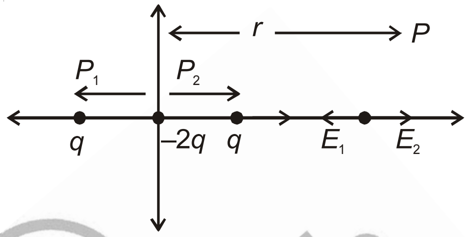
As $V_B - V_C$

$W_{AB} = W_{AC}$

13. Three charged particles having charges q, $-2q$ and q are placed in a line at points $(-a, 0)$, $(0,0)$ and $(a, 0)$ respectively. The expression for electric potential at $P(r, 0)$ for $r >> a$ is

(1) $\frac{1}{4\pi\varepsilon_0}\frac{qa^2}{r^4}$ (2) $\frac{1}{4\pi\varepsilon_0}\frac{2qa^2}{r^3}$ (3) $\frac{1}{4\pi\varepsilon_0}\frac{4qa^2}{r^2}$ (4) $\frac{1}{4\pi\varepsilon_0}\frac{8qa^2}{r}$

Sol. Answer (2)



$$E_1 = \frac{2kp}{\left(r+\frac{a}{2}\right)^3} \qquad E_2 = \frac{2kp}{\left(r-\frac{a}{2}\right)^3}$$

$$E_2 - E_1 = \frac{2kp}{\left(r-\frac{a}{2}\right)^3} - \frac{2kp}{\left(r+\frac{a}{2}\right)^3}$$

$$\frac{2kp}{r^3}\left[\frac{1}{\left(1-\frac{a}{2r}\right)^3} - \frac{1}{\left(1+\frac{a}{2r}\right)^3}\right]$$

$$\frac{2kp}{r^3}\left[1+\frac{3a}{2r} - \left(1-\frac{3a}{2r}\right)\right]$$

$$\frac{2kp}{r^3}\left[\frac{3a}{r}\right]$$

$$E = \frac{6kpa}{r^4} = \frac{{}^{3}\cancel{6}}{{}_{2}\cancel{4}\pi\varepsilon_0}\frac{pa}{r^4} = \frac{3pa}{2\pi\varepsilon_0 r^4}$$

$$V = \frac{-kp}{\left(r+\frac{a}{2}\right)^2} + \frac{kp}{\left(r-\frac{a}{2}\right)^2} = \frac{kp}{r^2}\left[1+\frac{2a}{2r}-1+\frac{2a}{2r}\right] = \frac{2kpa}{r^3}$$

14. Two metal spheres A and B of radii a & b ($a < b$) respectively are at a large distance apart. Each sphere carries a charge of 100 μC. The spheres are connected by a conducting wire, then

(1) Charge will flow from A to B

(2) Charge will flow from B to A

(3) No charge flows in the wire

(4) All charges will reside on the connecting wire

Sol. Answer (1)

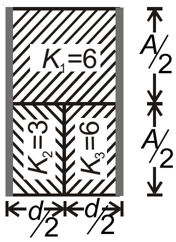
$$V_A = \frac{k(100)}{a} \qquad V_B = \frac{k(100)}{b}$$

$a < b$

$V_a > V_B$

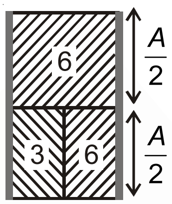
Charge flows from A to B.

15. Three different dielectrics are filled in a parallel plate capacitor as shown. What should be the dielectric constant of a material, which when fully filled between the plates produces same capacitance?



(1) 4 (2) 6 (3) 5 (4) 9

Sol. Answer (3)



$$C_1 = \frac{6A\varepsilon_0}{2d} = \frac{3A\varepsilon_0}{d}$$

$$C_2 = \frac{A\varepsilon_0}{2\left(d-\frac{d}{2}\left(1-\frac{1}{3}\right)-\frac{d}{2}\left(1-\frac{1}{6}\right)\right)}$$

$$C_2 = \frac{A\varepsilon_0}{2\left(\frac{d}{6}+\frac{d}{12}\right)}$$

$$C_2 = \frac{A\varepsilon_0}{2\left(\frac{d}{4}\right)}$$

$$C_2 = \frac{2A\varepsilon_0}{d}$$

$$C = C_1 + C_2 = \frac{5A\varepsilon_0}{d}$$

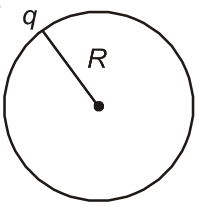
16. Consider a sphere of radius R having charge q uniformly distributed inside it. At what minimum distance from its surface the electric potential is half of the electric potential at its centre?

(1) R (2) $\frac{R}{2}$ (3) $\frac{4R}{3}$ (4) $\frac{R}{3}$

Sol. Answer (4)

$$V_C = \frac{3kQ}{2R}$$

$$V_S = \frac{kQ}{R+x} = \frac{3kQ}{4R}$$



$4R = 3R + 3x$

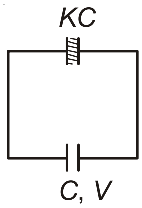
$3x = R$

$$x = \frac{R}{3}$$

17. There are two identical capacitors, the first one is uncharged and filled with a dielectric of constant K while the other one is charged to potential V having air between its plates. If two capacitors are joined end to end, the common potential will be

(1) $\frac{V}{K-1}$ (2) $\frac{KV}{K+1}$ (3) $\frac{KV}{K-1}$ (4) $\frac{V}{K+1}$

Sol. Answer (4)



$$V' = \frac{KC(0)+CV}{KC+C}$$

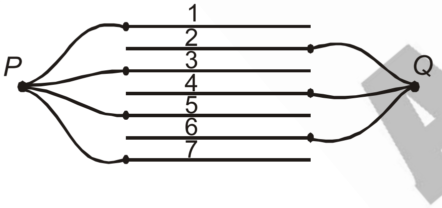
$$V' = \frac{CV}{C(I+K)}$$

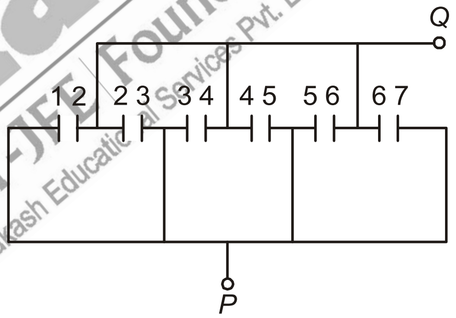
$$V' = \frac{V}{I+K}$$

18. Seven identical plates each of area A and successive separation d are arranged as shown in figures. The effective capacitance of the system between P & Q is

(1) $\frac{7\varepsilon_0 A}{d}$ (2) $\frac{6\varepsilon_0 A}{d}$ (3) $\frac{5\varepsilon_0 A}{d}$ (4) $\frac{3\varepsilon_0 A}{d}$

Sol. Answer (2)





All are in parallel

$$C_{net} = 6C = \frac{6A\varepsilon_0}{d}$$

19. In a certain region of space, variation of potential with distance from origin as we move along x-axis is given by $V = 8x^2 + 2$, where x is the x-coordinate of a point in space. The magnitude of electric field at a point (– 4, 0) is

(1) – 16 V/m (2) 16 V/m (3) – 64 V/m (4) 64 V/m

Sol. Answer (4)

$V = 8x^2 + 2$

$$E_x = \frac{-dV}{dx} = -16x$$

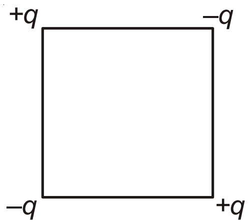
$x = -4$

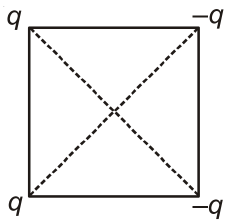
$E_x = 64$ V/m

20. Four charges +*q*, –*q*, +*q*, –*q* are placed in order on the four consecutive corners of a square of side *L*. The work done in inter changing the position of any two neighbouring charges of the opposite sign is

(1) $\frac{q^2}{4\pi\varepsilon_0 L}\left(-4+\sqrt{2}\right)$ (2) $\frac{q^2}{4\pi\varepsilon_0 L}\left(4+2\sqrt{2}\right)$ (3) $\frac{q^2}{4\pi\varepsilon_0 L}\left(4-2\sqrt{2}\right)$ (4) $\frac{q^2}{4\pi\varepsilon_0 L}\left(4+\sqrt{2}\right)$

Sol. Answer (3)





$$U_1 = \frac{-4kq^2}{a} + \frac{2kq^2}{a\sqrt{2}}$$

$$U_2 = \frac{-2kq^2}{a\sqrt{2}}$$

$$\Delta U = U_2 - U_1 = -\frac{4kq^2}{a\sqrt{2}} + \frac{4kq^2}{a}$$

$$\frac{kq^2\left[4-2\sqrt{2}\right]}{a} = W$$

21. The charge *q* is fired towards another charged particle *Q* which is fixed, with a speed *v*. It approaches *Q* upto a closest distance *r* and then returns. If *q* were given a speed 2*v*, the closest distance of approach would be

(1) *r* (2) 2*r* (3) $\frac{r}{2}$ (4) $\frac{r}{4}$

Sol. Answer (4)

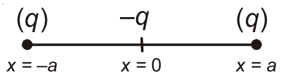
$$\frac{1}{2}mv^2 = \frac{kqQ}{r}$$

$$\frac{1}{2}m(2v)^2 = \frac{kqQ}{r'}$$

$$\frac{1}{4} = \frac{r'}{r}$$

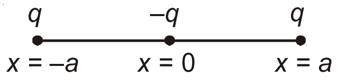
$$r' = \frac{r}{4}$$

22. Three charges are placed along x-axis at *x* = – *a*, *x* = 0 and *x* = *a* as shown in the figure. The potential energy of the system is



(1) $-\left(\frac{1}{4\pi\varepsilon_0}\right)\frac{q^2}{a}$ (2) $-\left(\frac{1}{4\pi\varepsilon_0}\right)\frac{3q^2}{2a}$ (3) $+\left(\frac{1}{4\pi\varepsilon_0}\right)\frac{q^2}{a}$ (4) $+\left(\frac{1}{4\pi\varepsilon_0}\right)\frac{3q^2}{2a}$

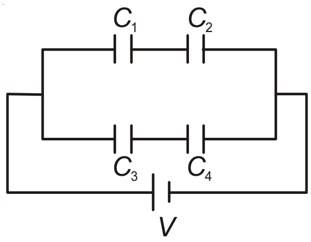
Sol. Answer (2)



$$U = \frac{-kq^2}{a} - \frac{kq^2}{a} + \frac{ka^2}{2a}$$

$$U = \frac{-3kq^2}{2a}$$

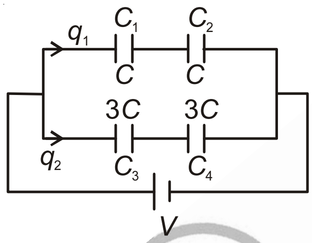
23. Find the charge on capacitor C_3



Given, that $C_1 = C_2 = C$ and $C_3 = C_4 = 3C$.

(1) $\frac{3}{2}CV$ (2) $\frac{CV}{2}$ (3) $3CV$ (4) $2CV$

Sol. Answer (1)



$C_{net} = 2C$

$q = 2CV$

$\frac{q_1}{q_2} = \frac{1}{3}$

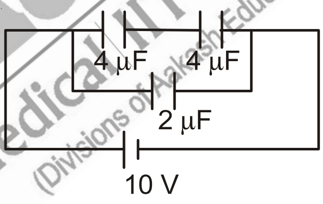
$3q_1 = q_2$

$q_1 + q_2 = 2CV$

$q_1 = \frac{CV}{2}$

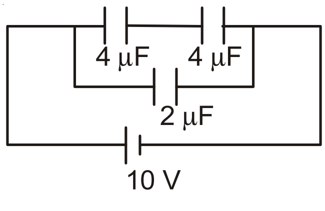
$q_2 = \frac{3CV}{2}$

24. If initial charge on all the capacitors were zero, work done by the battery in the circuit shown is



(1) 0.2 mJ (2) 200 mJ (3) 0.4 mJ (4) 400 mJ

Sol. Answer (3)



$C_{net} = 4\mu\text{F}$

$q = 40\ \mu\text{F}$

$W = qV = 40 \times 10^{-6} \times 10$

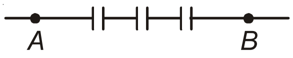
$W = 400\ \mu\text{J}$

25. While working on a physics project at school physics lab, you require a 4 μF capacitor in a circuit across a potential difference of 1 kV. Unfortunately, 4 μF capacitors are out of stock in your lab but 2 μF capacitors which can withstand a potential difference of 400 V are available in plenty. If you decide to use the 2 μF capacitors in place of 4 μF capacitor, minimum number of capacitors required are

(1) 16 (2) 18 (3) 20 (4) 12

Sol. Answer (2)

$$C_{AB}=\frac{2}{3}$$



Total number of benches $=\frac{{}^{2}\cancel{4}\times 3}{\cancel{2}}=6$

Total number of capacitors = 6 × 3 = 18

26. A parallel plate capacitor with air between the plates has a capacitance C. If the distance between the plates is doubled and the space between the plates is filled with a dielectric of dielectric constant 6, then the capacitance will become

(1) $3C$ (2) $\frac{C}{3}$ (3) $12C$ (4) $\frac{C}{6}$

Sol. Answer (1)

$$C=\frac{A\varepsilon_0}{d}$$

$$C'=\frac{6A\varepsilon_0}{2d}=\frac{2A\varepsilon_0}{d}$$

$C'=3C$

27. A capacitor of capacitance C is charged with the help of a 200 V battery. It is then discharged through a small coil of resistance wire embedded in a thermally insulated block of specific heat capacity 2.5×10^2 J/kg and mass 0.1 kg. If the temperature of the block rises by 0.4 K, the value of C is

(1) 500 F (2) 500 μF (3) 50 F (4) 50 μF

Sol. Answer (2)

$$\frac{1}{2}\times C\times(200)^2=2.5\times 10^2\times 0.1\times 0.4$$

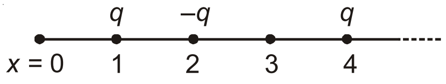
$$2\times 10^4 C=1\times 10$$

$$C=\frac{1}{2\times 10^3}=500\ \mu\text{F}$$

28. Electric charges having same magnitude of electric charge 'q' coulombs are placed at x = 1 m, 2 m, 4 m, 8m .... so on. If any two consecutive charges have opposite sign but the first charge is necessarily positive, what will be the potential at x = 0?

(1) Infinity (2) Zero (3) $\frac{1}{4\pi\varepsilon_0}\left(\frac{2q}{3}\right)$ (4) $\frac{1}{4\pi\varepsilon_0}(2q)$

Sol. Answer (3)



$$\frac{kq}{1}-\frac{kq}{2}+\frac{kq}{4}-\frac{kq}{8}+\ldots\ldots$$

$$kq\left[1-\frac{1}{2}+\frac{1}{4}-\frac{1}{8}+\ldots..\right]$$

$$\frac{kq.1}{1-\left(\frac{-1}{2}\right)}=V$$

$$V=\frac{2kq}{3}$$

29. A pellet carrying a charge of 0.5 coulomb is accelerated through a potential of 2000 volts. It attains some kinetic energy equal to

(1) 1000 erg (2) 1000 joule (3) 1000 kWh (4) 500 erg

Sol. Answer (2)

KE = qV

KE = (0.5) (2000) = 1000 J

30. A cylindrical capacitor has two co-axial cylinders of length 20 cm and radii $2r$ and r. Inner cylinder is given a charge 10 μC and outer cylinder a charge of –10 μC. The potential difference between the two cylinders will be

(1) $\frac{0.1\ \ln 2}{4\pi\varepsilon_0}\text{mV}$ (2) $\frac{\ln 2}{4\pi\varepsilon_0}\text{mV}$ (3) $\frac{10\ \ln 2}{4\pi\varepsilon_0}\text{mV}$ (4) $\frac{0.01\ \ln 2}{4\pi\varepsilon_0}\text{mV}$

Sol. Answer (1)

$$C = \frac{2\pi\varepsilon_0 l}{\ln\left(\frac{b}{a}\right)}$$

$$C = \frac{2\pi\varepsilon_0\left(\frac{20}{100}\right)}{\ln^2}$$

$$\Delta V = \frac{10\times10^{-6}\ln3}{2\pi\varepsilon_0\left(\frac{20}{100}\right)}$$

$$\Delta V = \frac{10^{-4}\ln2}{4\pi\varepsilon_0}$$

$$\Delta V = \frac{0.1\ln2}{4\pi\varepsilon_0}\text{mV}$$

31. A charge q is distributed uniformly on the surface of a sphere of radius R. It is covered by a concentric hollow conducting sphere of radius $2R$. Charge on the outer surface of the hollow sphere will be, if it is earthed

(1) $\frac{q}{2}$ (2) $2q$ (3) $4q$ (4) Zero

Sol. Answer (4)

If outer surface is earthed its charge becomes 0.

32. There exists an electric field of magnitude E in x-direction. If the work done in moving a charge of 0.2 C through a distance of 2 m along a line making an angle 60° with x-axis is 4 J, then the value of E is

(1) $\sqrt{3}$ N/C (2) 4 N/C (3) 5 N/C (4) 20 N/C

Sol. Answer (4)

$\xrightarrow{\hspace{4cm}} E$

$W = qEd\cos\theta$

$$4 = (0.2)(E)(2)\frac{1}{2}$$

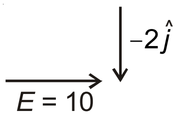
E = 20 N/C

33. In a region of space, suppose there exists a uniform electric field $\overrightarrow{E} = 10\hat{i}\left(\frac{\text{V}}{\text{m}}\right)$. If a positive charge moves with a velocity $\overrightarrow{v} = -2\hat{j}$, its potential energy

(1) Increases (2) Decreases

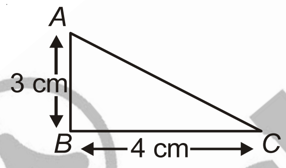
(3) Does not change (4) Initially increases then decreases

Sol. Answer (3)



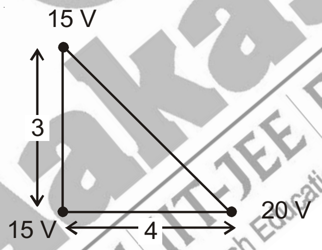
As charge moves perpendicular to $\vec{E}$, no change in energy occurs.

34. *ABC* is a right angled triangle situated in a uniform electric field $\overrightarrow{E}$ which is in the plane of the triangle. The points *A* and *B* are at the same potential of 15 V while the point C is at a potential of 20 V. *AB* = 3cm and *BC* = 4 cm. The magnitude of electric field is (in S.I. Units)



(1) 100 (2) 125 (3) 167 (4) 208

Sol. Answer (2)



$$5 = E\left(\frac{4}{100}\right)$$

E = 125 N/C

35. A hollow spherical conductor of radius *r* potential of 100 V at its outer surface. The potential inside the hollow at a distance of $\frac{r}{2}$ from its centre is

(1) 100 V (2) 50 V (3) 200 V (4) Zero

Sol. Answer (1)

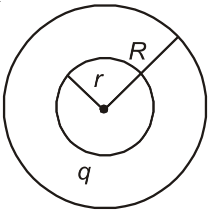
Inside the conductor, the field is 0 and potential is constant V = 100 V.

36. A spherical conductor having charge *q* and radius *r* is placed at the centre of a spherical shell of radius *R* and having charge *Q* (*R* > *r*). The potential difference between the two is

(1) Proportional to *Q* (2) Proportional to *q*

(3) Dependent on both *Q* and *q* (4) Independent of both *Q* and *q*

Sol. Answer (2)



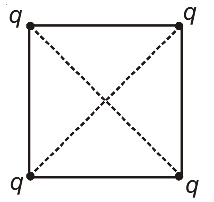
$$V_A - V_B = kq\left[\frac{1}{r} - \frac{1}{R}\right]$$

$$\Delta V \propto q$$

37. The work which is required to be done to make an arrangement of four particles each having a charge +*q* such that the particles lie at the four corners of a square of side *a* is

(1) $\left(4+\sqrt{2}\right)\frac{kq^2}{a}$ (2) $4\frac{kq^2}{a}$ (3) $\left(2+\sqrt{2}\right)\frac{kq^2}{a}$ (4) $2\frac{kq^2}{a}$

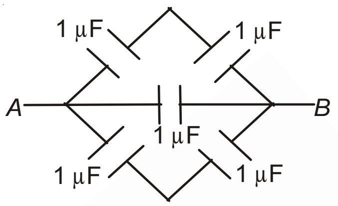
Sol. Answer (1)



$$U = \frac{4kq^2}{a} + \frac{2kq^2}{a\sqrt{2}}$$

$W = U$

38. The net capacitance of a system of capacitance as shown in the figure between points *A* and *B* is

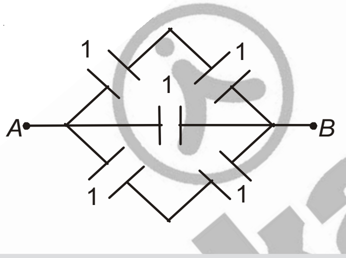


(1) 1 μF (2) 2 μF (3) 3 μF (4) 4 μF

Sol. Answer (2)

It is balanced W.S.B

C_{net} = 2 μF



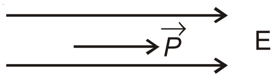
SECTION - C

Previous Years Questions

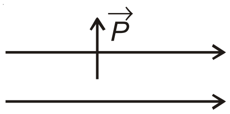
1. An electric dipole of dipole moment *p* is aligned parallel to a uniform electric field *E*. The energy required to rotate the dipole by 90° is

(1) pE^2 (2) p^2E (3) pE (4) Infinity

Sol. Answer (3)



$U_i = -pE$



$U_{\delta} = 0$

$W = \Delta U = 0 - (-pE)$

$W = pE$

2. An electric dipole of moment *p* is placed in an electric field of intensity *E*. The dipole acquires a position such that the axis of the dipole makes an angle θ with the direction of the field. Assuming that the potential energy of the dipole to be zero when θ = 90°, the torque and the potential energy of the dipole will respectively be

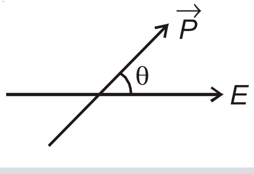
(1) $pE\sin\theta$, $2pE\cos\theta$ (2) $pE\cos\theta$, $-pE\sin\theta$

(3) $pE\sin\theta$, $-pE\cos\theta$ (4) $pE\sin\theta$, $-2pE\cos\theta$

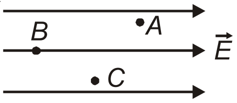
Sol. Answer (3)

$I = pE\sin\theta$

$U = -pE\cos\theta$



3. A, B and C are three points in a uniform electric field. The electric potential is

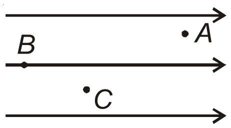


(1) Maximum at B (2) Maximum at C

(3) Same at all the three points A, B and C (4) Maximum at A

Sol. Answer (1)

$V_B > V_C > V_A$

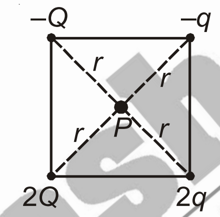


4. Four point charges $-Q$, $-q$, $2q$ and $2Q$ are placed, one at each corner of the square. The relation between Q and q for which the potential at the centre of the square is zero is

(1) $Q = q$ (2) $Q = \frac{1}{q}$ (3) $Q = -q$ (4) $Q = -\frac{1}{q}$

Sol. Answer (3)

$$V_p = \frac{k(-Q)}{r} + \frac{k(-q)}{r} + \frac{k(2q)}{r} + \frac{k(2Q)}{r} = 0$$



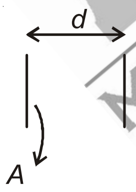
$$\frac{kQ}{r} + \frac{kq}{r} = 0$$

$q = -Q$

5. A parallel plate capacitor has a uniform electric field E in the space between the plates. If the distance between the plates is d and area of each plate is A, the energy stored in the capacitor is

(1) $\frac{1}{2}\varepsilon_0 E^2$ (2) $E^2\frac{Ad}{\varepsilon_0}$ (3) $\frac{1}{2}\varepsilon_0 E^2 Ad$ (4) $\varepsilon_0 EAd$

Sol. Answer (3)



$$C = \frac{A\varepsilon_0}{d}$$

$$U = \frac{1}{2}\varepsilon_0 E^2 \cdot Ad$$

6. Two metallic spheres of radii 1 cm and 3 cm are given charges of -1×10^{-2} C and 5×10^{-2} C, respectively. If these are connected by a conducting wire, the final charge on the bigger sphere is

(1) 2×10^{-2} C (2) 3×10^{-2} C (3) 4×10^{-2} C (4) 1×10^{-2} C

Sol. Answer (2)

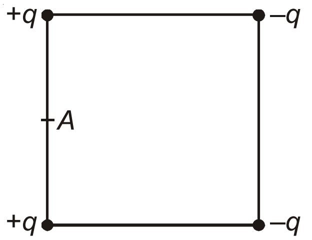
$$\frac{q}{3} = \frac{4\times10^{-2} - q}{1}$$

$q = 12 \times 10^{-2} - 3q$

$4q = 12 \times 10^{-2}$

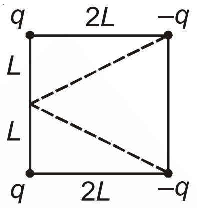
$q = 3 \times 10^{-2}$

7. Four electric charges $+q$, $+q$, $-q$ and $-q$ are placed at the corners of a square of side $2L$ (see figure). The electric potential at point A, midway between the two charges $+q$ and $+q$, is



(1) Zero (2) $\frac{1}{4\pi\varepsilon_0}\frac{2q}{L}(1+\sqrt{5})$ (3) $\frac{1}{4\pi\varepsilon_0}\frac{2q}{L}\left(1+\frac{1}{\sqrt{5}}\right)$ (4) $\frac{1}{4\pi\varepsilon_0}\frac{2q}{L}\left(1-\frac{1}{\sqrt{5}}\right)$

Sol. Answer (4)



$$V=\frac{kq}{L}+\frac{kq}{L}-\frac{kq}{L\sqrt{5}}-\frac{kq}{L\sqrt{5}}$$

$$=\frac{kq\left[2\sqrt{5}-2\right]}{L\sqrt{5}}$$

8. A parallel plate condenser has a uniform electric field E (V/m) in the space between the plates. If the distance between the plates is d (m) and area of each plate is A (m^2) the energy (joules) stored in the condenser is

(1) $\frac{1}{2}\varepsilon_0E^2Ad$ (2) E^2Ad/ε_0 (3) $\frac{1}{2}\varepsilon_0E^2$ (4) ε_0EAd

Sol. Answer (1)

$$U=\frac{1}{2}\varepsilon_0E^2Ad$$

9. The electric potential V at any, point (x, y, z), in meters in space is given by $V = 4x^2$ volt. The electric field at the point (1, 0, 2) in volt/meter, is

(1) 16 along positive X-axis (2) 8 along negative X-axis

(3) 8 along positive X-axis (4) 16 along negative X-axis

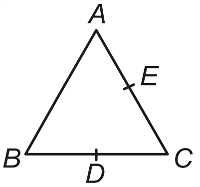
Sol. Answer (2)

$V = 4x^2$

$$E_x=-\frac{dV}{dx}=-8x$$

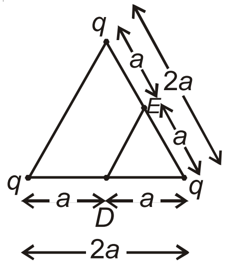
$E_x = -8$ N/C

10. Three charges, each $+q$, are placed at the corners of an isosceles triangle ABC of sides BC and AC, $2a$. D and E are the mid-points of BC and CA. The work done in taking a charge Q from D to E is



(1) Zero (2) $\frac{3qQ}{4\pi\varepsilon_0a}$ (3) $\frac{3qQ}{8\pi\varepsilon_0a}$ (4) $\frac{qQ}{4\pi\varepsilon_0a}$

Sol. Answer (1)



$V_D = V_E$

$W = q(V_D - V_E) = 0$

11. Which of the following is not true?

(1) For a point charge, the electrostatic potential varies as 1/*r*

(2) For a dipole, the potential depends on the position vector and dipole moment vector

(3) The electric dipole potential varies as 1/*r* at large distance

(4) For a point charge, the electrostatic field varies as $1/r^2$

Sol. Answer (3)

Option (3) is wrong for dipole, potential varies as $\frac{1}{r^2}$.

12. How many 1 μF capacitors must be connected in parallel to store a charge of 1 C with a potential of 110 V across the capacitors?

(1) 990 (2) 900 (3) 9090 (4) 909

Sol. Answer (3)

For *n* capacitors

$C_{net} = nC$

$1 = n(10^{-6})(110)$

$n = \frac{1000000}{110} = 9090$

13. The energy required to charge a parallel plate condenser of plate separation *d* and plate area of cross-section *A* such that the uniform electric field between the plates is *E*, is

(1) $\frac{1}{2}\varepsilon_0 E^2 Ad$ (2) $\frac{1}{2}\varepsilon_0 E^2 / A.d$ (3) $\varepsilon_0 E^2 / Ad$ (4) $\varepsilon_0 E^2 Ad$

Sol. Answer (1)

$U = \frac{1}{2} CV^2$

$U = \frac{1}{2} \frac{A\varepsilon_0}{d}(Ed)^2$

$U = \frac{A\varepsilon_0 E^2 d}{2}$

14. The electric potential at a point in free space due to a charge Q coulomb is Q × 10^{11} volts. The electric field at that point is

(1) $12\pi\varepsilon_0 Q\times10^{22}$ volt/m (2) $4\pi\varepsilon_0 Q\times10^{22}$ volt/m

(3) $12\pi\varepsilon_0 Q\times10^{20}$ volt/m (4) $4\pi\varepsilon_0 Q\times10^{20}$ volt/m

Sol. Answer (2)

$$\frac{9\times10^9 Q}{r} = Q\times10^{11}$$

$r = 9 \times 10^{-2}$

$$E = \frac{9\times10^9\times Q}{81\times10^{-4}}$$

$$E = \frac{1}{9}\times10^{13}\ Q$$

$$\frac{KQ}{r} = Q\times10^{11}$$

$$r = \frac{k}{10^{11}}$$

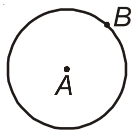
$$E = \frac{kQ}{k^2}10^{22}$$

$E = 4\pi\varepsilon_0 Q \times 10^{22}$

15. A hollow metallic sphere of radius 10 cm is charged such that potential of its surface is 80 V. The potential at the centre of the sphere would be

(1) 80 V (2) 800 V (3) Zero (4) 8 V

Sol. Answer (1)

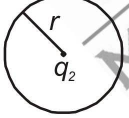


$V_A = V_B = 80$ V

16. Charge q_2 is at the centre of a circular path with radius r. Work done in carrying charge q_1 once around this equipotential path, would be

(1) $\frac{1}{4\pi\varepsilon_0}\times\frac{q_1q_2}{r^2}$ (2) $\frac{1}{4\pi\varepsilon_0}\times\frac{q_1q_2}{r}$ (3) Zero (4) Infinite

Sol. Answer (3)



$W = q(V_f - V_i)$

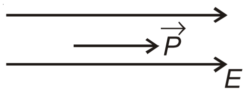
$$V_f = V_i = \frac{kq_2}{r}$$

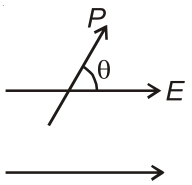
$W = 0$

17. An electric dipole of moment *an electric* is placed in the position of stable equilibrium in uniform electric field of intensity *E.* This is rotated through an angle θ from the initial position. The potential energy of the electric dipole in the final position is

(1) $-pE\cos\theta$ (2) $pE(1-\cos\theta)$ (3) $pE\cos\theta$ (4) $pE\sin\theta$

Sol. Answer (1)





$U = -pE\cos\theta$

18. There is an electric field E in x-direction. If the work done on moving a charge of 0.2 C through a distance of 2 m along a line making an angle 60° with x-axis is 4 J, then what is the value of E?

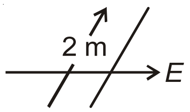
(1) 5 N/C (2) 20 N/C (3) $\sqrt{3}$ N/C (4) 4 N/C

Sol. Answer (2)

$q = 0.2$ C

$r = 2$ m

$\theta = 60°$



$$4 = (0.2\,E)(2)\left(\frac{1}{2}\right)$$

$E = 20$ N/C

19. Two metallic spheres of radii 1 cm and 2 cm are given charges 10^{-2} C and 5×10^{-2} C respectively. If they are connected by a conducting wire, the final charge on the smaller sphere is

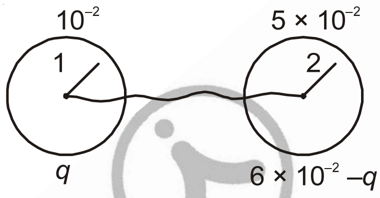
(1) 3×10^{-2} C (2) 2×10^{-2} C (3) 1×10^{-2} C (4) 6×10^{-2} C

Sol. Answer (2)

$$\frac{q}{1} = \frac{6\times10^{-2} - q}{2}$$

$2q = 6 \times 10^{-2} - q$

$q = 2 \times 10^{-2}$ C



20. The energy stored in a capacitor of capacity C and potential V is given by

(1) $\frac{CV}{2}$ (2) $\frac{C^2V^2}{2}$ (3) $\frac{C^2V}{2}$ (4) $\frac{CV^2}{2}$

Sol. Answer (4)

$$U = \frac{1}{2}CV^2$$

21. An electron of mass m and charge e is accelerated from rest through a potential difference V in vacuum. Its final velocity will be

(1) $\sqrt{\frac{2eV}{m}}$ (2) $\sqrt{\frac{eV}{m}}$ (3) $\frac{eV}{2m}$ (4) $\frac{eV}{m}$

Sol. Answer (1)

$$eV = \frac{1}{2}mv^2$$

$$\frac{2eV}{m} = v^2$$

$$v = \sqrt{\frac{2eV}{m}}$$

22. When a proton is accelerated through 1 V, then its kinetic energy will be

(1) 1 eV (2) 13.6 eV (3) 1840 eV (4) 0.54 eV

Sol. Answer (1)

KE = 1 × 1 = 1 eV

23. A parallel plate condenser with oil between the plates (dielectric constant of oil $K = 2$) has a capacitance C. If the oil is removed, then capacitance of the capacitor becomes

(1) $\dfrac{C}{\sqrt{2}}$ (2) $2C$ (3) $\sqrt{2}C$ (4) $\dfrac{C}{2}$

Sol. Answer (4)

$KC' = C, \qquad C' = \dfrac{C}{2}$

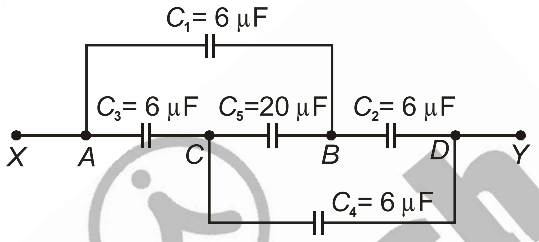
24. In bringing an electron towards another electron, the electrostatic potential energy of the system

(1) Becomes zero (2) Increases (3) Decreases (4) Remains same

Sol. Answer (2)

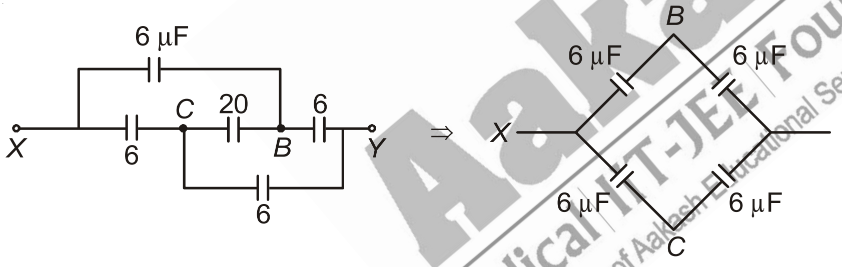
As '*r*' decreases so, PE increases.

25. What is the effective capacitance between points X and Y?



(1) 12 μF (2) 18 μF (3) 24 μF (4) 6 μF

Sol. Answer (4)



∵ $V_B = V_C$

Above is the diagram of a balanced W_0B_0

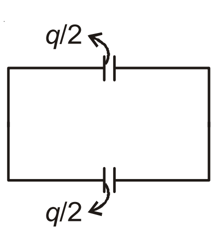
C_{net} = 6 μF

26. A capacitor is charged with a battery and energy stored is U. After disconnecting battery another capacitor of same capacity is connected in parallel to the first capacitor. Then energy stored in each capacitor is

(1) $U/2$ (2) $U/4$ (3) $4U$ (4) $2U$

Sol. Answer (2)

$U = \dfrac{q^2}{2C}$



$U' = \dfrac{\left(\dfrac{q}{2}\right)^2}{2C}$

$U' = \dfrac{q^2}{8C} = \dfrac{U}{4}$

27. Energy per unit volume for a capacitor having area A and separation d kept at potential difference V is given by

(1) $\frac{1}{2}\varepsilon_0\frac{V^2}{d^2}$ (2) $\frac{1}{2\varepsilon_0}\frac{V^2}{d^2}$ (3) $\frac{1}{2}CV^2$ (4) $\frac{Q^2}{2C}$

Sol. Answer (1)

Energy density $=\frac{1}{2}\varepsilon_0 E^2 = \frac{1}{2}\varepsilon_0\left(\frac{V}{d}\right)^2 = \frac{1}{2}\varepsilon_0\frac{V^2}{d^2}$

28. Some charge is being given to a conductor. Then its potential is

(1) Maximum at surface

(2) Maximum at centre

(3) Remain same throughout the conductor

(4) Maximum somewhere between surface and centre

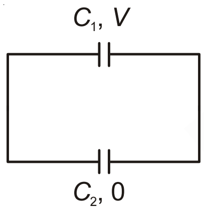
Sol. Answer (3)

The potential of a conductor is same throughout its interior and at its surface.

29. A capacitor of capacity C_1 is charged upto V volt and then connected to an uncharged capacitor of capacity C_2. The final potential difference across each will be

(1) $\frac{C_2V}{C_1+C_2}$ (2) $\frac{C_1V}{C_1+C_2}$ (3) $\left(1+\frac{C_2}{C_1}\right)V$ (4) $\left(1-\frac{C_2}{C_1}\right)\cdot V$

Sol. Answer (2)

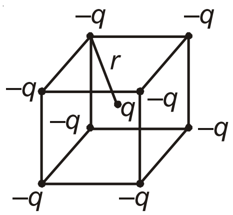


$V_{\text{net}}=\frac{C_1V}{C_1+C_2}$

30. Identical charges ($-q$) are placed at each corners of cube of side b then electrostatic potential energy of charge ($+q$) which is placed at centre of cube will be

(1) $\frac{-8\sqrt{3}q^2}{4\pi\varepsilon_0 b}$ (2) $\frac{-8\sqrt{2}q^2}{\pi\varepsilon_0 b}$ (3) $\frac{-4q^2}{\sqrt{3}\pi\varepsilon_0 b}$ (4) $\frac{8\sqrt{2}q^2}{4\pi\varepsilon_0 b}$

Sol. Answer (3)



$r=\frac{\sqrt{3}b}{2}$

$$U=8\left[\frac{k(q)(-q)}{\frac{b\sqrt{3}}{2}}\right]$$

$$U=\frac{-16q^2}{4\pi\varepsilon_0\sqrt{3}b}$$

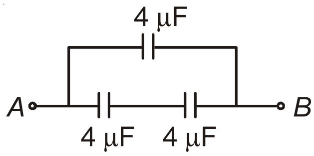
$$U=\frac{-4q^2}{\pi\varepsilon_0\sqrt{3}b}$$

31. Three capacitors each of capacity 4 μF are to be connected in such a way that the effective capacitance is 6 μF. This can be done by

(1) Connecting all of them in series (2) Connecting them in parallel

(3) Connecting two in series and one in parallel (4) Connecting two in parallel and one in series

Sol. Answer (3)

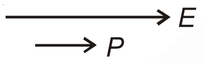


$C_{net} = 6\ \mu F$

32. An electric dipole has the magnitude of its charge as *q* and its dipole moment is *p*. It is placed in a uniform electric field *E*. If its dipole moment is along the direction of the field, the force on it and its potential energy are respectively

(1) $2qE$ and minimum (2) qE and pE (3) Zero and minimum (4) qE and maximum

Sol. Answer (3)



$F = 0$

$U = -pE$

↓

Minimum

33. A bullet of mass 2 kg is having a charge of 2 mC. Through what potential difference must it be accelerated, starting from rest, to acquire a speed of 10 m/s?

(1) 5 kV (2) 50 kV (3) 5 V (4) 50 V

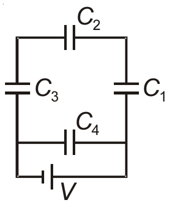
Sol. Answer (2)

$$\left(2\times10^{-3}\right)V = \frac{1}{2}\cdot 2\cdot 10^2$$

$$\left(2\times10^{-3}\right)V = 100$$

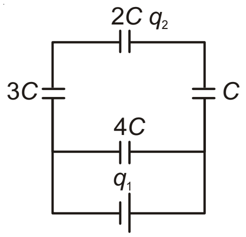
$$V = 50 \times 10^3 = 50\text{ kV}$$

34. A network of four capacitors of capacity equal to $C_1 = C$, $C_2 = 2C$, $C_3 = 3C$ and $C_4 = 4C$ are conducted to a battery as shown in the figure. The ratio of the charges on C_2 and C_4 is



(1) $\frac{4}{7}$ (2) $\frac{3}{22}$ (3) $\frac{7}{4}$ (4) $\frac{22}{3}$

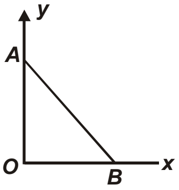
Sol. Answer (2)



$$\frac{q_1}{q_2} = \frac{24C\cdot 11}{36C}$$

$$\frac{q_1}{q_2} = \frac{22}{3}$$

35. As per the diagram a point charge $+q$ is placed at the origin O. Work done in taking another point charge $-Q$ from the point A [coordinates $(0, a)$] to another point B [coordinates $(a, 0)$] along the straight path AB is



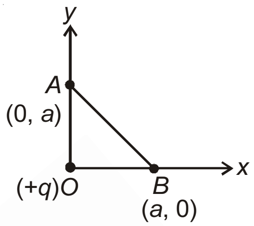
(1) Zero (2) $\left(\frac{qQ}{4\pi\varepsilon_0}\frac{1}{a^2}\right).\sqrt{2}\,a$ (3) $\left(\frac{-qQ}{4\pi\varepsilon_0}\frac{1}{a^2}\right).\sqrt{2}\,a$ (4) $\left(\frac{qQ}{4\pi\varepsilon_0}\frac{1}{a^2}\right).\frac{a}{\sqrt{2}}$

Sol. Answer (1)

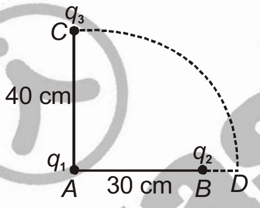
$V_A = V_B$

$W = -Q(V_B - V_A) \quad | \; V_A = V_B$

$W = 0$



36. Two charges q_1 and q_2 are placed 30 cm apart, as shown in the figure. A third charge q_3 is moved along the arc of a circle of radius 40 cm from C to D. The change in the potential energy of the system is $\frac{q_3}{4\pi\varepsilon_0}k$, where k is



(1) $8q_1$ (2) $6q_1$ (3) $8q_2$ (4) $10q_2$

Sol. Answer (3)

$$V_C = \frac{k(q_1)\times(100)}{40} + \frac{k(q_2)(100)}{50}$$

$$V_C = k(2.5q_1 + 2q_2)$$

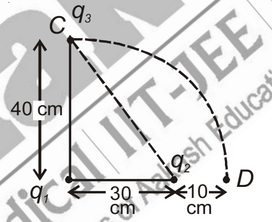
$$V_D = \frac{kq_1(100)}{40} + \frac{kq_2(100)}{10}$$

$V_D = k\,(2.5q_1 + 10q_2)$

$U = q_3\,(V_D - V_C)$

$U = q_3\,(8kq_2)$

$U = kq_3\,(8q_2)$



37. A parallel plate air capacitor is charged to a potential difference of V volts. After disconnecting the charging battery the distance between the plates of the capacitor is increased using an insulating handle. As a result the potential difference between the plates

(1) Increases (2) Decreases (3) Does not change (4) Becomes zero

Sol. Answer (1)

$$U = \frac{1}{2}CV^2$$

$q = C\ V$

constant decreases increases

d increases, C decreases

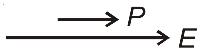
38. An electric dipole of moment $\vec{p}$ is lying along a uniform electric field $\vec{E}$. The work done in rotating the dipole by 90° is

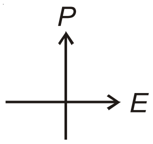
(1) pE (2) $\sqrt{2}\,pE$ (3) $pE/2$ (4) $2pE$

Sol. Answer (1)

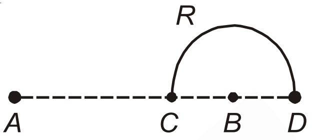
$W = -pE\cos 90° - (-pE\cos 0°)$

$W = pE$



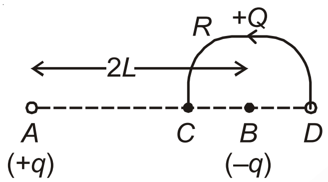


39. Charges $+q$ and $-q$ are placed at points A and B respectively which are a distance $2L$ apart, C is the midpoint between A and B. The work done in moving a charge $+Q$ along the semicircle CRD is



(1) $\dfrac{qQ}{2\pi\varepsilon_0 L}$ (2) $\dfrac{qQ}{6\pi\varepsilon_0 L}$ (3) $-\dfrac{qQ}{6\pi\varepsilon_0 L}$ (4) $\dfrac{qQ}{4\pi\varepsilon_0 L}$

Sol. Answer (3)



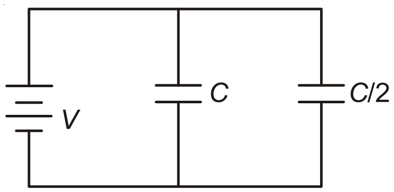
$$V_C = \frac{kq}{L} - \frac{kq}{L} = 0$$

$$V_D = \frac{kq}{3L} - \frac{kq}{L} = \frac{-2kq}{3L}$$

$W = +Q(V_C - V_D)$

$$W = Q \cdot \frac{2kq}{3L}$$

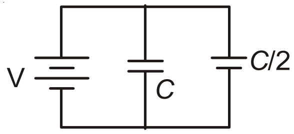
40. Two condensers, one of capacity C and other of capacity $C/2$ are connected to a V-volt battery, as shown. The work done in charging fully both the condensers is



(1) $\frac{1}{4}CV^2$ (2) $\frac{3}{4}CV^2$ (3) $\frac{1}{2}CV^2$ (4) $2CV^2$

Sol. Answer (2)

$$W = \frac{1}{2}CV^2 + \frac{1}{2}\frac{C}{2}V^2$$



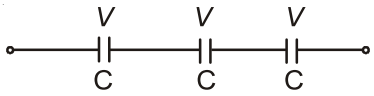
$$W = \frac{3}{4}CV^2$$

41. Three capacitors each of capacitance C and of breakdown voltage V are joined in series. The capacitance and breakdown voltage of the combination will be

(1) $3C, 3V$ (2) $\frac{C}{3}, \frac{V}{3}$ (3) $3C, \frac{V}{3}$ (4) $\frac{C}{3}, 3V$

Sol. Answer (4)

Net capacitance $= \frac{C}{3}$



Breakdown voltage = 3 V

42. The electric potential at a point (x, y, z) is given by $V = -x^2y - xz^3 + 4$. The electric field $\vec{E}$ at that point is

(1) $\vec{E} = \hat{i}(2xy - z^3) + \hat{j}xy^2 + \hat{k}3z^2x$ (2) $\vec{E} = \hat{i}(2xy + z^3) + \hat{j}x^2 + \hat{k}3xz^2$

(3) $\vec{E} = \hat{i}2xy + \hat{j}(x^2 + y^2) + \hat{k}(3xz - y^2)$ (4) $\vec{E} = \hat{i}z^3 + \hat{j}xyz + \hat{k}z^2$

Sol. Answer (2)

$V = -x^2y - xz^3 + 4$

$$E_x = -\frac{dV}{dx} = +2xy + z^3$$

$$E_y = -\frac{dV}{dy} = x^2$$

$E_z = +3xz^2$

$$\vec{E} = \left(2xy + z^3\right)\hat{i} + x^2\hat{j} + 3xz^2\hat{k}$$

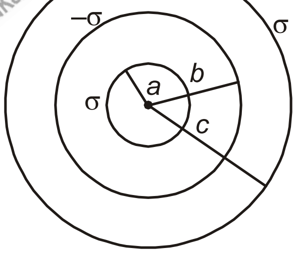
43. Three concentric spherical shells have radii a, b and c ($a < b < c$) and have surface charge densities σ, $-\sigma$ and σ respectively. If V_A, V_B and V_C denote the potentials of the three shells, then, for $c = a + b$, we have

(1) $V_C = V_B = V_A$ (2) $V_C = V_A \neq V_B$ (3) $V_C = V_B \neq V_A$ (4) $V_C \neq V_B \neq V_A$

Sol. Answer (2)

$$V_A = \frac{k\sigma 4\pi a^2}{a} - \frac{k\sigma 4\pi b^2}{b} + \frac{k\sigma 4\pi c^2}{c}$$

$V_A = 4\pi k\sigma(a - b + c)$



$$V_B = \frac{k\sigma 4\pi a^2}{b} - \frac{k\sigma 4\pi b^2}{b} + \frac{k\sigma 4\pi c^2}{c}$$

$$V_B = k\sigma 4\pi\left[\frac{a^2}{b} - b + c\right]$$

$$V_C = \frac{k\sigma 4\pi a^2}{c} - \frac{k\sigma 4\pi b^2}{c} + \frac{k\sigma 4\pi c^2}{c}$$

$$V_C = k\sigma 4\pi\left[\frac{a^2 - b^2}{c} + c\right]$$

If $V_A = V_C$

$$a - b + c = \frac{a^2 - b^2}{c} + c$$

$c = a + b$

44. The mean free path of electrons in a metal is 4×10^{-8} m. The electric field which can give on an average 2 eV energy to an electron in the metal will be in units of V/m

(1) 5×10^{7} (2) 8×10^{7} (3) 5×10^{-11} (4) 8×10^{-11}

Sol. Answer (1)

$2 = E\,(4 \times 10^{-8})$

$$E = \frac{2}{4} \times 10^{8}$$

$E = 0.5 \times 10^{8}$ N/C

$E = 5 \times 10^{7}$

45. A series combination of n_1 capacitors, each of value C_1, is charged by a source of potential difference 4 V. When another parallel combination of n_2 capacitors, each of value C_2, is charged by a source of potential difference V, it has the same (total) energy stored in it, as the first combination has. The value of C_2, in terms of C_1, is then

(1) $\dfrac{16C_1}{n_1 n_2}$ (2) $\dfrac{2C_1}{n_1 n_2}$ (3) $16\dfrac{n_2}{n_1}C_1$ (4) $2\dfrac{n_2}{n_1}C_1$

Sol. Answer (1)

$$C_{\text{net}} = \frac{C_1}{n_1}$$

$$U = \frac{1}{2}\frac{C_1}{n_1} \cdot 4^2 V^2$$

$$U = \frac{8C_1V^2}{n_1}$$

$$C_{\text{net}} = n_2 C_2$$

$$U = \frac{1}{2} n_2 C_2 V^2$$

$$\frac{8C_1V^2}{n_1} = \frac{n_2C_2V^2}{2}$$

$$C_2 = \frac{16C_1}{n_1 n_2}$$

46. Two parallel metal plates having charges $+Q$ and $-Q$ face each other at a certain distance between them. If the plates are now dipped in kerosene oil tank, the electric field between the plates will

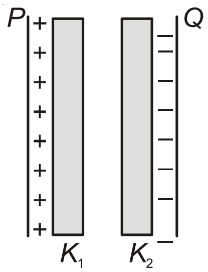
(1) Become zero (2) Increase (3) Decrease (4) Remain same

Sol. Answer (3)

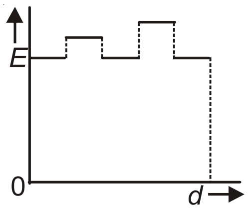
$$\underset{\text{constant}}{\underset{\downarrow}{q}} = \underset{\text{increases}}{\underset{\downarrow}{C}}\;\underset{\text{decreases}}{\underset{\searrow}{V}}$$

E decreases

47. Two thin dielectric slabs of dielectric constants K_1 and K_2 ($K_1 < K_2$) are inserted between plates of a parallel plate capacitor, as shown in the figure. The variation of electric field *E* between the plates with distance *d* as measured from plate *P* is correctly shown by



(1)



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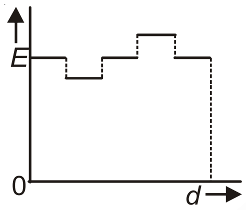

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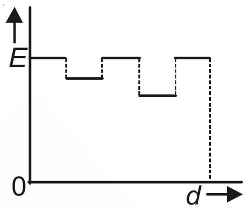

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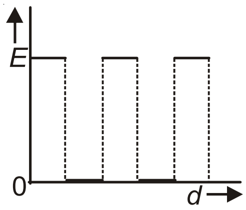


Sol. Answer (3)

In vacuum electric field between parallel plate capacitor is given by

$$E = \frac{Q}{A\varepsilon_0}$$

In medium,

$$E' = \frac{Q}{kA\varepsilon_0}$$

as $K_2 > K_1$

$\Rightarrow$ Electric field will be less in K_2.

48. A conducting sphere of radius *R* is given a charge *Q*. The electric potential and the electric field at the centre of the sphere respectively are

(1) Zero and $\frac{Q}{4\pi\varepsilon_0 R^2}$ (2) $\frac{Q}{4\pi\varepsilon_0 R}$ and zero (3) $\frac{Q}{4\pi\varepsilon_0 R}$ and $\frac{Q}{4\pi\varepsilon_0 R^2}$ (4) Both are zero

Sol. Answer (2)

Electric field inside a conductor is always zero and conductor is a equipotential body. The value of electric potential at the surface will be at the centre.

49. In a region, the potential is represented by $V(x, y, z) = 6x - 8xy - 8y + 6yz$, where *V* is in volts and *x*, *y*, *z* are in metres. The electric force experienced by a charge of 2 coulomb situated at point (1, 1, 1) is

(1) $6\sqrt{5}$ N (2) 30 N (3) 24 N (4) $4\sqrt{35}$ N

Sol. Answer (4)

Electric force $F = qE$

$$E = \frac{-\partial V}{\partial r} = -\left[\frac{\partial V}{\partial x}\hat{i} + \frac{\partial V}{\partial y}\hat{j} + \frac{\partial V}{\partial z}\hat{k}\right]$$

$$\frac{\partial V}{\partial x} = \frac{\partial}{\partial x}\left[6x - 8xy - 8y + 6yz\right] = 6 - 8y$$

$$\frac{\partial V}{\partial y} = -8x - 8 + 6z$$

$$\frac{\partial V}{\partial z} = 6y$$

$$E_{(1,\,1,\,1)} = -\left[(6-8)\hat{i} + (-8-8+6)\hat{j} + (6)\hat{k}\right]$$

$$= -\left[2\hat{i} + 10\hat{j} + 6\hat{k}\right]$$

$$|E| = 2\sqrt{35} \text{ N/C}$$

$$F = qE = (2)(2\sqrt{35}) = 4\sqrt{35} \text{ N}$$

SECTION - D

Assertion-Reason Type Questions

1. A : For a given potential function, electric intensity function can be uniquely derived.

   R : For a given electric intensity function, electric potential function can be uniquely derived.

Sol. Answer (3)

Reason is wrong. Electric potential difference can be derived but not electric potential function.

2. A : An equipotential surface is normal to electric field lines.

   R : Potential increases in the direction of electric field.

Sol. Answer (3)

Reason is wrong. Electric potential decreases in the direction of electric field.

3. A : One may have zero potential but non-zero electric field at a point in space.

   R : Potential is a scalar quantity.

Sol. Answer (2)

Both are correct but reason is not the correct explanation of assertion.

4. A : Absolute value of potential is not defined.

   R : Two equipotential lines cannot intersect each other.

Sol. Answer (2)

Both are correct but reason is not the correct explanation of assertion.

5. A : Two large conducting spheres carrying charges Q_1 and Q_2 are brought close to each other. The magnitude of electrostatic force between them is exactly given by $Q_1 Q_2/4\pi\varepsilon_0 r^2$, where r is the distance between their centres.

   R : Here charges Q_1 and Q_2 can be assumed to be concentrated at the centres of their respective spheres.

Sol. Answer (4)

Both are wrong.

6. A : Work done by the field of a nucleus in a complete orbit of the electron is zero even if the orbit is elliptical.

   R : Electrostatic force is conservative in nature.

Sol. Answer (1)

Both are correct and reason is correct explanation of assertion.

7. A : Electric field is discontinuous across the surface of a charged conductor.

R : Electric potential is discontinuous across the surface of a charged conductor.

Sol. Answer (3)

Reason is wrong. Potential is continuous across the surface of charged conductor.

8. A : Water has a much greater dielectric constant than any other ordinary substance.

R : Water has permanent dipole moment.

Sol. Answer (1)

Both are correct and reason is the correct explanation of assertion.

9. A : Electric potential of a positively charged body may be negative.

R : The potential of a conductor does not depend on the charge of the conductor.

Sol. Answer (3)

Reason is wrong. Potential of a conductor depends on the charge of the conductor.

10. A : The potential difference between two concentric spherical shells depends only on the charge of inner shell.

R : The electric field in the region in between two shells depends on the charge of inner shell and electric field is the negative of potential gradient.

Sol. Answer (1)

Both are correct and reason is the correct explanation of assertion.

11. A : If E be electric field at a point, in free space then energy density at that point will be $\frac{1}{2}\varepsilon_0 E^2$.

R : Electrostatic field is a conservative field.

Sol. Answer (2)

Both are correct but reason is not the correct explanation of assertion.

12. A : A capacitor is a device which stores electric energy in the form of electric field.

R : Net charge on the capacitor is always zero.

Sol. Answer (2)

Both are correct but reason is not the correct explanation of assertion.

13. A : When two conductors charged to different potentials are connected to each other, the negative charge always flows from lower potential to higher potential.

R : In the charging process, there is always a flow of electrons only.

Sol. Answer (2)

Both are correct but reason is not the correct explanation of assertion.

❑ ❑ ❑

Chapter 3

Current Electricity

Solutions

SECTION - A

Objective Type Questions

1. Electric current has both magnitude and direction. It is a

(1) Vector quantity (2) Scalar quantity (3) Tensor quantity (4) None of these

Sol. Answer (2)

Current is a scalar quantity.

2. Identical piece of Ge and Cu are taken and cooled, then

(1) Resistivity of both increases

(2) Resistivity of both decreases

(3) Resistivity of Cu increases and Ge decreases

(4) Resistivity of Cu decreases and Ge increases

Sol. Answer (4)

Ge is a semiconductor so its resistivity decreases with increase in temperature.

3. A current of 10 A is maintained in a conductor of cross-section 1 cm^2. If the number density of free electrons be 9×10^{28} m^{-3}, the drift velocity of free electrons is

(1) 6.94×10^{-6} m/s (2) 5.94×10^{-2} m/s (3) 1.94×10^{-3} m/s (4) 2.94×10^{-4} m/s

Sol. Answer (1)

$i = neAV_d$

$10 = (9 \times 10^{28})\,(1.6 \times 10^{-19})\,(10^{-4})\,V_D$

Solving, we get

$V_D = 6.94 \times 10^{-6}$ m/s

4. A potential difference of 5 V is applied across a conductor of length 10 cm. If drift velocity of electrons is 2.5×10^{-4} m/s, then electron mobility will be

(1) 5×10^{-4} m^2 V^{-1} s^{-1} (2) 5×10^{-6} m^2 V^{-1} s^{-1} (3) 5×10^{-2} m^2 V^{-1} s^{-1} (4) Zero

Sol. Answer (2)

$$\mu = \frac{V_D}{E}$$

$$\mu = \frac{2.5\times10^{-4}\times0.1}{5}$$

$\mu = 5 \times 10^{-6}$ m^{2}V^{-1}s^{-1}

5. A potential difference of 10 V is applied across a conductor of 1000 Ω. The number of electrons flowing through the conductor in 300 s is

(1) 1.875×10^{16} (2) 1.875×10^{17} (3) 1.875×10^{22} (4) 1.875×10^{19}

Sol. Answer (4)

$$i = \frac{10}{1000} = 0.01 \text{ A}$$

$$n = \frac{0.01}{1.6 \times 10^{-19}}$$

6. If n, e, τ and m are representing electron density, charge, relaxation time and mass of an electron respectively, then the resistance of a wire of length l and cross-sectional area A is given by

(1) $\frac{ml}{ne^2\tau A}$ (2) $\frac{m\tau A}{ne^2 l}$ (3) $\frac{ne^2 \tau A}{ml}$ (4) $\frac{ne^2 A}{m\tau l}$

Sol. Answer (1)

$$R = \frac{Pl}{A}$$

$$R = \frac{ml}{ne^2 lA}$$

7. Ohm's law fails in

(1) Diode (2) Thyristor (3) *PN* junction system (4) All of these

Sol. Answer (4)

Ohm's law is not applicable for diode, thyristor as well as *PN* junction

8. The resistance of a rectangular block of copper of dimensions 2 mm × 2 mm × 5 m between two square faces is 0.02 Ω. What is the resistivity of copper?

(1) 1.6×10^{-8} Ω (2) 1.6×10^{-6} Ω-m (3) 1.6×10^{-8} Ω-m (4) Zero

Sol. Answer (3)

$$R = \frac{\rho l}{A}$$

$$0.02 = \frac{\rho(5)}{4 \times 10^{-6}}$$

$$\rho = \frac{8 \times 10^{-8}}{5}$$

$\rho = 1.6 \times 10^{-8}$ Ω-m

9. If a copper wire is stretched to make its radius decrease by 0.1%, then the percentage increase in resistance is nearly

(1) 0.1% (2) 0.8% (3) 0.4% (4) 0.2%

Sol. Answer (3)

For x% decrease in radius, increase in resistance is $4x$%

$\Rightarrow$ 0.4 %

10. A certain piece of copper is to be shaped into a conductor of minimum resistance. Its length and diameter should respectively be

(1) L, D (2) $2L, \frac{D}{2}$ (3) $\frac{L}{2}, 2D$ (4) $L, \frac{D}{2}$

Sol. Answer (3)

For (L / 2, D), resistance is minimum

11. A wire of resistance x ohm is drawn out, so that its length is increased to twice its original length, and its new resistance becomes 20 Ω, then x will be

(1) 5 Ω (2) 10 Ω (3) 15 Ω (4) 20 Ω

Sol. Answer (1)

$$x = \frac{\rho l}{A}$$

$$20 = \frac{\rho(2l)}{(A/2)}$$

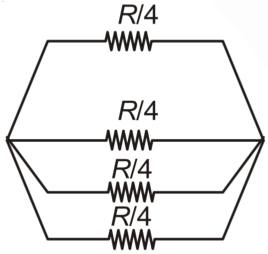
$$\frac{x}{20} = \frac{1}{4}$$

$x = 5$

12. A piece of wire is cut into four equal parts and the pieces are bundled together side by side to form a thicker wire. Compared with that of the original wire, the resistance of the bundle is

(1) The same (2) $\frac{1}{16}$ as much (3) $\frac{1}{8}$ as much (4) $\frac{1}{4}$ as much

Sol. Answer (2)



$$R_{net} = \frac{R}{16}$$

13. Two wires A and B of the same material, having radii in the ratio 1 : 2 carry currents in the ratio 4 : 1. The ratio of drift speed of electrons in A and B is

(1) 16 : 1 (2) 1 : 16 (3) 1 : 4 (4) 4 : 1

Sol. Answer (1)

$4i = neA\ V_D$

$i = ne(4A)\ V'_D$

$$4 = \frac{V_D}{4V'_D}$$

$$\frac{V_D}{V'_D} = 16:1$$

14. The temperature co-efficient of resistance of a wire at 0°C is 0.00125 $°C^{-1}$. At 25°C its resistance is one ohm. The resistance of the wire will be 1.2 ohm at

(1) 225 K (2) 190°C (3) 260°C (4) 185 K

Sol. Answer (2)

$1 = R_0(1 + (0.00125)(25))$

$1.2 = R_0(1 + (0.00125)\,\theta)$

$$\frac{12}{10} = \frac{1 + 0.00125\theta}{1.03125}$$

Solving, we get

$\theta = 190°C$

15. A conductor behaves as a superconductor

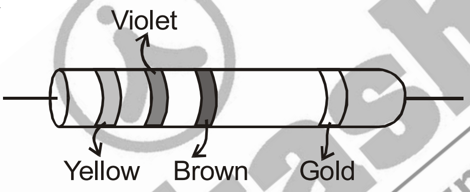
(1) Above critical temperature (2) At critical temperature

(3) At 100°C (4) At boiling point of that metal

Sol. Answer (2)

A conductor behaves as a superconductor at critical temperature.

16. A carbon resistor has coloured strips as shown in figure. What is its resistance?



(1) 410 Ω ± 2% (2) 470 Ω ± 5% (3) 420 Ω ± 3% (4) 405 Ω ± 2%

Sol. Answer (2)

$$\begin{array}{cccc} Y & V & B & G \\ \downarrow & \downarrow & \downarrow & \downarrow \\ 4 & 7 & 1 & 5 \end{array}$$

47 × 10 ± 5%

470 ± 5%

17. Two resistors are joined in parallel whose resultant is $\frac{6}{5}\,\Omega$. One of the resistance wire is broken and the effective resistance becomes 2 ohms. Then the resistance (in ohm) of the wire that got broken is

(1) $\frac{6}{5}$ (2) 2 (3) $\frac{3}{5}$ (4) 3

Sol. Answer (4)

$$\frac{R_1R_2}{R_1 + R_2} = \frac{6}{5}$$

$R_1 = 2$

$$\frac{2R_2}{2 + R_2} = \frac{6}{5}$$

$5R_2 = 6 + 3R_2$

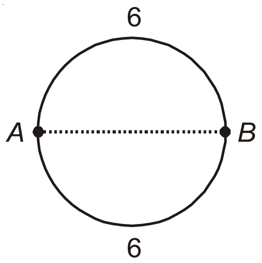
$2R_2 = 6$

$R_2 = 3\ \Omega$

18. A wire has resistance 12 ohm. It is bent in the form of a circle. The effective resistance between the two points on any diameter of the circle is

(1) 12 Ω (2) 24 Ω (3) 3 Ω (4) 6 Ω

Sol. Answer (3)



$R = 3$

19. A technician has only two resistance coils. By using them singly, in series or in parallel, he is able to obtain the resistance 3, 4, 12 and 16 ohms. The resistance of the two coils are

(1) 6 and 10 ohms (2) 4 and 12 ohms (3) 7 and 9 ohms (4) 4 and 16 ohms

Sol. Answer (2)

$$\frac{R_1R_2}{R_1+R_2} = 3$$

$R_1 + R_2 = 16$

$R_1R_2 = 48$

$R_1(16 - R_1) = 48$

$R_1^2 - 16R_1 + 48 = 0$

$R_1 = 4, 12$

20. Two resistances r_1 and r_2 ($r_1 < r_2$) are joined in parallel. The equivalent resistance R is such that

(1) $R > r_1 + r_2$ (2) $R > \sqrt{r_1 r_2}$ (3) $r_1 < R < r_2$ (4) $R < r_1$

Sol. Answer (4)

In parallel the equivalent resistance is less than both the resistances.

21. The resultant resistance value of n resistances each of r ohms and connected in series is x. When those n resistances are connected in parallel, the resultant value is

(1) $\frac{x}{n}$ (2) $\frac{x}{n^2}$ (3) n^2x (4) nx

Sol. Answer (2)

For series

$R_{eq} = x = nr$

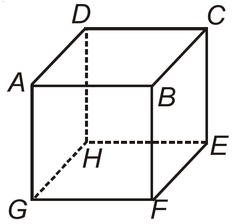
$\Rightarrow r = \frac{x}{n}$

for parallel

$$\frac{1}{R_{eq}} = \frac{n}{r}$$

$$R_{eq} = \frac{r}{n} \Rightarrow R_{eq} = \frac{x}{n(n)} = \frac{x}{n^2}$$

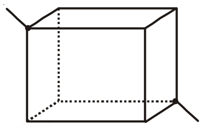
22. Twelve wires of equal resistance R are connected to form a cube. The effective resistance between two diagonal ends A and E will be



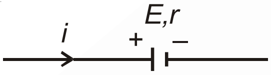
(1) $\frac{5R}{6}$ (2) $\frac{6R}{5}$ (3) $12\ R$ (4) $3\ R$

Sol. Answer (1)

The resistance between the body diagonal ends are $\frac{5R}{6}$



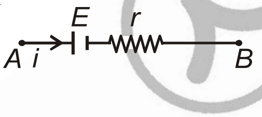
23. According to this diagram, the potential difference across the terminals is (internal resistance of cell = r)



(1) $V = E - i\,r$ (2) $V = E + i\,r$ (3) $V = E$ (4) Zero

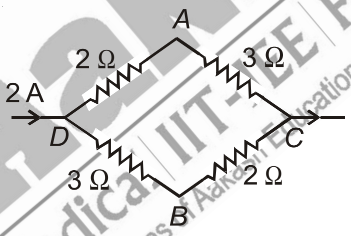
Sol. Answer (2)

$V_A - E - ir = V_B$



$V_A - V_B = E + ir$

24. A current of 2 A flows in a system of conductors shown in figure. The potential difference $V_A - V_B$ will be

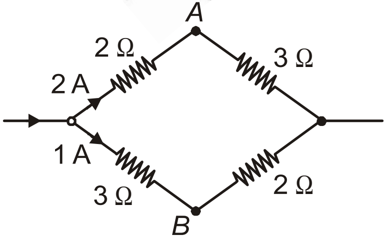


(1) +2 volt (2) –1 volt (3) +1 volt (4) –2 volt

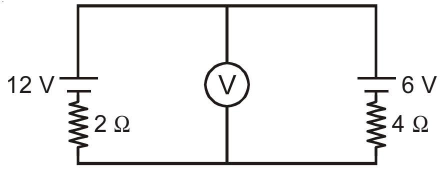
Sol. Answer (3)

$V_A + 2 - 3 = V_B$

$V_A - V_B = 1$

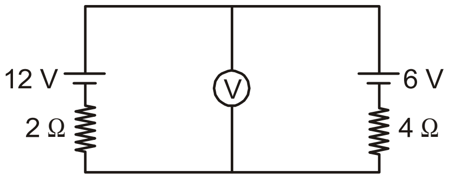


25. Reading of the ideal voltmeter in the circuit below is



(1) 10 V (2) 8 V (3) 6 V (4) Zero

Sol. Answer (1)



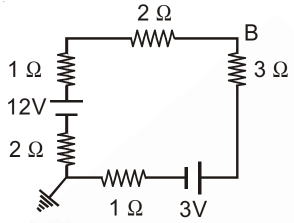
Aliter $\Delta V = \frac{E_1r_2 + E_2r_1}{r_1 + r_2} = \frac{48+12}{6} = \frac{60}{6} = 10\text{ V}$

$i = \frac{6}{6} = 1\text{A}$

$\Delta V = 6 + 1(4)$

$\Delta V = 10\text{ V}$

26. Potential of the point *B* in the circuit below is



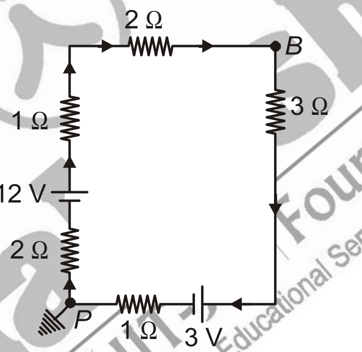
(1) 5 V (2) 6 V (3) 7 V (4) 8 V

Sol. Answer (3)

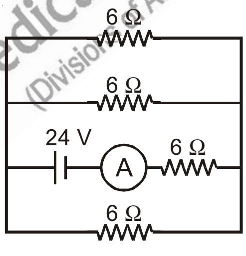
$i = \frac{9}{9} = 1\text{ A}$ | $V_p = 0$ Volt

$V_A - 3 - 3 - 1 = V_B$

$V_A - V_B = 7$



27. Reading of the ammeter in the circuit below is



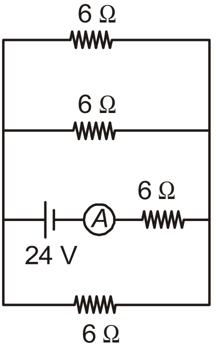
(1) 16 A (2) 3 A (3) 4 A (4) 12 A

Sol. Answer (2)

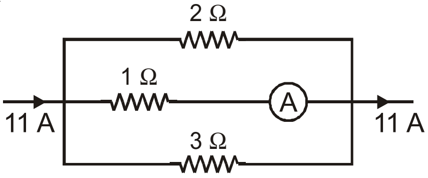
$R_{net} = 8\ \Omega$

$i = \frac{24}{8}$

$i = 3\text{ A}$

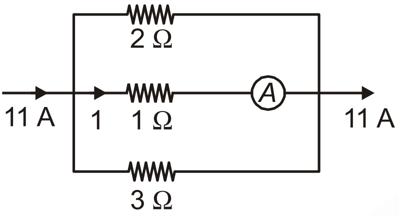


28. The ammeter reading in the circuit below is



(1) 2 A (2) 3 A (3) 6 A (4) 5 A

Sol. Answer (3)



$$\frac{i}{11-i}=\frac{1.2}{1}$$

i = 13.2 – 1.2i

$$i=\frac{13.2}{2.2}=\frac{132}{22}$$

i = 6 A

29. Thousand cells of same emf E and same internal resistance r are connected in series in same order without an external resistance. The potential drop across 399 cells is found to be

(1) Zero (2) 399 E (3) 601 E (4) 1000 E

Sol. Answer (1)

Current through the circuit $i=\frac{1000E}{1000r}=\frac{E}{r}$

Potential drop across one cell $= E-ir = E-\left(\frac{E}{r}\right)r = 0$

⇒ For 399 cells, total potential drop is zero

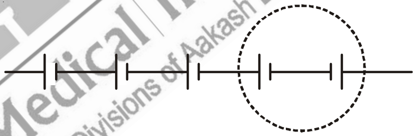
30. Five cells each of e.m.f. E and internal resistance r are connected in series. If due to over sight, one cell is connected wrongly, then the equivalent e.m.f. of the combination is

(1) 5 E (2) 2 E (3) 3 E (4) 4 E

Sol. Answer (3)

Net Emf $= E + E + E + E - E$

$= 3E$



31. Two batteries of different e.m.f.'s and internal resistance connected in series with each other and with an external load resistor. The current is 3.0 A. When the polarity of one battery is reversed, the current becomes 1.0 A. The ratio of the e.m.f.'s of the two batteries is

(1) 2.5 (2) 2 (3) 1.5 (4) 1

Sol. Answer (2)

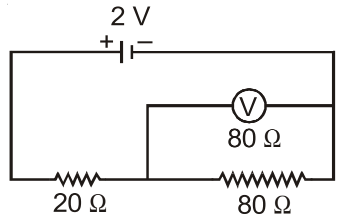
$$3=\frac{E_1+E_2}{R+r_1+r_2}$$

$$1=\frac{E_1-E_2}{R+r_1+r_2}$$

$$3=\frac{E_1+E_2}{E_1-E_2}$$

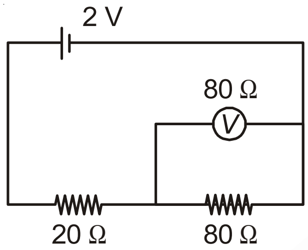
$$2=\frac{E_1}{E_2}$$

32. In figure, the e.m.f. of the cell is 2 V and internal resistance is negligible. The resistance of the voltmeter is 80 ohm. The reading of the voltmeter will be



(1) 2 volt (2) 1.33 volt (3) 1.60 volt (4) 0.80 volt

Sol. Answer (2)



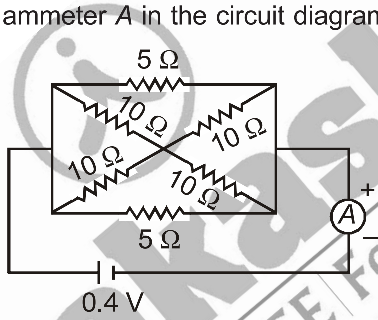
$R_{\text{net}} = 60\ \Omega$

$i = \frac{2}{60} = \frac{1}{30}\text{A}$

$i = \frac{1}{60}A$

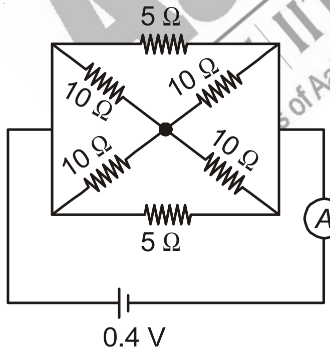
$\Delta V = \frac{80}{60} = \frac{4}{3}\text{V}$

33. Calculate the current shown by the ammeter *A* in the circuit diagram



(1) 0.1 A (2) 0.2 A (3) 0.3 A (4) 0.4 A

Sol. Answer (2)

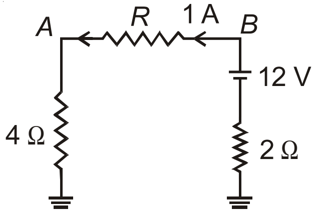


$R_{\text{net}} = 2\ \Omega$

$0.4 = i(2)$

$i = 0.2$ A

34. In the circuit shown



(1) *R* = 8 ohms (2) *R* = 6 ohms

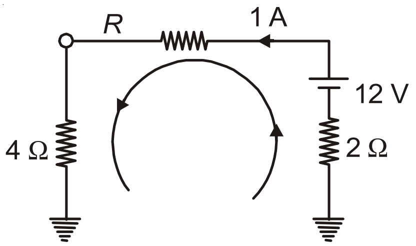
(3) *R* = 10 ohms (4) Potential difference between *A* and *B* is 2 V

Sol. Answer (2)

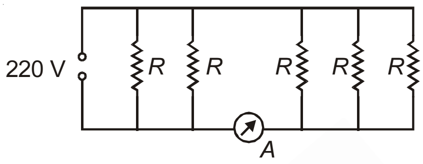
$0 - 2 + 12 - R - 4 = 0$

$6 - R = 0$

$R = 6$



35. Five identical lamps each of resistance $R = 1100\ \Omega$ are connected to 220 V as shown in figure. The reading of ideal ammeter A is



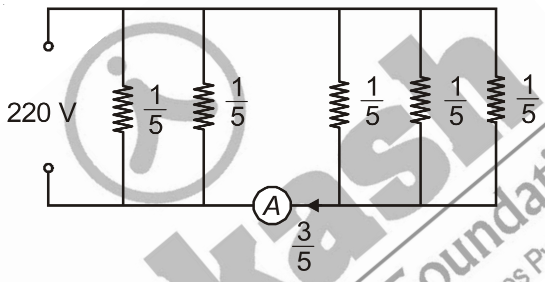
(1) $\frac{1}{5}$ A (2) $\frac{2}{5}$ A (3) $\frac{3}{5}$ A (4) 1 A

Sol. Answer (3)

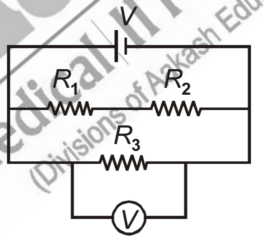
$$R_{\text{net}} = \frac{1100}{5} = 220\ \Omega$$

$$i = \frac{220}{220} = 1\text{A}$$

$$i_A = \frac{3}{5}\text{A}$$



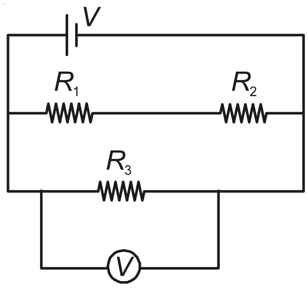
36. In the circuit shown, R_1 is increased. What happens to the reading of the voltmeter (ideal)?



(1) Increases (2) Decreases

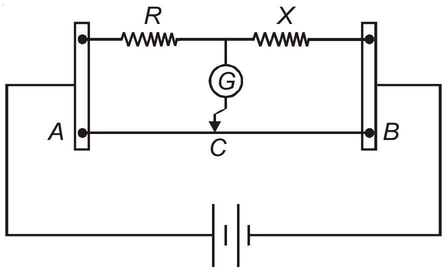
(3) First increases then decreases (4) Does not change

Sol. Answer (4)



Voltmeter reading is always V

37. In the meter bridge shown, the resistance *X* has a negative temperature coefficient of resistance. Neglecting the variation in other resistors, when current is passed for some time, in the cirucit, balance point should shift towards.

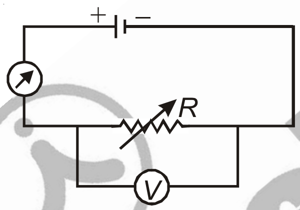


(1) *A* (2) *B* (3) First *A* then *B* (4) It will remain at *C*

Sol. Answer (2)

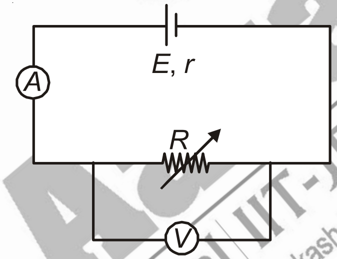
When current is passed, temperature increases, so resistance decreases thus, balance point shift towards

38. A voltmeter is connected in parallel with a variable resistance *R* which is in series with an ammeter and a cell as shown in the figure. For one value of *R*, the meters read 0.3 A and 0.9 V. For another value of *R* the readings are 0.25 A and 1.0 V. What is the internal resistance of the cell?



(1) 0.5 Ω (2) 2 Ω (3) 1.2 Ω (4) 1 Ω

Sol. Answer (2)



$$\overset{-}{0.9} = \overset{-}{E} \overset{+}{-} 0.3r$$

$$1 = E - 0.25r$$

$$0.1 = 0.05r$$

$$r = \frac{10}{5} = 2r$$

39. A galvanometer of resistance 100 Ω gives full scale deflection at 10 mA current. What should be the value of shunt so that it can measure a current of 100 mA?

(1) 11.11 Ω (2) 1.1 Ω (3) 9.9 Ω (4) 4.4 Ω

Sol. Answer (1)

$$S = \frac{10 \times 10^{-3} \times 100}{(100 - 10) \times 10^{-3}} = \frac{1000}{90} = 11.11\,\Omega$$

40. Two cells of e.m.f. E_1 and E_2 are joined in series and the balancing length of the potentiometer wire is 625 cm. If the terminals of E_1 are reversed, the balancing length obtained is 125 cm. Given $E_2 > E_1$, the ratio $E_1 : E_2$ will be

(1) 2 : 3 (2) 5 : 1 (3) 3 : 2 (4) 1 : 5

Sol. Answer (1)

$$\frac{E_1 + E_2}{E_1 - E_2} = \frac{625}{125} = 5$$

$$\frac{E_1}{E_2} = \frac{3}{2}$$

41. A 10 m long potentiometer wire is connected to a battery having a steady voltage. A Leclanche cell is balanced at 4 m length of the wire. If the length is kept the same, but its cross-section is doubled, the null point will be obtained at

(1) 8 m (2) 4 m (3) 2 m (4) None of these

Sol. Answer (2)

If length is kept same, potential gradient remains same, so null point does not change.

42. Of the two bulbs in a house hold circuit, one glows brighter than the other, Which of the two bulbs has a large resistance?

(1) The bright bulb

(2) The dim bulb

(3) Both have the same resistance

(4) The brightness does not depend upon the resistance

Sol. Answer (2)

$$R \propto \frac{1}{P}$$

Thus, bulb which glows dimmer has larger resistance.

43. Two electric bulbs whose resistance are in the ratio of 1 : 2, are connected in parallel to a constant voltage source. The power dissipated in them has the ratio

(1) 2 : 1 (2) 1 : 1 (3) 1 : 4 (4) 1 : 2

Sol. Answer (1)

$$P = \frac{V^2}{R}$$

$$P \propto \frac{1}{R}$$

$$\frac{P_1}{P_2} = \frac{R_2}{R_1} = \frac{2}{1}$$

44. The same mass of aluminium is drawn into two wires 1 mm and 2 mm thick. Two wires are connected in series and current is passed through them. Heat produced in the wire is in the ratio

(1) 16 : 1 (2) 8 : 32 (3) 8 : 2 (4) 4 : 2

Sol. Answer (1)

$4l$ $\quad l$

A $\quad 4A$

$$H_1 : H_2 = R_1 : R_2 = \frac{4l}{A} : \frac{l}{4A} = 16 : 1$$

45. How many 60 W bulbs may be safely run on 220 V using a 5 A fuse?

(1) 18 (2) 16 (3) 14 (4) 12

Sol. Answer (1)

$P = (220)(5) = 1100$

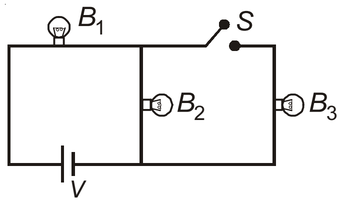
$nP_1 = 1100$

$n60 = 1100$

$n = 18.3$

n = 18 bulbs

46. Three identical bulbs B_1, B_2 and B_3 are connected to the mains as shown in figure. If B_3 is disconnected from the circuit by opening switch S, then incandescence of bulb B_1 will



(1) Increase (2) Decrease (3) Become zero (4) No change

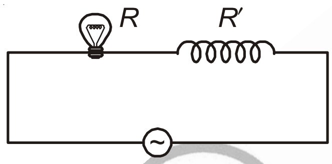
Sol. Answer (2)

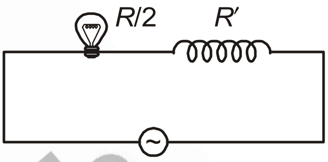
As net resistance increases, so current decreases, so bulb B_1 gets dimer.

47. A 50 W bulb connected in series with a heater coil is put to an AC mains. Now the bulb is replaced by a 100 W bulb. The heater output will

(1) Double (2) Halve (3) Increase (4) Decrease

Sol. Answer (3)



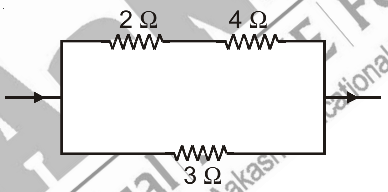


$$P_1 = \left(\frac{E}{R+R'}\right)^2 R'$$

$$P_2 = \frac{ER'}{\left(\frac{R}{2}+R'\right)^2}$$

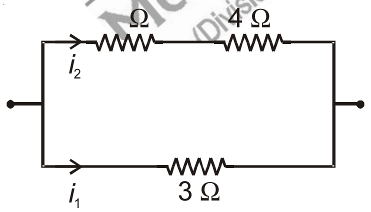
$P_2 > P_1$

48. In a circuit shown in figure, the heat produced in 3 ohm resistor due to a current flowing in it is 12 J. The heat produced in 4 ohm resistor is



(1) 2 J (2) 4 J (3) 64 J (4) 32 J

Sol. Answer (2)



$12 = i_1^2(3)$

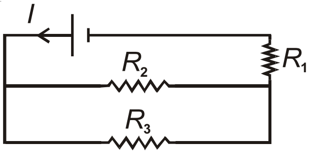
$i_1 = 2$

$$\frac{2}{i_2} = \frac{6}{3}$$

$i_2 = 1$

$H = 1^2 4 = 4$ J

49. Refer to the circuit shown. What will be the total power dissipation in the circuit if P is the power dissipated in R_1? It is given that $R_2 = 4\ R_1$ and $R_3 = 12\ R_1$



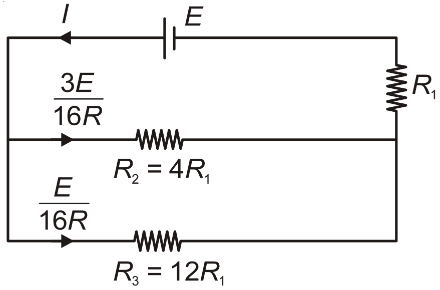
(1) $4P$ (2) $7P$ (3) $13P$ (4) $17P$

Sol. Answer (1)

$$\frac{E}{16R}R_3 = 12R_1$$

$R_{\text{net}} = 4R_1$

$$i = \frac{E}{4R_1}$$



$$P = \frac{E^2R_1}{16R_1^2} = \frac{E^2}{16R_1}$$

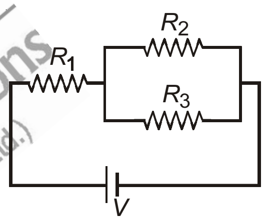
$$P_2 = \frac{9E^2}{256R_1^2}.4R_1 = \frac{9P}{4}$$

$$P_3 = \frac{E^2}{256R_1^2}.12R_1 = \frac{3E^2}{64R_1} = \frac{3P}{4}$$

$$P + \frac{9P}{4} + \frac{3P}{4} = \frac{16P}{4}$$

$$= 4P$$

50. Three identical resistors $R_1 = R_2 = R_3$ are connected as shown to a battery of constant e.m.f. The power dissipated is



(1) The least in R_1

(2) Greatest in R_1

(3) In the ratio 1:2 in resistance R_1 and R_2 respectively

(4) The same in R_1 and in the parallel combination of R_2 and R_3

Sol. Answer (2)

Power dissipated is maximum in R_1.

51. Four equal resistance dissipated 5 W of power together when connected in series to a battery of negligible internal resistance. The total power dissipated in these resistance when connected in parallel across the same battery would be

(1) 125 W	(2) 80 W	(3) 20 W	(4) 5 W

Sol. Answer (2)

$$\frac{P}{4} = 5$$

$P = 20$

$4(20) = 80$ W

Net power in parallel

52. Two heater coils separately take 10 minute and 5 minute to boil certain amount of water. If both the coils are connected in series, the time taken will be

(1) 15 min	(2) 7.5 min	(3) 3.33 min	(4) 2.5 min

Sol. Answer (1)

$t = t_1 + t_2$

$t = 10 + 5$

$t = 15$ minute

53. A cell sends a current through a resistance R for time t. Now the same cell sends current through another resistance r for the same time. If same amount of heat is developed in both the resistance, then the internal resistance of cell is

(1) $\frac{(R+r)}{2}$ (2) $\frac{(R-r)}{2}$ (3) $\frac{(Rr)}{2}$ (4) $\sqrt{(Rr)}$

Sol. Answer (4)

$$H_1 = \frac{E^2R}{(R+r_1)^2}$$

$$H_2 = \frac{E^2R}{(r+r_1)^2}$$

$$\frac{R}{(R+r_1)^2} = \frac{r}{(r+r_1)^2}$$

$$\frac{r+r_1}{R+r_1} = \frac{\sqrt{r}}{\sqrt{R}}$$

$$\sqrt{R}r_1 + r\sqrt{R} = \sqrt{r}r_1 + R\sqrt{r}$$

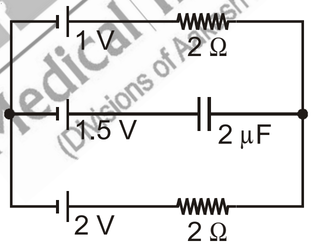
$$r_1\left(\sqrt{R}-\sqrt{r}\right) = \sqrt{Rr}\left(\sqrt{R}-\sqrt{r}\right)$$

$$r_1 = \sqrt{Rr}$$

SECTION - B

Objective Type Questions

1. The charge in the 2 μF capacitor at steady state is



(1) Zero (2) 2 μC (3) 4 μC (4) 6 μC

Sol. Answer (1)

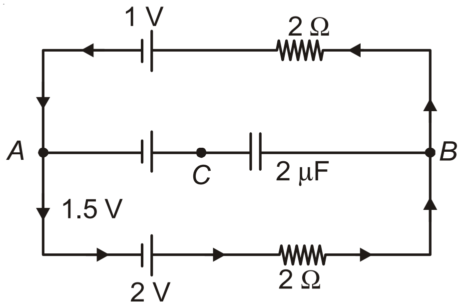
$$i = \frac{1}{4} = 0.25 \text{ A}$$

$$V_B - 0.5 - 1 + 1.5 = V_c$$

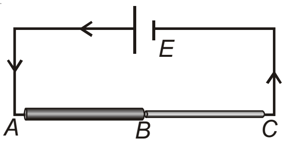
$$V_B = V_C$$

$$\Delta V = 0$$

$$q = 0$$



2. In the following diagram, the lengths of wires *AB* and *BC* are equal, but the radius of wire *AB* is double that of *BC*. The ratio of potential gradient on wires *AB* and on *BC* will be (wires are made of same material)



(1) 4 : 1 (2) 1 : 4 (3) 2 : 1 (4) 1 : 1

Sol. Answer (2)

$= \frac{R}{4}$

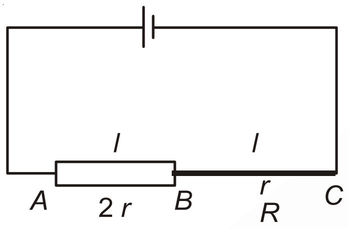
$i = \frac{4E}{5R}$

$\Delta V_1 = \frac{E}{5}$

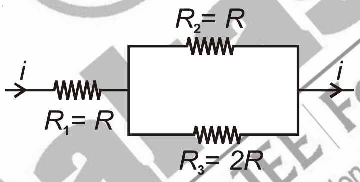
$\Delta V_2 = \frac{4E}{5}$

$\Delta V_1 = \Delta V_2$

$= 1 : 4$



3. In the circuit shown, the thermal power dissipated in R_1 is *P*. The thermal power dissipated in R_2 is

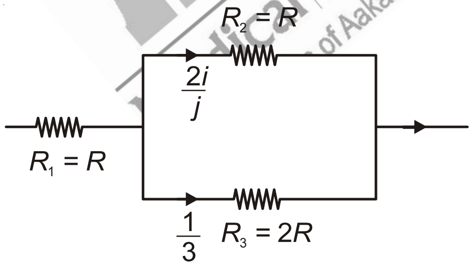


(1) *P* (2) $\frac{4P}{9}$ (3) $\frac{2P}{3}$ (4) $\frac{P}{9}$

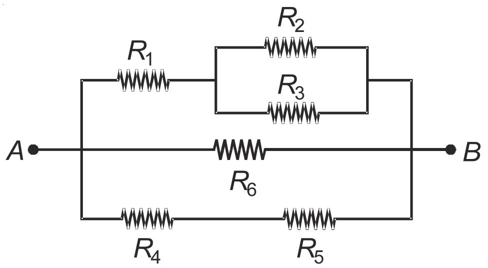
Sol. Answer (2)

$P = i^2R$

$P_2 - \frac{4i^2}{9}R = \frac{4P}{9}$



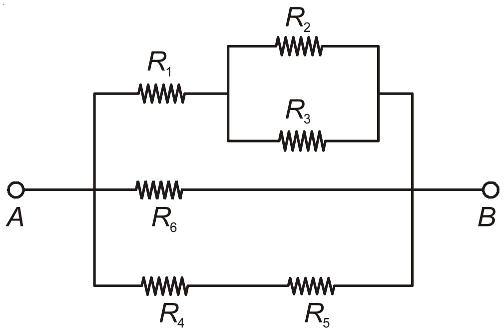
4. Consider the combination of resistors as shown in figure and pick out the correct statement



(1) R_1 & R_4 are connected in parallel (2) R_1 & R_2 are connected in series

(3) R_2 & R_3 are connected in parallel (4) R_6 & R_4 are connected in parallel

Sol. Answer (3)



R_2 and R_3 ⇒ Parallel

5. Select the correct statement

(1) Electric current is a vector quantity

(2) Resistivity of a conductor decreases with increase in temperature

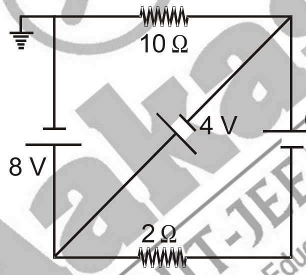
(3) Resistance is the opposition to the flow of current

(4) Current density is a scalar quantity

Sol. Answer (3)

Resistance is the opposition to the flow of current

6. In the circuit shown in figure, all cells are ideal. The current through 2 Ω resistor is



(1) 5 A (2) 1 A (3) 0.2 A (4) Zero

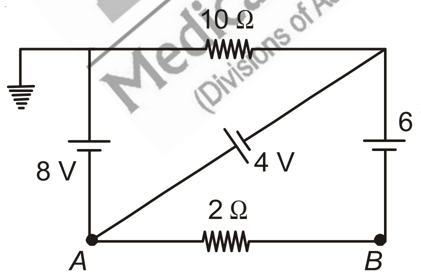
Sol. Answer (1)

$V_A - 4 - 6 = V_B$

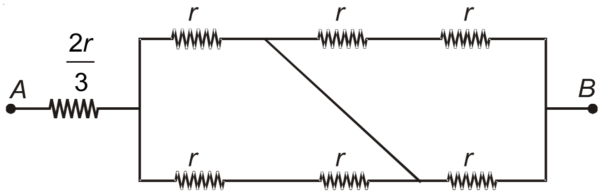
$V_A - V_B = w$

$10 = i(2)$

$i = 5$ A

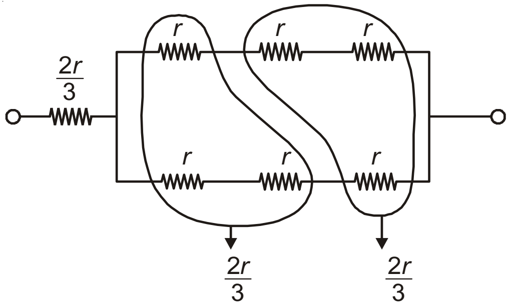


7. The effective resistance of the network between points *A* & *B* is



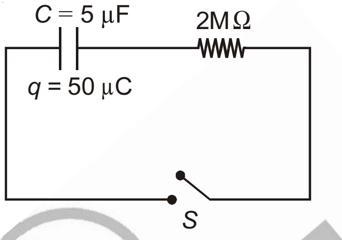
(1) r (2) $2r$ (3) $\frac{4r}{3}$ (4) $\frac{7r}{3}$

Sol. Answer (2)



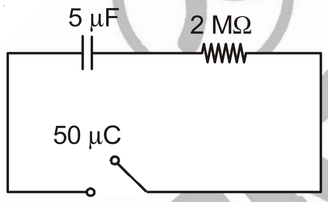
$R_{\text{net}} = 2r$

8. The following circuit consist of a 5 μF capacitor, having charge 50 μC as shown. The switch is closed at $t = 0$. The value of current in 2 MΩ resistor at $t = 0$ is



(1) 1 μA (2) 2 μA (3) 5 μA (4) 5 A

Sol. Answer (3)



$$\Delta V = \frac{50}{5} = 10\text{V}$$

$10 = i(2 \times 10^6)$

$i = 5$ μA

9. There are a large number of cells available, each marked (6 V, 0.5 Ω) to be used to supply current to a device of resistance 0.75 Ω, requiring 24 A current. How should the cells be arranged, so that power is transmitted to the load using minimum number of cells?

(1) Six rows, each containing four cells (2) Four rows, each containing six cells
(3) Four rows, each containing four cells (4) Six rows, each containing six cells

Sol. Answer (2)

$E = 6$V

$r = 0.5$ Ω

$R = 0.75$ Ω

$i = 24$ Ω

$S(0.5) = P(0.75)$

$2s = 3p$

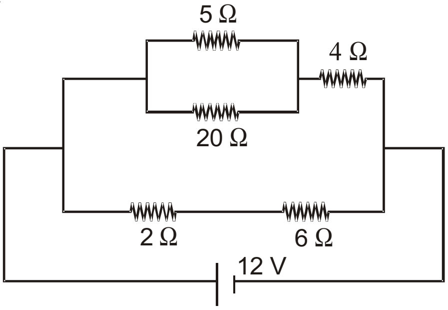
$$i = \frac{PSE}{Sr + PR}$$

$$24 = \frac{P\left(\frac{3}{2}P\right)6}{15P}$$

$P = 4$ rows

$S = 6$ cells

10. A circuit containing five resistors is connected to a battery with a 12 V emf as shown in figure. The potential difference across 4Ω resistor is

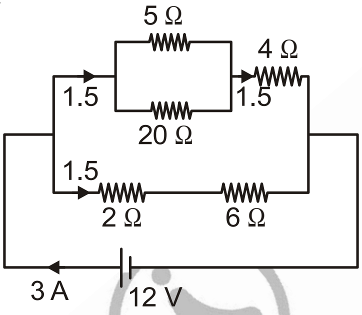


(1) 3 V (2) 6 V (3) 9 V (4) 12 V

Sol. Answer (2)

$$i = \frac{12}{4} = 3\text{A}$$

$$\Delta V_4 = 6\text{V}$$



11. The temperature coefficient of resistance of tungsten is 4.5×10^{-3} °C^{-1} and that of germanium is -5×10^{-2} °C^{-1}. A tungsten wire of resistance 100 Ω is connected in series with a germanium wire of resistance R. The value of R for which the resistance of combination does not change with temperature is

(1) 9 Ω (2) 1111 Ω (3) 0.9 Ω (4) 111.1 Ω

Sol. Answer (1)

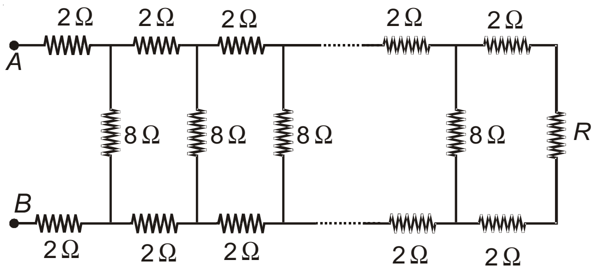
$R_1\alpha_1 + R_2\alpha_2 = 0$

$(100)\,(4.5 \times 10^{-3}) = R(5 \times 10^{-2})$

$0.9 \times 10 = R$

$R = 9r$

12. Consider the ladder network shown in figure. What should be the value of resistance R, so that effective resistance between A & B becomes independent of number of elements in the combination?

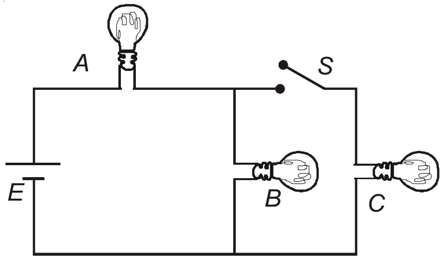


(1) 2 Ω (2) 4 Ω (3) 8 Ω (4) 16 Ω

Sol. Answer (2)

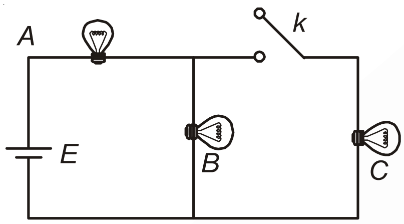
For $R = 4r$, the sequence repeats itself.

13. Three identical bulbs are connected as shown in figure. When switch *S* is closed, the power consumed in bulb *B* is *P*. What will be the power consumed by the same bulb when switch *S* is opened?



(1) $\frac{9P}{4}$ (2) $\frac{16P}{9}$ (3) $\frac{9P}{16}$ (4) $\frac{4P}{9}$

Sol. Answer (1)



$$P = \left(\frac{E}{2R}\right)^2 R$$

$$P = \frac{E^2}{4R}$$

When *K* is closed

$$i = \frac{2E}{3R}$$

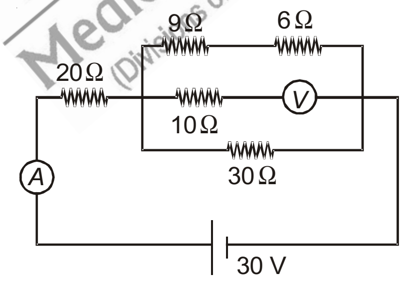
$$P' = \frac{E^2}{9R^2}.R$$

$$P' = \frac{E^2}{9R}$$

$$\frac{P}{P'} = \frac{9}{4}$$

$$P' = \frac{4P}{9}$$

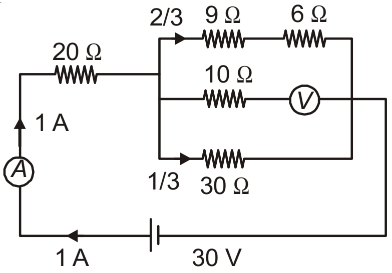
14. In the circuit shown in figure, if ammeter and voltmeter are ideal, then the power consumed in 9 Ω resistor will be



(1) 3.33 W (2) 4 W (3) 1.44 W (4) 500 W

Sol. Answer (2)

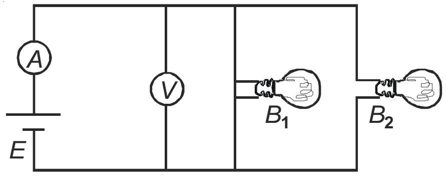
No current goes through ideal voltmeter



$$i = \frac{30}{30} = 1\text{ A}$$

$$P = \frac{4}{9}.\ 9 = 4\text{ W}$$

15. Two identical bulbs are connected in parallel across an ideal source of emf E. The ammeter A and voltmeter V are ideal. If bulb B_2 gets fused, then



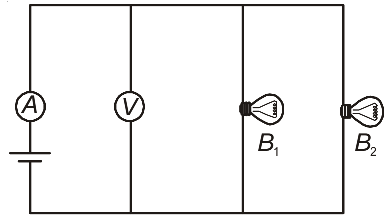
(1) Reading of A will increase but that of V will remain same

(2) Reading of A will decrease but that of V will increase

(3) Reading of A will decrease but that of V will remain same

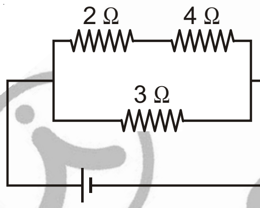
(4) Reading of A will increase and reading of V will also increase

Sol. Answer (3)



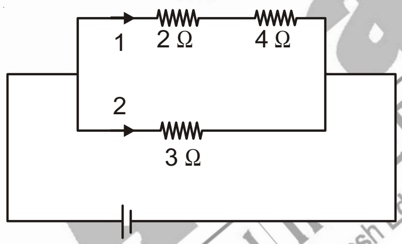
If B_2 gets fused, R_{net} increases, i decreases, but reading of V remains same.

16. In the network shown in figure, power dissipated in 3 Ω is 12 W. Power dissipated in 4 Ω will be



(1) 4 W (2) 2 W (3) 64 W (4) 32 W

Sol. Answer (1)

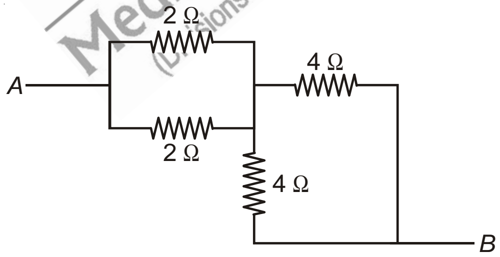


$1_2 = i^2$ (3)

$i = 2$

$P' = 1^2(4) = 4$ W

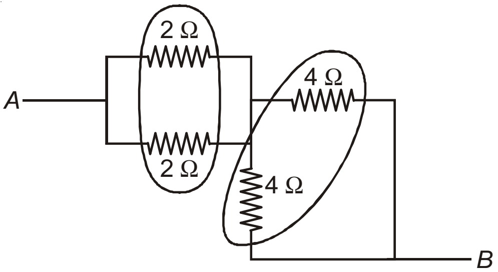
17. Effective resistance across AB in the network shown in



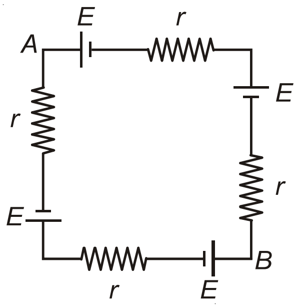
(1) 6 Ω (2) 3 Ω (3) 5 Ω (4) 8 Ω

Sol. Answer (2)

$R_{net} = 3$ Ω

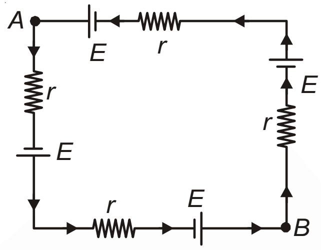


18. Potential difference across AB in the network shown is



(1) Zero (2) E (3) $E-\frac{Ir}{2}$ (4) $E-2Ir$

Sol. Answer (1)



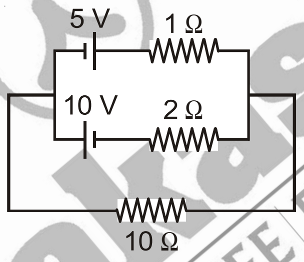
$$i=\frac{E}{R}$$

$V_A - E + ir - E + ir = V_B$

$V_A - E + E - E + E = V_B$

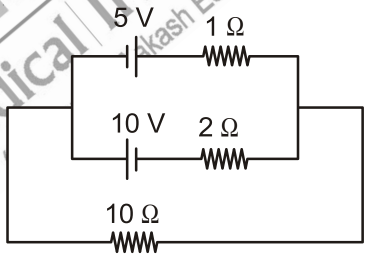
$V_A = V_B$

19. Current through 10 Ω resistor shown in figure is



(1) Zero (2) 1 A (3) 1.5 A (4) 2 A

Sol. Answer (1)

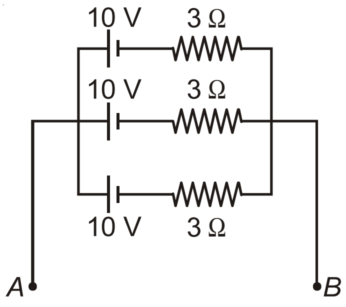


$$E_{\text{net}} = \frac{\frac{5}{1}-\frac{10}{2}}{1+\frac{1}{2}}$$

$E_{\text{net}} = 0$

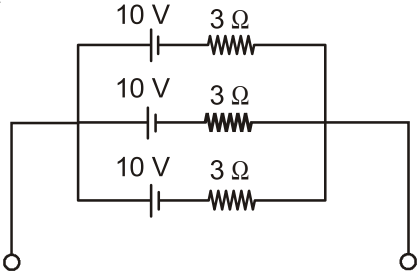
$i = 0$

20. Three identical cells are connected in parallel across AB. Net emf across AB is



(1) 10 V (2) 30 V (3) 15 V (4) 12 V

Sol. Answer (1)



$$E_{\text{net}} = \frac{\frac{10}{3}+\frac{10}{3}+\frac{10}{3}}{\frac{1}{3}+\frac{1}{3}+\frac{1}{3}} = 10 \text{ volt}$$

21. When current supplied by a cell to a circuit is 0.3 A, its terminal potential difference is 0.9 V. When the current supplied becomes 0.25 A, its terminal potential difference becomes 1.0 V. The internal resistance of the cell is

(1) 0.5 Ω (2) 2 Ω (3) 1.2 Ω (4) 1 Ω

Sol. Answer (2)

$0.9 = E - 0.3\,r$

$1 = E - 0.25\,r$

$0.1 = 0.05\,r$

$r = 2\,r$

22. Coefficient of linear expansion of material of resistor is α. Its temperature coefficient of resistivity and resistance are α_ρ and α_R respectively, then correct relation is

(1) $\alpha_R = \alpha_\rho - \alpha$ (2) $\alpha_R = \alpha_\rho + \alpha$ (3) $\alpha_R = \alpha_\rho + 3\alpha$ (4) $\alpha_R = \alpha_\rho - 3\alpha$

Sol. Answer (1)

$$R = \frac{\rho l}{A}$$

$$\frac{\Delta R}{R} = \frac{\Delta P}{P} + \frac{\Delta l}{l} - \frac{DA}{A}$$

$\alpha_R = \alpha_P + \alpha_R - 2\alpha$

$\alpha_R = \alpha_P - \alpha$

23. A current of 10 A is maintained in a conductor of cross-section 1 cm^2. If the free electron density in the conductor is 9×10^{28} m^{-3}, then drift velocity of free electrons is

(1) 6.94×10^{-6} m/s (2) 5.94×10^{-2} m/s (3) 1.94×10^{-3} m/s (4) 2.94×10^{-4} m/s

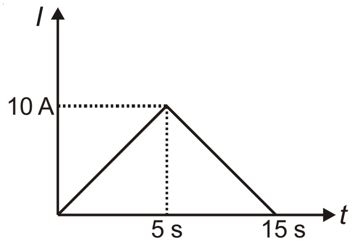
Sol. Answer (1)

$10 = 9 \times 10^{28} \times 1.6 \times 10^{-19} \times 10^{-4} \times V_D$

Solving, we get

$V_0 = 6.94 \times 10^{-6}$ m/s

24. Current I versus time t graph through a conductor is shown in the figure. Average current through the conductor in the interval 0 to 15 s is



(1) 1 A (2) 10 A (3) 7.5 A (4) 5 A

Sol. Answer (4)

Δq = Area (I / t)

$$\Delta q = \frac{1}{2}.10\times 15 = 75\text{ C}$$

$$i_{avg} = \frac{75}{15} = 5\text{ A}$$

25. Ten 60 W, 220 V bulbs are connected in series to 220 V supply. Power consumed in the circuit is

(1) 6 W (2) 12 W (3) 180 W (4) 600 W

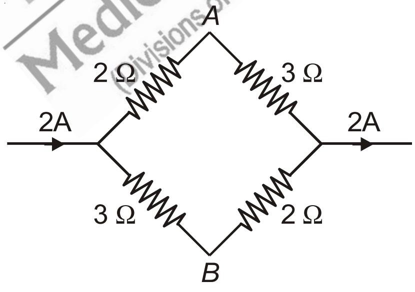
Sol. Answer (1)

$$P = \frac{V^2}{R}$$

$$R = \frac{V^2}{P} = \frac{(220)^2}{60}$$

$$P_{\text{Total}} = \frac{V^2}{R_{\text{eq}}} = \frac{(220)^2}{10(220)^2}\cdot 60 = 6\text{ W}$$

26. Potential difference $V_A - V_B$ in the network shown is



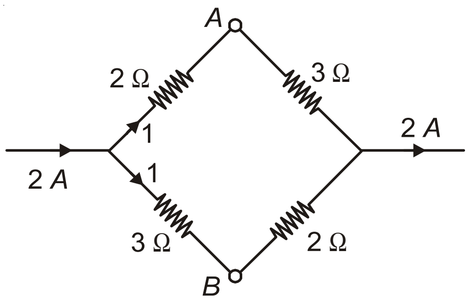
(1) 1 V (2) –1 V (3) 2 V (4) –2 V

Sol. Answer (1)

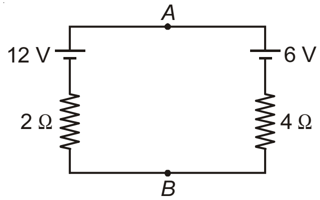
$V_A + 2 - 3 = V_B$

$V_A - 1 = V_B$

$V_A - V_B = 1$

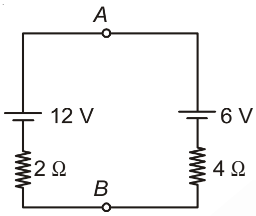


27. Potential difference across *AB i.e.*, $V_A - V_B$ is



(1) 10 V
(2) 8 V
(3) 6 V
(4) Zero

Sol. Answer (1)



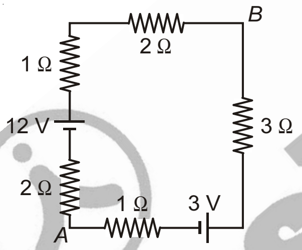
$6 = 6i$

$i = 1$ A

$\Delta V = 6 + 4$

$\Delta V = 10$

28. Potential difference $V_B - V_A$ in the network shown is



(1) 7 V
(2) 6 V
(3) 5 V
(4) 8 V

Sol. Answer (1)

$R_{\text{net}} = 9$

$V = 9$ V

$i = 1$ A

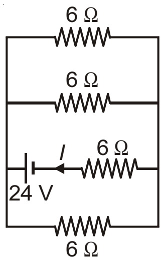
29. Five cells each of emf *E* and internal resistance *r* are connected in series. Due to oversight one cell is connected wrongly. The equivalent internal resistance of the combination is

(1) 3*r*
(2) 2*r*
(3) 5*r*
(4) 4*r*

Sol. Answer (3)

All the internal resistances will be still in series, there will be no impact of polarity on the equivalent resistance.

30. Current *I* in the network shown in figure is



(1) 16 A
(2) 3 A
(3) 4 A
(4) 12 A

Sol. Answer (2)

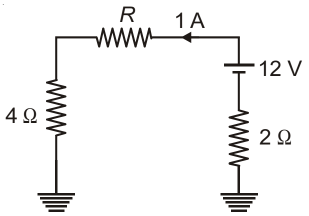
$R_{\text{net}} = 8$ Ω

$V = 24$ V

$24 = i(8)$

$i = 3$ A

31. Value of the resistance R in the figure is



(1) 6 Ω (2) 8 Ω (3) 10 Ω (4) 12 Ω

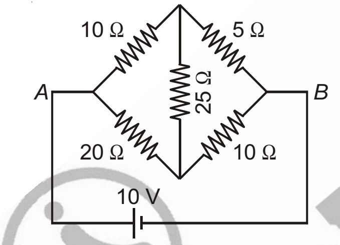
Sol. Answer (1)

$0 - 2(1) + 12 - 1(R) - 4(1) = 0$

$6 - R = 0$

$R = 6\ \Omega$

32. Current through the 25 Ω resistor as shown in figure is



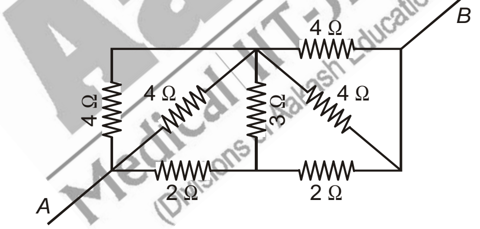
(1) 1 A (2) 2 A (3) 2.5 A (4) Zero

Sol. Answer (4)

$$R_{\text{net}} = \frac{(15)(30)}{45} = 10\ \Omega$$

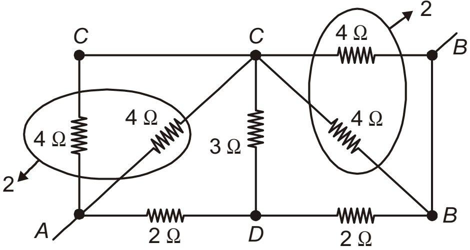
Current through 25 Ω resistance is zero in balanced wheatstone Bridge.

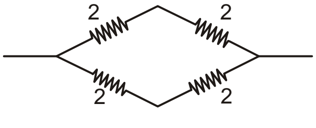
33. Resistance across AB as shown in figure is



(1) 2 Ω (2) 4 Ω (3) 6 Ω (4) 12 Ω

Sol. Answer (1)





2 Ω net resistance

34. Two cells of emf E_1 and E_2 ($E_1 > E_2$) are connected individually to a potentiometer and their corresponding balancing length are 625 cm and 500 cm, then the ratio $\frac{E_1}{E_2}$ is

(1) 5 : 4 (2) 3 : 1 (3) 5 : 1 (4) 4 : 5

Sol. Answer (1)

$E_1 = kl_1$ k is potential gradient

$E_2 = kl_2$

$$\frac{E_1}{E_2} = \frac{l_1}{l_2} = \frac{625}{500} = \frac{25}{20} = \frac{5}{4}$$

SECTION - C

Previous Years Questions

1. A wire of resistance 4 Ω is stretched to twice its original length. The resistance of stretched wire would be

(1) 4 Ω (2) 8 Ω (3) 16 Ω (4) 2 Ω

Sol. Answer (3)

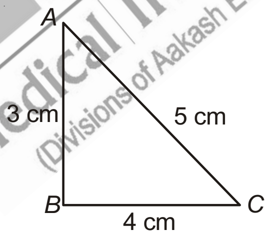
$$4 = \frac{\rho l}{A}$$

$$R = \frac{\rho(2l)}{(A/2)}$$

$$\frac{4}{R} = 4$$

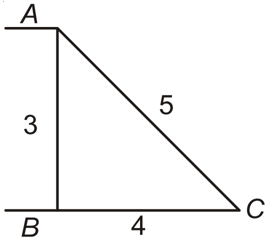
$R = 1\ \Omega$

2. A 12 cm wire is given a shape of a right angled triangle ABC having sides 3 cm, 4 cm and 5 cm as shown in the figure. The resistance between two ends (AB, BC, CA) of the respective sides are measured one by one by a multi-meter. The resistances will be in the ratio

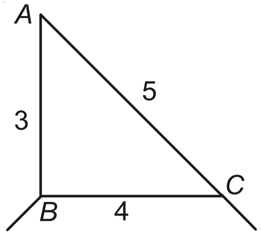


(1) 3 : 4 : 5 (2) 9 : 16 : 25 (3) 27 : 32 : 35 (4) 21 : 24 : 25

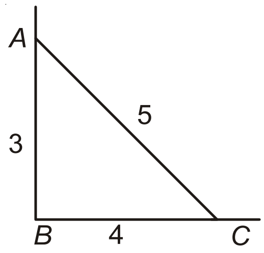
Sol. Answer (3)



$$R_{AB} = \frac{27}{12}$$



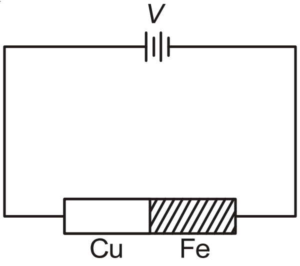
$$R_{BC} = \frac{32}{12}$$



$$R_{AC} = \frac{35}{12}$$

3. Two rods are joined end to end, as shown. Both have a cross-sectional area of 0.01 cm^2. Each is 1 meter long. One rod is a copper with a resistivity of 1.7×10^{-6} ohm-centimeter, the other is of iron with a resistivity of 10^{-5} ohm-centimeter.

How much voltage is required to produce a current of 1 ampere in the rods?



(1) 0.117 V (2) 0.00145 V (3) 0.0145 V (4) 1.7×10^{-6} V

Sol. Answer (1)

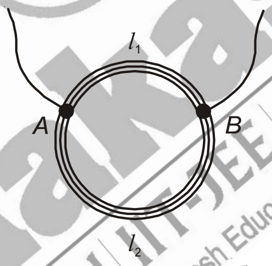
$$R = \frac{(1.17 \times 10^{-5})100}{0.01}$$

$R = 0.117\ \Omega$

$V = (1)(0.117)$

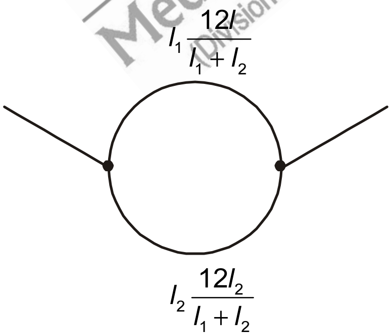
$V = 0.117$ V

4. A ring is made of a wire having a resistance $R_0 = 12\ \Omega$. Find the points A and B, as shown in the figure, at which a current carrying conductor should be connected so that the resistance R of the sub circuit between these points is equal to $\frac{8}{3}\Omega$.



(1) $\frac{l_1}{l_2} = \frac{3}{8}$ (2) $\frac{l_1}{l_2} = \frac{1}{2}$ (3) $\frac{l_1}{l_2} = \frac{5}{8}$ (4) $\frac{l_1}{l_2} = \frac{1}{3}$

Sol. Answer (2)



$$\frac{l_1 + l_2}{12l_1} + \frac{l_1 + l_2}{12l_2} = \frac{3}{8}$$

$$\frac{(l_1 + l_2)^2}{12l_1l_2} = \frac{3}{8}$$

$$2(l_1^2 + l_2^2 + 2l_1l_2) = 9$$

$$2l_1^2 + l_2^2 - 5l_1l_2 = 0$$

$$2l_1^2 - 4l_1l_2 - l_1l_2 + 2l_2 = 0$$

$$2l_1(l_1 - 2l_2) - l_2(l_1 - 2l_2) = 0$$

$$\frac{l_1}{l_2} = \frac{1}{2}$$

5. Ten identical cells connected in series are needed to heat a wire of length one meter and radius '*r*' by 10ºC in time '*t*'. How many cells will be required to heat the wire of length two meter of the same radius by the same temperature in time '*t*'?

(1) 10 (2) 20 (3) 30 (4) 40

Sol. Answer (2)

$$\left(\frac{10E}{r}\right)^2 rt = MC(10)$$

$$\left(\frac{nE}{2r}\right)2rt = 2MC(10)$$

$$\frac{100(4)}{2n^2} = \frac{1}{2}$$

$n = 20$

6. If voltage across a bulb rated 220 volt - 100 watt drops by 2.5% of its rated value, the percentage of the rated value by which the power would decrease is

(1) 5% (2) 10% (3) 20% (4) 2.5%

Sol. Answer (1)

$$P = \frac{V^2}{R}$$

$$\frac{\Delta P}{P} = 2\frac{\Delta V}{IV}$$

5% = 2.5%

7. The internal resistance of a 2.1 V cell which gives a current of 0.2 A through a resistance of 10 Ω is

(1) 0.5 Ω (2) 0.8 Ω (3) 1.0 Ω (4) 0.2 Ω

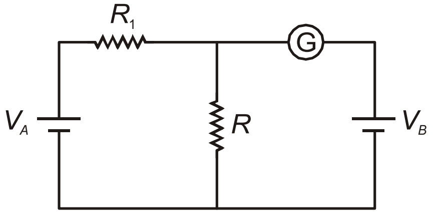
Sol. Answer (1)

$2.1 = 0.2(10 + r)$

$10.5 = 10 + r$

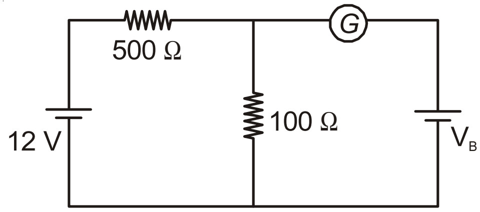
$r = 0.5$

8. In the circuit shown the cells *A* and *B* have negligible resistances. For V_A = 12 V, R_1 = 500 Ω and *R* = 100 Ω the galvanometer (G) shows no deflection. The value of V_B is



(1) 12 V (2) 6 V (3) 4 V (4) 2 V

Sol. Answer (4)



$$i = \frac{12}{600} = \frac{1}{50}\text{A}$$

$$V_B = \frac{1}{50}.100 = 2\text{ V}$$

9. A milli voltmeter of 25 milli volt range is to be converted into an ammeter of 25 ampere range. The value (in ohm) of necessary shunt will be

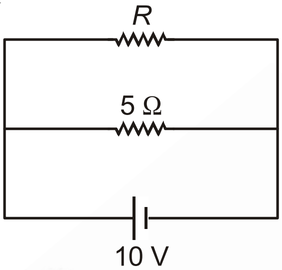
(1) 1 (2) 0.05 (3) 0.001 (4) 0.01

Sol. Answer (3)

$$\frac{25}{1000} = 25R$$

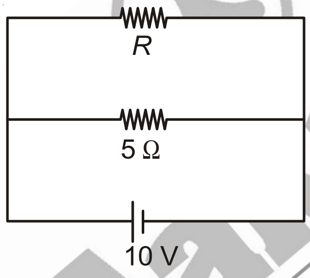
R = 0.001 Ω

10. The power dissipated in the circuit shown in the figure is 30 watts. The value of *R* is



(1) 20 Ω (2) 15 Ω (3) 10 Ω (4) 30 Ω

Sol. Answer (3)

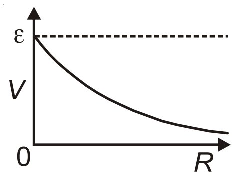


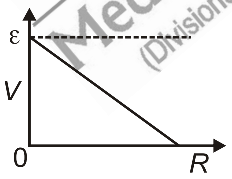
$$\frac{100}{5} + \frac{100}{R} = 30$$

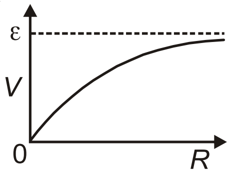
$$\frac{100}{R} = 10$$

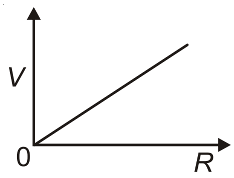
R = 10 Ω

11. A cell having an emf ε and internal resistance *r* is connected across a variable external resistance *R*. As the resistance *R* is increased, the plot of potential difference *V* across *R* is given by

(1)


(2)


(3)


(4)


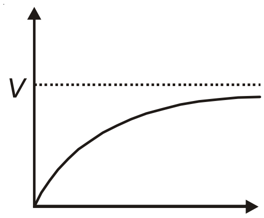
Sol. Answer (3)

$V = E - ir$

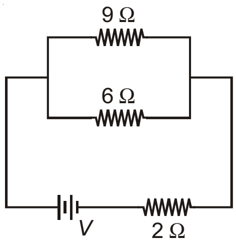
$$i = \frac{E}{R+r}$$

$$\Delta V = \frac{ER}{R+r}$$

$$\Delta V = \frac{E}{1+\frac{r}{R}}$$

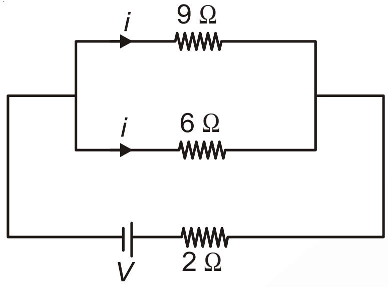


12. If power dissipated in the 9 Ω resistor in the circuit shown is 36 watt, the potential difference across the 2 Ω resistor is



(1) 2 volt (2) 4 volt (3) 8 volt (4) 10 volt

Sol. Answer (4)



$36 = i^2 9$

$i^2 = 4$

$i = 2$

$\frac{2}{i_1} = \frac{6}{9}$

$i_1 = 3$

$\Delta V_2 = (5)(2) = 10$ V

13. A current of 2 A flows through a 2 Ω resistor when connected across a battery. The same battery supplies a current of 0.5 A when connected across a 9 Ω resistor. The internal resistance of the battery is

(1) 1 Ω (2) 0.5 Ω (3) 1/3 Ω (4) 1/4 Ω

Sol. Answer (3)

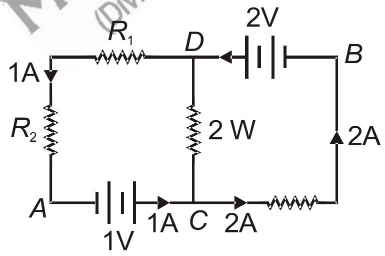
$$Z = \frac{E}{2+r}$$

$$0.5 = \frac{E}{9+r}$$

$$4 = \frac{9+r}{2+r}$$

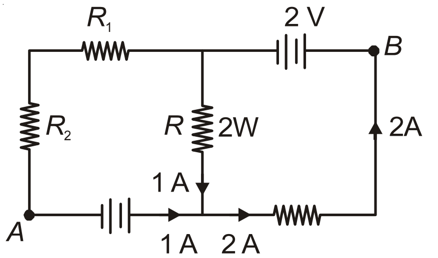
$8 + 4r = 9 + r$

14. In the circuit shown in the figure, if the potential at point *A* is taken to be zero, the potential at point *B* is



(1) –2 V (2) +1 V (3) –1 V (4) +2 V

Sol. Answer (2)



$R = 1^2 R$

$R = 2$ Ω

$V_A + 1 + 2 - 2 = V_B$

$V_A + 1 = V_B$

$V_A - V_B = -1$

15. A galvanometer of resistance, G is shunted by a resistance S ohm. To keep the main current in the circuit unchanged, the resistance to be put in series with the galvanometer is

(1) $\frac{G^2}{(S+G)}$ (2) $\frac{G}{(S+G)}$ (3) $\frac{S^2}{(S+G)}$ (4) $\frac{SG}{(S+G)}$

Sol. Answer (1)

$$\frac{E}{G}=\frac{E}{\frac{GS}{G+S}+R}$$

$$G=\frac{GS}{G+S}+R$$

$$R=\frac{G^2}{G+S}$$

16. The mobility of charge carriers increases with

(1) Increase in the average collision time (2) Increase in the electric field

(3) Increase in the mass of the charge carriers (4) Decrease in the charge of the mobile carriers

Sol. Answer (1)

Theory

17. A 1250 W heater operates at 115 V. What is the resistance of the heating coil?

(1) 1.6 Ω (2) 13.5 Ω (3) 1250 Ω (4) 10.6 Ω

Sol. Answer (4)

$$R=\frac{(115)^2}{1250}$$

R = 10.58 Ω

18. A cell can be balanced against 110 cm without being short circuited and can be balanced against 100 cm with short circuited through a resistance of 10 Ω. Its internal resistance is

(1) Zero (2) 1.0 ohm (3) 0.5 ohm (4) 2.0 ohm

Sol. Answer (2)

Let the potential gradient of the potentiometer is k

$E = k(110)$ …(i)

$iR = k(100)$

$$i=\frac{E}{R+r}=\frac{E}{10+r}$$

$$\left(\frac{E}{10+r}\right)(10)=k(100) \quad \text{…(ii)}$$

divide (i) and (ii)

r = 1 Ω

19. A wire of a certain material is stretched slowly by ten percent. It new resistance and specific resistance become respectively

(1) 1.1 times, 1.1 times (2) 1.2 times, 1.1 times

(3) 1.21 times, same (4) Both remain the same

Sol. Answer (3)

$$Al = A'\frac{11l}{10}$$

$$A' = \frac{10A}{11}$$

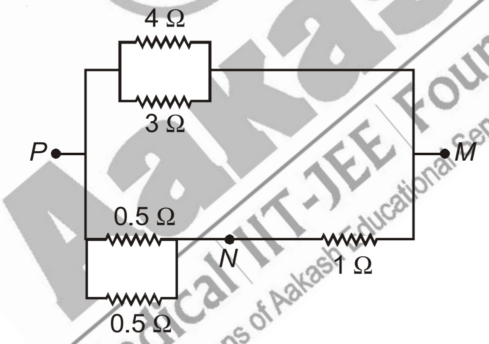
$$R = \frac{\rho l}{A}$$

$$R' = \frac{\rho 11l}{100A}$$

$$\frac{R}{R'} = \frac{100}{121}$$

$R' = 1.21R$

20. In the circuit shown, the current through the 4 Ω resistor is 1 amp when the points *P* and *M* are connected to a d.c. voltage source. The potential difference between the points *M* and *N* is



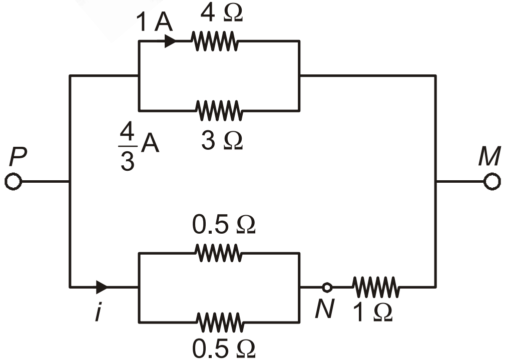
(1) 3.2 volt (2) 1.5 volt (3) 1.0 volt (4) 0.5 volt

Sol. Answer (1)

$$\frac{7}{3i} = \frac{2}{12}$$

$i = 2$

$\Delta V = 2$ V



21. A galvanometer of resistance 50 Ω is connected to a battery of 3 V along with a resistance of 2950 Ω in series. A full scale deflection of 30 divisions is obtained in the galvanometer. In order to reduce this deflection to 20 divisions, the resistance in series should be

(1) 4450 Ω (2) 5050 Ω (3) 5550 Ω (4) 6050 Ω

Sol. Answer (1)

$$i = \frac{3}{3000}\text{A}$$

$$1 \text{ division } = \frac{1}{30000}\text{A}$$

$$\text{Required } = \frac{20}{30000}A$$

$$= \frac{2}{3000}A$$

$$\frac{2}{3000} = \frac{3}{3000+R}$$

$6000 + 2R = 9000$

$R = 1500\ \Omega$

22. A wire 50 cm long and 1 mm^2 in cross-section carries a current of 4 A when connected to a 2 V battery. The resistivity of the wire is

(1) $4 \times 10^{-6}\ \Omega$-m (2) $1 \times 10^{-6}\ \Omega$-m (3) $2 \times 10^{-7}\ \Omega$-m (4) $5 \times 10^{-7}\ \Omega$-m

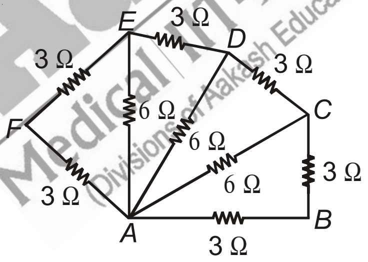
Sol. Answer (2)

$2 = 4R$

$$R = \frac{1}{2} = \frac{P(0.5)}{10^{-6}}$$

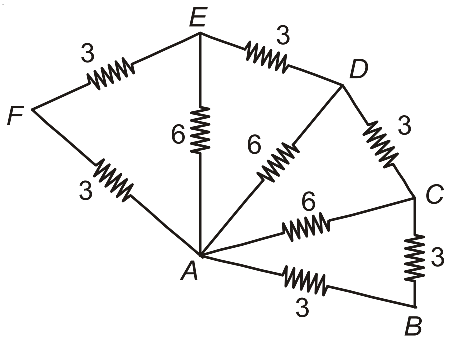
$\rho = 10^{-6}$

23. Six resistors of 3 Ω each are connected along the sides of a hexagon and three resistors of 6 Ω each are connected along *AC, AD* and *AE* as shown in the figure. The equivalent resistance between *A* and *B* is equal to



(1) 2 Ω (2) 6 Ω (3) 3 Ω (4) 9 Ω

Sol. Answer (1)



$R_{net} = 2\ \Omega$

24. Identify the set in which all the three materials are good conductors of electricity?

(1) Cu, Hg and NaCl (2) Cu, Ge and Hg (3) Cu, Ag and Au (4) Cu, Si and diamond

Sol. Answer (3)

Cu, Ag, Au

25. A flow of 10^7 electrons per second in a conducting wire constitutes a current of

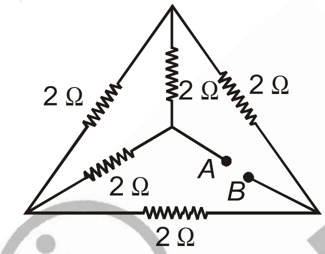
(1) 1.6×10^{-12} A (2) 1.6×10^{26} A (3) 1.6×10^{-26} A (4) 1.6×10^{12} A

Sol. Answer (1)

$i = 10^7 \times 1.6 \times 10^{-19}$

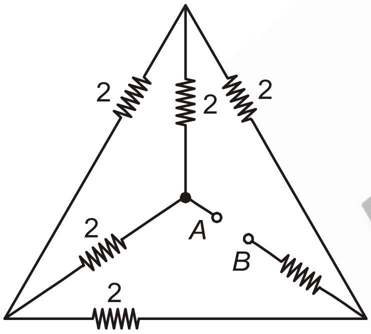
$i = 1.6 \times 10^{-12}$

26. In the network shown in the figure, each of the resistance is equal to 2 Ω. The resistance between the points *A* and *B* is



(1) 3 Ω (2) 4 Ω (3) 1 Ω (4) 2 Ω

Sol. Answer (4)



$R_{net} = 2\ \Omega$

27. Two wires of the same metal have same length, but their cross-sectional areas are in the ratio 3 : 1. They are joined in series. The resistance of thicker wire is 10 Ω. The total resistance of the combination will be

(1) 40 Ω (2) 100 Ω (3) $\frac{5}{2}$ Ω (4) $\frac{40}{3}$ Ω

Sol. Answer (1)

$l \quad l$

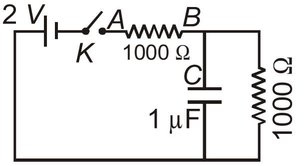
$3A \quad A$

$\frac{\rho l}{3A} = 10$

$\frac{\rho l}{A} = 30$

$R_{net} = 40\ \Omega$

28. When the key K is pressed at time $t = 0$, then which of the following statement about the current I in the resistor AB of resistance 1000 Ω of the given circuit is true?



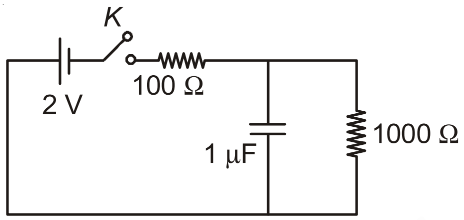
(1) I oscillates between 1 mA and 2 mA

(2) At $t = 0$, $I = 2$ mA and with time it goes to 1 mA

(3) $I = 1$ mA at all t

(4) $I = 2$ mA at all t

Sol. Answer (2)



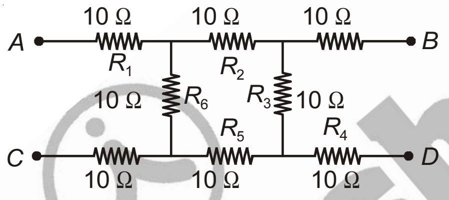
$t = 0$

$$i = \frac{2}{1000} = 2\,\text{mA}$$

$t = \infty$

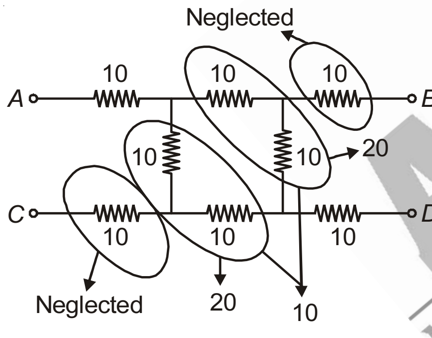
$$i = \frac{2}{1000} = 1\,\text{mA}$$

29. What will be the equivalent resistance between the two points A and D?



(1) 30 Ω (2) 40 Ω (3) 20 Ω (4) 10 Ω

Sol. Answer (1)



$R_{net} = 30\ \Omega$

30. Three copper wires have lengths and cross-sectional areas as (l, A), ($2l$, $A/2$) and ($l/2$, $2A$). Resistance is minimum in

(1) Wire of cross-sectional area 2A

(2) Wire of cross-sectional area 1/2 A

(3) Wire of cross-sectional area A

(4) Same in all three cases

Sol. Answer (1)

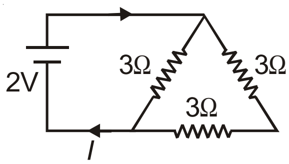
$$R_1 = \frac{\rho l}{A}$$

$$R_2 = \frac{\rho 2l}{A}.2$$

$$R_3 = \frac{\rho l}{2.2a}$$

R_3 is least

31. The current in the following circuit is



(1) $\frac{2}{3}$ A (2) 1 A (3) $\frac{1}{8}$ A (4) $\frac{2}{9}$ A

Sol. Answer (2)

$R_{net} = 2$

$2 = i(2)$

$i = 1$ A

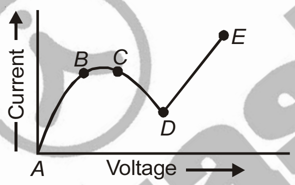
32. Kirchhoff's first law, *i.e.* $\Sigma\, i = 0$ at a junction, deals with the conservation of

(1) Momentum (2) Angular momentum (3) Charge (4) Energy

Sol. Answer (3)

Theory

33. From the graph between current *(I)* and voltage *(V)* is shown below. Identify the portion corresponding to negative resistance



(1) *CD* (2) *DE* (3) *AB* (4) *BC*

Sol. Answer (1)

Thoery

34. A galvanometer having a resistance of 8 ohms is shunted by a wire of resistance 2 ohms. If the total current is 1 A, the part of it passing through the shunt will be

(1) 0.2 A (2) 0.8 A (3) 0.25 A (4) 0.5 A

Sol. Answer (2)

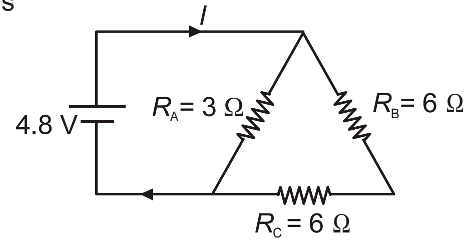
$$2 = \frac{i_G(8)}{1-i_G}$$

$2 - 2i_G = 8i_G$

$i_G = 0.2$

$i - i_G = 0.8$ A

35. The current in the given circuit is



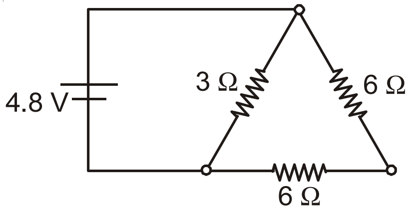
(1) 4.9 A (2) 6.8 A (3) 8.3 A (4) 2.0 A

Sol. Answer (4)

$R_{net} = \frac{36}{15} = \frac{12}{5}$

$\frac{4.8}{10} = i\frac{12}{5}$

$i = 2$ A



36. The internal resistance of a cell of e.m.f. 2 V is 0.1 Ω. It is connected to a resistance of 3.9 Ω. The voltage across the cell will be

(1) 1.95 V (2) 1.9 V (3) 0.5 V (4) 2 V

Sol. Answer (1)

$i = \frac{2}{4} = 0.5\text{A}$

$\Delta V = 2 - (0.1)\ (0.5)\text{A}$

$\Delta V = 1.95$ V

37. In a meter bridge, the balancing length from the left end (standard resistance of one ohm is in the right gap) is found to be 20 cm. The value of the unknown resistance is

(1) 0.8 Ω (2) 0.5 Ω (3) 0.4 Ω (4) 0.25 Ω

Sol. Answer (4)

$\frac{x}{20} = \frac{1}{80}$

$x = \frac{1}{4}\Omega$

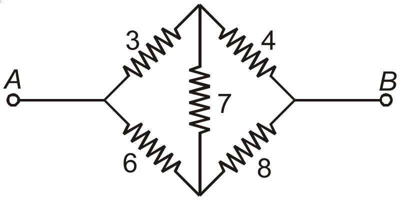
38. A potentiometer consists of a wire of length 4 m and resistance 10 Ω. It is connected to a cell of e.m.f. 2 V. The potential difference per unit length of the wire will be

(1) 5 V/m (2) 2 V/m (3) 0.5 V/m (4) 10 V/m

Sol. Answer (3)

$\frac{\Delta V}{\Delta l} = \frac{2}{4} = 0.5$ V/m

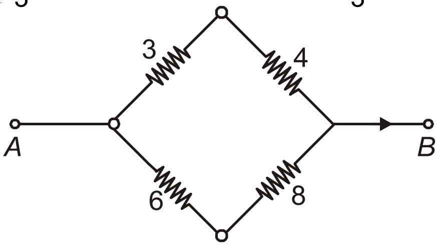
39. Calculate the net resistance of the circuit between *A* and *B*



(1) $\frac{8}{3}\Omega$ (2) $\frac{14}{3}\Omega$ (3) $\frac{16}{3}\Omega$ (4) $\frac{22}{3}\Omega$

Sol. Answer (2)

$R_{net} = \frac{7\times14}{21} = \frac{14}{3}\Omega$



40. A car battery of emf 12 V and internal resistance $5 \times 10^{-2}\ \Omega$, receives a current of 60 A, from external source, then terminal potential difference of battery is

(1) 12 V (2) 9 V (3) 15 V (4) 20 V

Sol. Answer (3)

$$\Delta V = 12 + \frac{5}{100}.60$$

ΔV = 15 V

41. The potentiometer is best for measuring voltage as

(1) It has a sensitive galvanometer
(2) It has wire of high resistance
(3) It measures p.d. in closed circuit
(4) It measures p.d in open circuit

Sol. Answer (4)

Theory

42. If specific resistance of a potentiometer wire is $10^{-7}\ \Omega$m and current flow through it is 0.1 A, cross-sectional area of wire is 10^{-6} m^2 then potential gradient will be

(1) 10^{-2} volt/m (2) 10^{-4} volt/m (3) 10^{-6} volt/m (4) 10^{-8} volt/m

Sol. Answer (1)

$\rho = 10^{-7}$

$i = 0.1$

$$R = \frac{10^{-7} l}{10^{-6}} = \frac{l}{10}$$

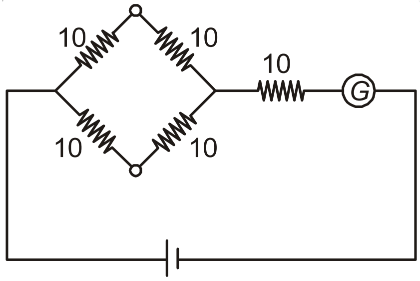
$$V = 0.1 \times \frac{l}{10}$$

$$\frac{V}{l} = 0.01$$

43. The resistance of each arm of the Wheatstone's bridge is 10 ohm. A resistance of 10 ohm is connected in series with a galvanometer then the equivalent resistance across the battery will be

(1) 10 ohm (2) 15 ohm (3) 20 ohm (4) 40 ohm

Sol. Answer (1)



R_{net} = 20

44. Copper and silicon are cooled from 300 K to 60 K, the specific resistance

(1) Decreases in copper but increases in silicon
(2) Increases in copper but decreases in silicon
(3) Increases in both
(4) Decreases in both

Sol. Answer (1)

Theory

45. Specific resistance of a conductor increases with

(1) Increase in temperature
(2) Increase in cross-sectional area
(3) Increase in cross-sectional and decrease in length
(4) Decrease in cross-sectional area

Sol. Answer (1)

Theory

46. For a cell, terminal potential difference is 2.2 V when circuit is open and reduces to1.8 V when cell is connected to a resistance of $R = 5\ \Omega$. Determine internal resistance of cell (r)

(1) $\frac{10}{9}\Omega$ (2) $\frac{9}{10}\Omega$ (3) $\frac{11}{9}\Omega$ (4) $\frac{5}{9}\Omega$

Sol. Answer (1)

$1.8 = 2.2 - ir$

$ir = 0.4$

$i = \frac{2.2}{5+r}$

$\frac{2.2}{5+r} = 0.4$

$22r = 20 + 4r$

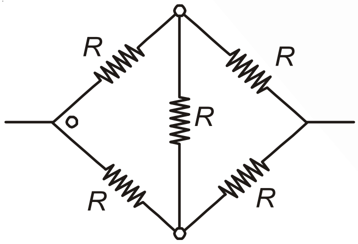
$18r = 20$

$r = \frac{10}{9}$

47. In a Wheatstone's bridge all the four arms have equal resistance R. If the resistance of the galvanometer arm is also R, the equivalent resistance of the combination as seen by the battery is

(1) $R/4$ (2) $R/2$ (3) R (4) $2R$

Sol. Answer (3)



$\Rightarrow$ $R_{net} = R$

48. The electric resistance of a certain wire of iron is R. If its length and radius are both doubled, then

(1) The resistance will be doubled and the specific resistance will be halved
(2) The resistance will be halved and the specific resistance will remain uncharged
(3) The resistance will be halved and the specific resistance will he doubled
(4) The resistance and the specific resistance, will both remain unchanged

Sol. Answer (2)

$R = \frac{\rho l}{A}$

$R' = \frac{\rho 2l}{4A}$

$R' = \frac{R}{2}$

49. n resistances, each of r ohm, when connected in parallel give an equivalent resistance of R ohm. If these resistances were connected in series, the combination would have a resistance in ohms, equal to

(1) n^2R (2) R/n^2 (3) R/n (4) nR

Sol. Answer (1)

$$\frac{r}{n} = R$$

$$nr = R'$$

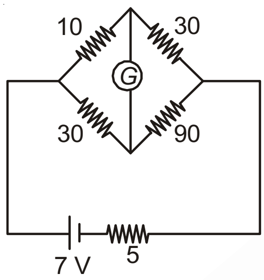
$$\frac{1}{n^2} = \frac{R}{R'}$$

$$R' = n^2R$$

50. The resistances of the four arms P, Q, R and S in a Wheatstone's bridge are 10 ohm, 30 ohm, 30 ohm and 90 ohm, respectively. The e.m.f. and internal resistance of the cell are 7 volt and 5 ohm respectively. If the galvanometer resistance is 50 ohm, the current drawn from the cell will be

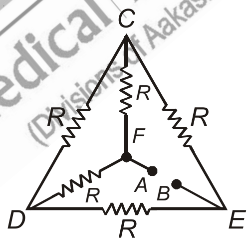
(1) 0.2 A (2) 0.1 A (3) 2.0 A (4) 1.0 A

Sol. Answer (1)



$$i = \frac{7}{37}\,\text{A}$$

51. Five equal resistances each of resistance R are connected as shown in the figure. A battery of V volts is connected between A and B. The current flowing in $AFCEB$ will be



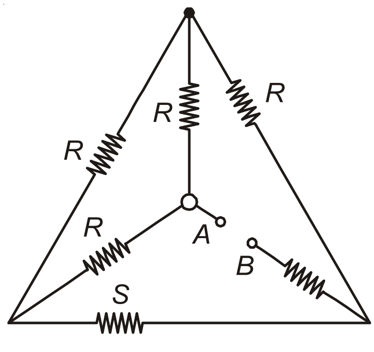
(1) $\frac{3V}{R}$ (2) $\frac{V}{R}$ (3) $\frac{V}{2R}$ (4) $\frac{2V}{R}$

Sol. Answer (3)

$$R_{\text{net}} = R$$

$$i = \frac{V}{R}$$

$$i_{AFCEB} = \frac{V}{2R}$$



52. A 6 volt battery is connected to the terminals of a three metre long wire of uniform thickness and resistance of 100 ohm. The difference of potential between two points on the wire separated by a distance of 50 cm will be

(1) 2 volt (2) 3 volt (3) 1 volt (4) 1.5 volt

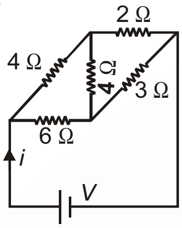
Sol. Answer (3)

$$i = \frac{6}{100}$$

$$\Delta V = \frac{100}{6} \times \frac{6}{100}$$

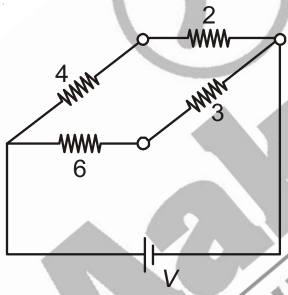
ΔV = 1 V

53. For the network shown in the figure the value of the current *i* is



(1) $\frac{9V}{35}$ (2) $\frac{18V}{5}$ (3) $\frac{5V}{9}$ (4) $\frac{5V}{18}$

Sol. Answer (4)

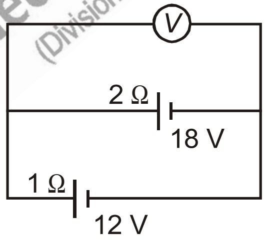


$$R_{\text{net}} = \frac{18}{5}$$

$$V = i\frac{18}{5}$$

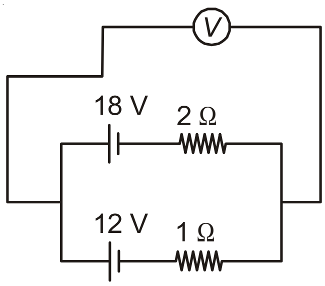
$$i = \frac{5V}{18}$$

54. Two batteries, one of emf 18 volts and internal resistance 2 Ω and the other of emf 12 volt and internal resistance 1 Ω, are connected as shown. The voltmeter *V* will record a reading of



(1) 30 volt (2) 18 volt (3) 15 volt (4) 14 volt

Sol. Answer (4)



$$i = \frac{6}{3} = 2\text{A}$$

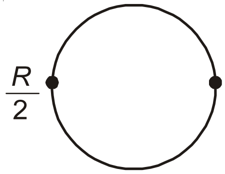
V = 18 – 2(2)

V = 14 V

55. When a wire of uniform cross-section a, length l and resistance R is bent into a complete circle, resistance between any two of diametrically opposite points will be

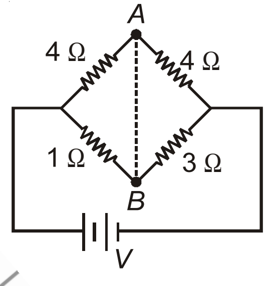
(1) $\frac{R}{4}$ (2) $4R$ (3) $\frac{R}{8}$ (4) $\frac{R}{2}$

Sol. Answer (1)



$$R_{\text{net}} = \frac{R}{4}$$

56. In the circuit shown, if a conducting wire is connected between points A and B, the current in this wire will



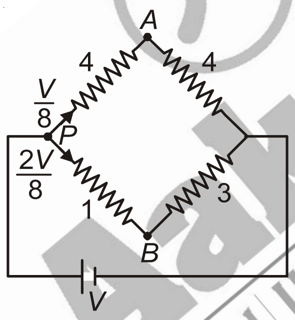
(1) Flow from B to A

(2) Flow from A to B

(3) Flow in the direction which will be decided by the value of V

(4) Be zero

Sol. Answer (1)



$$i = \frac{12V}{32} = \frac{3V}{8}$$

$$\frac{i}{\frac{3V}{8} - i} = \frac{4}{8}$$

$$2i = \frac{3V}{8} - i$$

$$i = \frac{V}{8}$$

$$V_P - V_A = \frac{V}{2}$$

$$V_P - V_B = \frac{V}{4}$$

$$V_B > V_A$$

Current flows from B to A

57. Kirchhoff's first and second laws of electrical circuits are consequences of

(1) Conservation of energy and electric charge respectively

(2) Conservation of energy

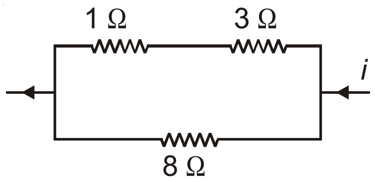
(3) Conservation of electric charge and energy respectively

(4) Conservation of electric charge

Sol. Answer (3)

Theory

58. Power dissipated across the 8 Ω resistor in the circuit shown here is 2 watt. The power dissipated in watt units across the 3 Ω resistor is



(1) 3.0 (2) 2.0 (3) 1.0 (4) 0.5

Sol. Answer (1)

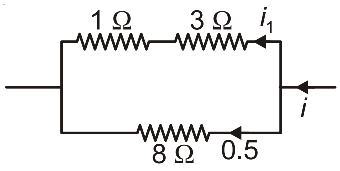
$2 = i^2 8$

$i = \frac{1}{2}$

$\frac{0.5}{i} = \frac{4}{8}$

$i = 2$

$P = 3$ W



59. Two cells, having the same e.m.f. are connected in series through an external resistance R. Cells have internal resistances r_1 and r_2 ($r_1 > r_2$) respectively. When the circuit is closed, the potential difference across the first cell is zero. The value of R is

(1) $r_1 + r_2$ (2) $r_1 - r_2$ (3) $\frac{r_1 + r_2}{2}$ (4) $\frac{r_1 - r_2}{2}$

Sol. Answer (2)

$$\frac{2E}{r_1 + r_2 + R} = \frac{E}{r_1}$$

$2r_1 = r_1 + r_2 + R$

$R = r_1 - r_2$

60. An electric kettle takes 4 A current at 220 V. How much time will it take to boil 1 kg of water from temperature 20°C? The temperature of boiling water is 100°C.

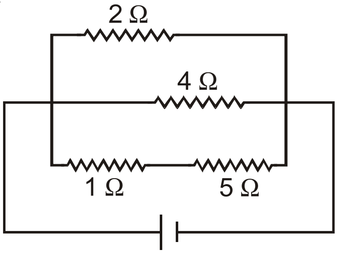
(1) 4.2 min (2) 6.3 min (3) 8.4 min (4) 12.6 min

Sol. Answer (2)

$$t = \frac{1 \times 4200 \times 80}{880 \times 60}$$

$t = 6.3$ minute

61. A current of 3 amp. flows through the 2 Ω resistor shown in the circuit. The power dissipated in the 5 Ω resistor is



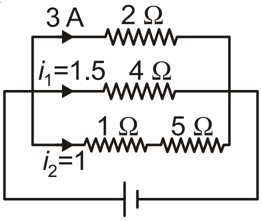
(1) 5 watt (2) 4 watt (3) 2 watt (4) 1 watt

Sol. Answer (1)

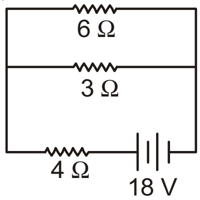
$\frac{3}{i_1} = \frac{4}{2}$ $i_1 = 1.5$

$\frac{3}{i_2} = \frac{6}{2}$ $i_2 = 1$

$P = (1^2)(5) = 5$ W



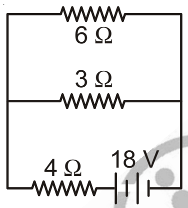
62. The total power dissipated in watt in the circuit shown here is



(1) 40 (2) 54 (3) 4 (4) 16

Sol. Answer (2)

$P = \frac{(18)}{6} = 54\text{W}$



63. Three resistances *P*, *Q*, *R* each of 2 Ω and an unknown resistances *S* form the four arms of a Wheatstone bridge circuit. When a resistance of 6 Ω is connected in parallel to *S* the bridge gets balanced. What is the value of *S*?

(1) 3 Ω (2) 6 Ω (3) 1 Ω (4) 2 Ω

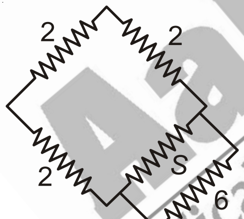
Sol. Answer (1)

$\frac{2}{2} = \frac{2(6+S)}{6S}$

$3S = 6 + S$

$2S = 6$

$S = 3$



64. An elctric bulb is rated 60 W, 220 V. The resistance of its filament is about

(1) 870 Ω (2) 780 Ω (3) 708 Ω (4) 807 Ω

Sol. Answer (4)

$R = \frac{(220)^2}{60} = 806.7\ \Omega$

65. A heating coil is labelled 100 W, 220 V. The coil is cut in half and the two pieces are joined in parallel to the same source. The energy now liberated per second is

(1) 200 J (2) 400 J (3) 25 J (4) 50 J

Sol. Answer (2)

$R = \frac{(220)^2}{60} = 484\ \Omega$

$R_{\text{net}} = 121\ \Omega$

$P = \frac{(220)^2}{121} = \frac{220 \times 220}{121} = 400$ W

66. A 4 μF capacitor is charged to 400 V. If its plates are joined through a resistance of 2 kΩ, then heat produced in the resistance is

(1) 0.64 J
(2) 1.28 J
(3) 0.16 J
(4) 0.32 J

Sol. Answer (4)

$$\text{Heat} = \frac{P}{2}\times 4\times 10^{-6}\times (400)^2$$

$$= 2 \times 10^{-6} \times 16 \times 10^4$$

$$= \frac{32}{100}$$

$$= 0.32 \text{ J}$$

67. A (100 W, 200 V) bulb is connected to a 160 volt supply. The power consumption would be

(1) 100 W
(2) 125 W
(3) 64 W
(4) 80 W

Sol. Answer (3)

$$\frac{100}{P} = \left(\frac{200}{160}\right)^2$$

$$\frac{100}{P} = \frac{25}{16}$$

P = 64 W

68. If two bulbs, whose resistances are in the ratio of 1 : 2 are connected in series, the power dissipated in them has the ratio of

(1) 2 : 1
(2) 1 : 4
(3) 1 : 1
(4) 1 : 2

Sol. Answer (4)

$P_1 : P_2 = R_1 : R_2 = 1 : 2$

69. Two bulbs of (40 W, 200 V), and (100 W, 200 V). Then correct relation for their resistances

(1) $R_{40} < R_{100}$
(2) $R_{40} > R_{100}$
(3) $R_{40} = R_{100}$
(4) No relation can be predicted

Sol. Answer (2)

$$R_{40} = \frac{(200)^2}{40}$$

$$R_{60} = \frac{(200)^2}{100}$$

$R_{40} > R_{60}$

70. Two 220 volt, 100 watt bulbs are connected first in series and then in parallel. Each time the combination is connected to a 220 volt a.c. supply line. The power drawn by the combination in each case respectively will be

(1) 50 watt, 100 watt
(2) 100 watt, 50 watt
(3) 200 watt, 150 watt
(4) 50 watt, 200 watt

Sol. Answer (4)

Series

$$P = \frac{100\times 100}{200} = 50\,\text{W}$$

Parallel

P = 100 + 100 = 200 W

71. An electric kettle has two heating coils. When one of the coils is connected to an a.c. source, the water in the kettle boils in 10 minute. When the other coil is used the water boils in 40 minute. If both the coils are connected in parallel, the time taken by the same quantity of water to boil will be

(1) 8 minute (2) 4 minute (3) 25 minute (4) 15 minute

Sol. Answer (1)

$$\frac{1}{t}=\frac{1}{10}+\frac{1}{40}$$

$$\frac{1}{t}=\frac{50}{400}$$

t = 8 minute

72. Fuse wire is a wire of

(1) High resistance and high melting point (2) High resistance and low melting point

(3) Low resistance and low melting point (4) Low resistance and high melting point

Sol. Answer (3)

Thoery

73. A battery is charged at a potential of 15 V for 8 hour when the current flowing is 10 A. The battery on discharge supplies a current of 5 A for 15 hour. The mean terminal voltage during discharge is 14 V. The "Watt-hour efficiency of the battery is

(1) 82.5% (2) 80% (3) 90% (4) 87.5%

Sol. Answer (4)

$$\begin{array}{l} 15 = E + 10r \\ {}^{-}14 = \overset{-}{E} \overset{+}{-} 5r \\ \hline 1 = 15r \end{array}$$

$$r=\frac{1}{15}$$

$$E=15-\frac{10}{15}$$

$$E=\frac{215}{15}$$

U_i = 150 × 8

U_0 = 5 × 15 × 14

$$\eta=\frac{5\times15\times14}{150\times8}$$

$$n=\frac{7}{8}$$

74. When three identical bulbs of 60 watt, 200 volt rating are connected in series to a 200 volt supply, the power drawn by them will be

(1) 60 watt (2) 180 watt (3) 10 watt (4) 20 watt

Sol. Answer (4)

$$\frac{1}{P}=\frac{3}{60}$$

P = 20 W

75. A 5-ampere fuse wire can withstand a maximum power of 1 watt in the circuit. The resistance of the fuse wire is

(1) 0.04 ohm (2) 0.2 ohm (3) 5 ohm (4) 0.4 ohm

Sol. Answer (1)

$1 = 5^2R$

$$R = \frac{1}{25} = 0.04$$

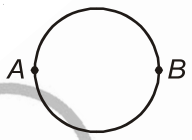
76. If the cold junction of a thermo-couple is kept at 0°C and the hot junction is kept at T°C then the relation between neutral temperature (T_n) and temperature of inversion (T_i) is

(1) $T_n = 2T_i$ (2) $T_n = T_i - T$ (3) $T_n = T_i + T$ (4) $T_n = T_i/2$

Sol. Answer (4)

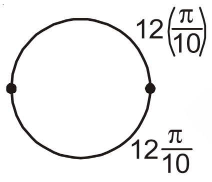
$T_i = 2T_n$

77. A wire of resistance 12 ohms per metre is bent to form a complete circle of radius 10 cm. The resistance between its two diametrically opposite points, A and B as shown in the figure, is



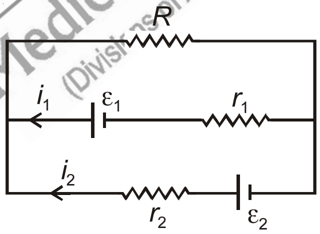
(1) 6 Ω (2) 0.6π Ω (3) 3 Ω (4) 6π Ω

Sol. Answer (2)



$$R_{\text{net}} = \frac{6\pi}{10} = 0.6\ \pi$$

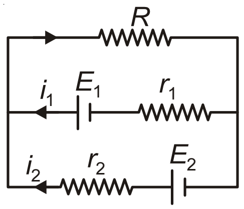
78. See the electrical circuit shown in this figure. Which of the following equations is a correct equation for it?



(1) $\varepsilon_1 - (i_1 + i_2)R + i_1r_1 = 0$ (2) $\varepsilon_1 - (i_1 + i_2)R - i_1r_1 = 0$

(3) $\varepsilon_2 - i_2r_2 - \varepsilon_1 - i_1r_1 = 0$ (4) $-\varepsilon_2 - (i_1 + i_2)R + i_2r_2 = 0$

Sol. Answer (2)

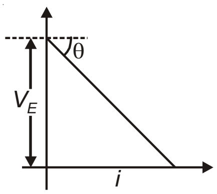


$-(i_1 + i_2)R - i_1r_1 + E_1 = 0$

79. A student measures the terminal potential difference (V) of a cell (of emf ε and internal resistance r) as a function of the current (I) flowing through it. The slope and intercept of the graph between V and I, then, respectively, equal

(1) $-\varepsilon$ and r (2) ε and $-r$ (3) $-r$ and ε (4) r and $-\varepsilon$

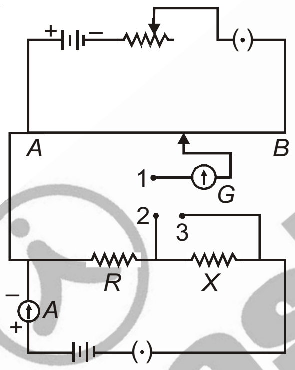
Sol. Answer (3)



$\tan\theta = r$

slope = $-r$

80. A potentiometer circuit is set up as shown. The potential gradient, across the potentiometer wire, is k volt/cm and the ammeter, present in the circuit, reads 1.0 A when two way key is switched off. The balance points, when the key between the terminals (i) 1 and 2 (ii) 1 and 3, is plugged in, are found to be at lengths l_1 cm and l_2 cm respectively. The magnitudes, of the resistors R and X, in ohms, are then, equal, respectively, to



(1) kl_1 and kl_2 (2) $k(l_2 - l_1)$ and kl_2 (3) kl_1 and $k(l_2 - l_1)$ (4) $k(l_2 - l_1)$ and kl_1

Sol. Answer (3)

$1R = kl_1$

$1(R + x) = kl_2$

$x = kl_2 - kl_1$

$R = kl_1$

81. A galvanometer has a coil of resistance 100 ohm and gives a full scale deflection for 30 mA current. If it is to work as a voltmeter of 30 volt range, the resistance required to be added will be

(1) 1000 Ω (2) 900 Ω (3) 1800 Ω (4) 500 Ω

Sol. Answer (2)

$$M = \frac{30}{30} \times 1000 - 100 = 900\ \Omega$$

82. Consider the following two statements

(A) Kirchhoff's junction law follows from the conservation of charge.

(B) Kirchhoff's loop law follows from the conservation of energy.

Which of the following is correct?

(1) Both (A) and (B) are correct (2) Both (A) and (B) are wrong

(3) (A) is correct and (B) is wrong (4) (A) is wrong and (B) is correct

Sol. Answer (1)

Both A and B are correct based on theory

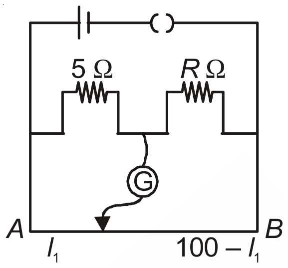
83. Two cities are 150 km apart. Electric power is sent from one city to another city through copper wires. The fall of potential per km is 8 volt and the average resistance per km is 0.5 Ω. The power loss in the wire is

(1) 19.2 W (2) 19.2 kW (3) 19.2 J (4) 12.2 kW

Sol. Answer (2)

Total power loss = $150\left(\dfrac{(8)^2}{0.5}\right) = 150\times\dfrac{640}{5} = 19.2\text{ kW}$

84. The resistances in the two arms of the meter bridge are 5 Ω and R Ω, respectively. When the resistance R is shunted with an equal resistance, the new balance point is at 1.6 l_1. The resistance R, is



(1) 10 Ω (2) 15 Ω (3) 20 Ω (4) 25 Ω

Sol. Answer (2)

When R is not shunted

$\dfrac{5}{R} = \dfrac{l_1}{100-l_1}$ ...(i)

When R is shunted with R (*i.e.*, a resistance R is connected in parallal)

$\dfrac{5}{\left(R/2\right)} = \dfrac{1.6l_1}{100-1.6l_1}$ ...(ii)

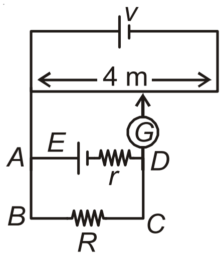
Solve (i) and (ii) for R

85. A potentiometer circuit has been set up for finding the internal resistance of a given cell. The main battery, used across the potentiometer wire, has an emf of 2.0 V and a negligible internal resistance. The potentiometer wire itself is 4 m long. When the resistance, R, connected across the given cell, has values of (i) Infinity, (ii) 9.5 Ω, the 'balancing lengths', on the potentiometer wire are found to be 3 m and 2.85 m, respectively. The value of internal resistance of the cell is

(1) 0.25 Ω (2) 0.95 Ω (3) 0.5 Ω (4) 0.75 Ω

Sol. Answer (3)

Potential gradient $(k) = \dfrac{V}{l} = \dfrac{2}{4} = 0.5\,\dfrac{\text{V}}{\text{m}}$



When $R \to \infty$, No current will flow through R.

So at the balance point

(0.5) (3) = E

$\Rightarrow E$ = 1.5 volt ...(i)

When R = 9.5 Ω

Using KVL in loop $ABCD$

$i = \dfrac{E}{R+r}$ ...(ii)

and $E - ir$ = (0.5) (2.85) ...(iii)

From (i) E = 1.5 volt and R = 9.5 Ω

Solving (ii) and (iii) r = 0.5 Ω

SECTION - D

Assertion-Reason Type Questions

1. A : For a given conductor, electric current does not vary even if its cross sectional area varies.

   R : A conductor remains uncharged when current flows through it.

Sol. Answer (2)

2. A : When a steady current flows through a conductor of non-uniform cross-section, the current density, electric field and drift velocity do not remain constant.

   R : For a constant current the current density, electric field and drift velocity are inversely proportional to cross-sectional area.

Sol. Answer (1)

3. A : To a metal wire of diameter *d* and length *L* when the applied voltage is doubled, drift velocity gets doubled.

   R : For a constant voltage when the length is doubled, drift velocity will be halved but drift velocity is independent of diameter.

Sol. Answer (2)

4. A : Kirchhoff's Current law is applicable at any junction or node in the circuit.

   R : Kirchhoff's laws are general in nature.

Sol. Answer (2)

5. A : Voltage across a resistor decreases in the direction of current and increases opposite to the direction of current.

   R : Voltage drop or gain across a capacitor depends on the direction of current.

Sol. Answer (3)

6. A : The voltage across a battery may be less, equal or more than the emf of the battery.

   R : Voltage across a battery also depends on the magnitude and direction of current.

Sol. Answer (1)

7. A : Practically a voltmeter will measure the voltage across the battery but not its EMF.

   R : EMF of a cell is measured with the help of a potentiometer.

Sol. Answer (2)

8. A : A potentiometer can act as an ideal voltmeter.

   R : An ideal voltmeter has infinite resistance.

Sol. Answer (2)

9. A : Ohm's law is universally applicable for all conducting elements.

   R : All conducting elements show straight line graphic variation on ($I - V$) plot.

Sol. Answer (4)

10. A : A low voltage supply, from which high currents are to be withdrawn, must have very low internal resistance.

    R : Maximum current drawn from a source is inversely proportional to internal resistance.

Sol. Answer (1)

11. A : High voltage (high tension) supply must have very large internal resistance

R : If the circuit is accidentally shorted, then the current drawn will not exceed safety limits if internal resistance is high.

Sol. Answer (1)

12. A : Alloys of metals usually have greater resistivity than that of their constituent metals.

R : Alloys usually have much lower thermal coefficient of resistance than pure metals.

Sol. Answer (2)

13. A : Current density is a vector quantity.

R : Electric current, passing through a given area is the flux of current density through that area.

Sol. Answer (2)

14. A : When two cells of equal EMF and equal internal resistances are connected in parallel with positive plate of one to the positive plate of the other then, the net EMF of the combination will be equal to the EMF of each cell.

R : Effective internal resistance of the parallel combination of two identical cells will be half of the internal resistance of each cell.

Sol. Answer (2)

15. A : The drift velocity of electrons in a conductor is very small still current in a conductor is established almost instantaneously on closing the switch.

R : Electric field in the conductor sets up with speed of light.

Sol. Answer (1)

16. A : When temperature of a metallic wire is increased, its resistance increases.

R : As the temperature is increased, average relaxation time increases.

Sol. Answer (3)

17. A : The potentiometer wire should have uniform cross sectional area.

R : On the potentiometer wire the jockey is gently touched, not pressed hard.

Sol. Answer (2)

❑ ❑ ❑

Chapter 4

Moving Charges and Magnetism

Solutions

SECTION - A

Objective Type Questions

1. Numerically 1 gauss = x tesla, then x is

(1) 10^{-4} (2) 10^{4} (3) 10^{8} (4) 10^{-8}

Sol. Answer (1)

1 gauss = 10^{-4} T

2. An electron having a charge e moves with a velocity v in positive x direction. A magnetic field acts on it in positive y direction. The force on the electron acts in (where outward direction is taken as positive z-axis).

(1) Negative direction of y-axis (2) Positive direction of y-axis

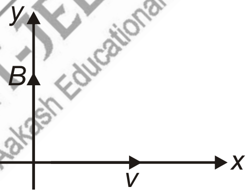
(3) Positive direction of z-axis (4) Negative direction of z-axis

Sol. Answer (4)

$\vec{F} = -e(\vec{v} \times \vec{B})$

So using right hand thumb rule

$\vec{F}$ will be in –z direction.



3. If a proton enters perpendicularly a magnetic field with velocity v , then time period of revolution is T. If proton enters with velocity $2v$, then time period will be

(1) T (2) $2T$ (3) $3T$ (4) $4T$

Sol. Answer (1)

$T = \dfrac{2\pi m}{qB} \Rightarrow$ independent of v.

4. A proton, a deutron and an α-particle accelerated through the same potential difference enter a region of uniform magnetic field, moving at right angles to it. What is the ratio of their kinetic energy?

(1) 1 : 1 : 2 (2) 2 : 2 : 1 (3) 1 : 2 : 1 (4) 2 : 1 : 1

Sol. Answer (1)

K.E. = qV V is same for all

K.E. $\propto q$

So $\text{K.E.}_p : \text{K.E}_d : \text{K.E}_\alpha = 1 : 1 : 2$

5. A particle of mass m carrying charge q is accelerated by a potential difference V. It enters perpendicularly in a region of uniform magnetic field B and executes circular arc of radius R, then $\frac{q}{m}$ equals

(1) $\frac{2V}{B^2 R^2}$ (2) $\frac{V}{2BR}$ (3) $\frac{VB}{2R}$ (4) $\frac{mV}{BR}$

Sol. Answer (1)

$$r = \frac{\sqrt{2mk}}{qB} = \frac{\sqrt{2mqV}}{qB}$$

$$\Rightarrow \; r = \frac{\sqrt{2V}}{B}\sqrt{\frac{m}{q}} \Rightarrow \quad \frac{q}{m} = \frac{2V}{R^2 B^2}$$

6. The net charge in a current carrying wire is zero still magnetic field exerts a force on it, because a magnetic field exerts force on

(1) Stationary charge (2) Moving charge

(3) A positive charge only (4) A negative charge only

Sol. Answer (2)

$$F = q(\vec{V} \times \vec{B})$$

Moving charge are only electrons and magnetic field exert force on moving charges only.

7. If a charged particle enters perpendicularly in the uniform magnetic field then

(1) Energy remains constant but momentum changes

(2) Energy and momentum both remains constant

(3) Momentum remains constant but energy changes

(4) Neither energy nor momentum remains constant

Sol. Answer (1)

Work done by magnetic force will always be zero as $\vec{F} \perp \vec{V}$

so using work energy theorem

$W_{\text{all}} = \Delta K$

$W = 0$

$\Rightarrow \; k = \text{constant}$

$\vec{P}$ change as direction of velocity changes.

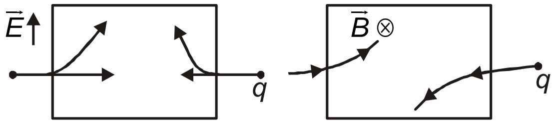
8. The motion of a charged particle can be used to distinguish between a magnetic field and electric field in a certain region by firing the charge

(1) Perpendicular to the field (2) Parallel to the field

(3) From opposite directions (4) With different speeds

Sol. Answer (3)

To distinguish between $\vec{E}$ and $\vec{B}$



9. The correct expression for Lorentz force is

(1) $q\,[\vec{E}+(\vec{B}\times\vec{v})]$ (2) $q\,[\vec{E}+(\vec{v}\times\vec{B})]$ (3) $q(\vec{v}\times\vec{B})$ (4) $q\,\vec{E}$

Sol. Answer (2)

$$\vec{F}=q\left[\vec{E}+(\vec{v}\times\vec{B})\right]$$

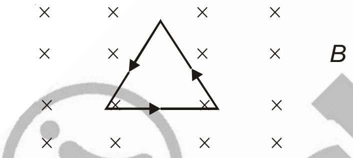
10. A charged particle moves in a gravity free space without change in velocity. Which of the following is not possible in that space?

(1) $E = 0,\ B = 0$ (2) $E \neq 0,\ B = 0$ (3) $E = 0,\ B \neq 0$ (4) $E \neq 0,\ B \neq 0$

Sol. Answer (2)

If $\vec{E}\neq 0$ and $\vec{B}\neq 0$, $\vec{E}$ will definitely deflect / increase / decrease velocity of charge. If both $\vec{E}$ and $\vec{B}$ are non zero, they may balance each other.

11. A wire is bent in the form of an equilateral triangle of side 100 cm and carries a current of 2 A. It is placed in a magnetic field of induction 2.0 T directed perpendicular into the plane of paper. The direction and magnitude of magnetic force acting on each side of the triangle will be



(1) 2 N, normal to the side towards centre of the triangle

(2) 2 N, normal to the side away from the centre of the triangle

(3) 4 N, normal to the side towards centre of the triangle

(4) 4 N, normal to the side away from the centre of the triangle

Sol. Answer (3)

$$\vec{F}=i(\vec{l}\times\vec{B})$$

$$=2(1)(2)$$

$$=4\text{ N}$$

Normal to side towards centre of triangle.

12. The oscillator frequency of a cyclotron is 10 MHz. What should be the operating magnetic field for accelerating proton?

(1) 0.156 T (2) 0.256 T (3) 0.356 T (4) 0.656 T

Sol. Answer (4)

$$f=\frac{qB}{2\pi m} \qquad \left(\because T=\frac{2\pi m}{qB}\right)$$

$$\Rightarrow \quad 10\times10^{6}=\frac{1.6\times10^{-19}\times B}{2\pi\left(1.6\times10^{-27}\right)}$$

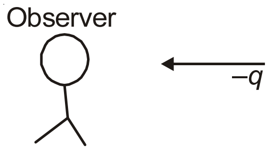
$$B = 0.656\text{ T}$$

13. A negative charge is coming towards the observer. The direction of the magnetic field produced by it will be (as seen by observer)

(1) Clockwise (2) Anti-clockwise

(3) In the direction of motion of charge (4) In the direction opposite to the motion of charge

Sol. Answer (1)



$\vec{B}$ will be clockwise as seen by observer.

14. When equal current is passed through two coils, equal magnetic field is produced at their centres. If the ratio of number of turns in the coils is 8 : 15, then the ratio of their radii will be

(1) 1 : 1 (2) 15 : 8 (3) 8 : 15 (4) 1 : 2

Sol. Answer (3)

$$B_1 = B_2$$

$$\frac{\mu_0 n_1 i}{2r_1} = \frac{\mu_0 n_2 i}{2r_2}$$

$$\frac{n_1}{n_2} = \frac{8}{15} = \frac{r_1}{r_2}$$

15. The radius of a circular current carrying coil is R. At what distance from the centre of the coil on its axis, the intensity of magnetic field will be $\frac{1}{2\sqrt{2}}$ times that at the centre?

(1) $2R$ (2) $\frac{3R}{2}$ (3) R (4) $\frac{R}{2}$

Sol. Answer (3)

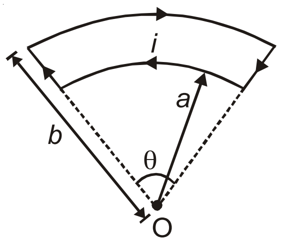
$$\frac{\mu_0 i R^2}{2(R^2+x^2)^{3/2}} = \frac{1}{2\sqrt{2}}\frac{\mu_0 i}{2R}$$

$$2\sqrt{2}R^3 = (R^2+x^2)^{3/2}$$

$$(2\sqrt{2})^{2/3} R^2 = R^2 + x^2$$

$$x^2 = 2R^2 - R^2 = R^2 \Rightarrow \quad x = R$$

16. The figure below shows a current loop having two circular arcs joined by two radial lines. The magnetic field at O is

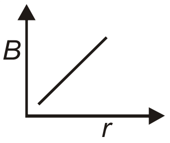


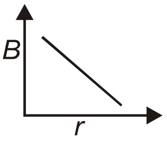
(1) $\frac{\mu_0 i \theta}{2\pi a b}(b-a)$ (2) $\frac{\mu_0 i \theta}{4\pi a b}(b-a)$ (3) Zero (4) $\frac{\mu_0 i \theta}{3\pi a b}(b+a)$

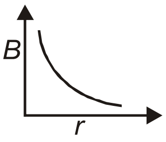
Sol. Answer (2)

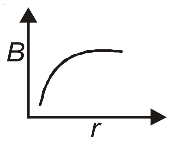
$$\vec{B} = \vec{B_1} - \vec{B_2} = \frac{\mu_0 i}{2a}\left(\frac{\theta}{2\pi}\right) - \frac{\mu_0 i}{2b}\left(\frac{\theta}{2\pi}\right) = \frac{\mu_0 i \theta}{4\pi}\left(\frac{1}{a} - \frac{1}{b}\right)$$

17. Which one of the following graphs shows the variation of magnetic induction B with distance r from a long wire carrying a current?

(1) 

(2) 

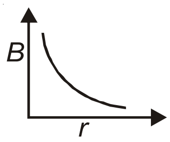
(3) 

(4) 

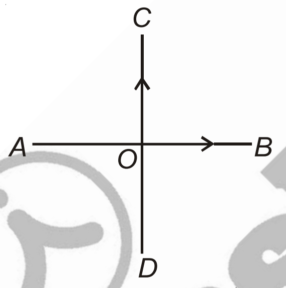
Sol. Answer (3)

$$B = \frac{\mu_0 i}{2\pi r}$$

$$B \propto \frac{1}{r}$$



18. Two straight long conductors AOB and COD are perpendicular to each other and carry currents i_1 and i_2. The magnitude of the magnetic induction at a point P at a distance d from the point O in a direction perpendicular to the plane $ABCD$ is



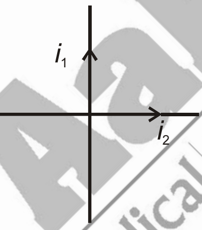
(1) $\frac{\mu_0}{2\pi d}(i_1 + i_2)$ (2) $\frac{\mu_0}{4\pi d}(i_1 - i_2)$ (3) $\frac{\mu_0}{2\pi d}(i_1^2 + i_2^2)^{1/2}$ (4) $\frac{\mu_0}{2\pi d}\left[\frac{i_1 i_2}{i_1 + i_2}\right]$

Sol. Answer (3)

$$\Rightarrow \vec{B} = \vec{B_1} + \vec{B_2}$$

$$\vec{B} = \frac{\mu_0 i_1}{2\pi d}\hat{i} - \frac{\mu_0 i_2}{2\pi d}\hat{j}$$

$$|\vec{B}| = \frac{\mu_0}{2\pi d}\sqrt{i_1^2 + i_2^2}$$



19. A current of i ampere is flowing in an equilateral triangle of side a. The magnetic induction at the centroid will be

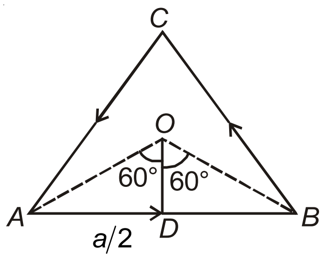
(1) $\frac{\mu_0 i}{3\sqrt{3}\pi a}$ (2) $\frac{3\mu_0 i}{2\pi a}$ (3) $\frac{5\sqrt{2}\mu_0 i}{3\pi a}$ (4) $\frac{9\mu_0 i}{2\pi a}$

Sol. Answer (4)

O is centroid and using the ΔOAD distance $OD = \frac{a}{2\sqrt{3}}$

By all the three sides AB, BC and CA, direction of magnetic field produced will be same and inward to the plane of paper

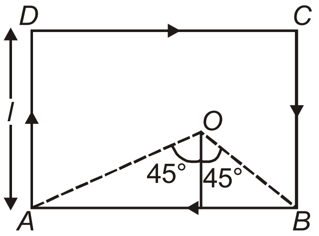
So $B_{\text{total}} = 3\left[\frac{\mu_0 i}{4\pi\left(\frac{a}{2\sqrt{3}}\right)}(\sin 60° + \sin 60°)\right] = \frac{9\mu_0 i}{2\pi a}$



20. A square frame of side l carries a current i. The magnetic field at its centre is B. The same current is passed through a circular coil having the same perimeter as the square. The field at the centre of the circular coil is B'. The ratio of $\frac{B}{B'}$ is

(1) $\frac{8\sqrt{2}}{\pi^2}$ (2) $\frac{8\sqrt{2}}{\pi^3}$ (3) $\frac{8\sqrt{2}}{\pi}$ (4) $\frac{4\sqrt{2}}{\pi^2}$

Sol. Answer (1)

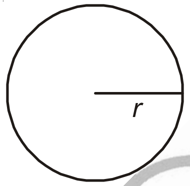


$$OD = \frac{l}{2}$$

$$B = 4\left[\frac{\mu_0 i}{4\pi\left(\frac{l}{2}\right)}(\sin 45^\circ + \sin 45^\circ)\right]$$

$$B = 2\sqrt{2}\frac{\mu_0 i}{\pi l}$$

For circle



$$2\pi r = 4l$$

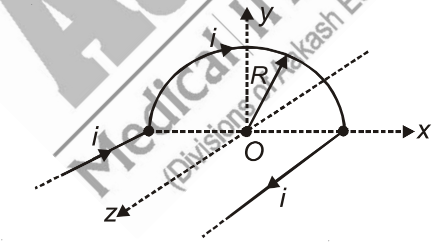
$$r = \frac{2l}{\pi}$$

So $B' = \frac{\mu_0 i}{2r} = \frac{\mu_0 i}{2\left(\frac{2l}{\pi}\right)}$

$\Rightarrow \quad B' = \frac{\mu_0 i \pi}{4l}$

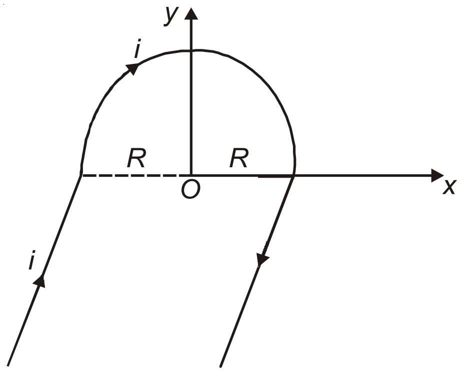
$\Rightarrow \quad$ So $\frac{B}{B'} = \frac{8\sqrt{2}}{\pi^2}$

21. The magnetic induction at the point O, if the wire carries a current i, is



(1) $\frac{\mu_0 i}{2R}$ (2) $\frac{\mu_0 i}{2\pi R}$ (3) $\frac{\mu_0 i(\pi^2+4)^{1/2}}{4\pi R}$ (4) $\frac{\mu_0 i(\pi^2+4)}{4\pi R}$

Sol. Answer (3)



Due to straight wires $\overrightarrow{B_1}$ at O

$$B_1 = \frac{\mu_0 i}{4\pi R}(-\hat{j}) + \frac{\mu_0 i}{4\pi R}(-\hat{j})$$

$$= -\frac{\mu_0 i}{2\pi R}\hat{j}$$

Due to semicircle

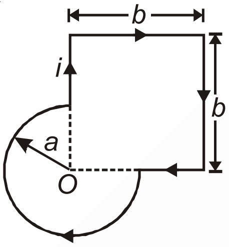
$$\overrightarrow{B_2} = -\frac{\mu_0 i}{4R}\hat{k}$$

Net $\vec{B} = \vec{B_1} + \vec{B_2} = \sqrt{\left(\frac{\mu_0 i}{2\pi R}\right)^2 + \left(\frac{\mu_0 i}{4R}\right)^2}$

$$= \frac{\mu_0 i}{2R}\sqrt{\frac{1}{\pi^2} + \frac{1}{4}}$$

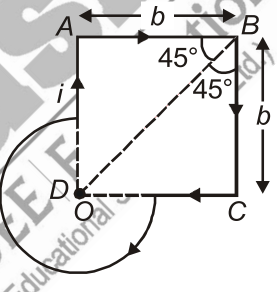
$$= \frac{\mu_0 i}{2R(2\pi)}\sqrt{\pi^2 + 4}$$

22. The magnetic field intensity at the point *O* of a loop with current *i*, whose shape is illustrated below is



(1) $\frac{\mu_0 i}{4\pi}\left[\frac{3\pi}{2a} + \frac{\sqrt{2}}{b}\right]$ (2) $\frac{\mu_0 i}{4\pi^2}\left[\frac{2}{a} + b\right]$ (3) $\frac{\mu_0 i}{2\pi}\left[\frac{1}{a} + \frac{1}{b}\right]$ (4) $\frac{\mu_0 i}{4\pi}\left[\frac{1}{a} + \frac{1}{b}\right]$

Sol. Answer (1)



$\vec{B}$ due to square part :-

$\vec{B}$ due to side *OA* and *OC* will be zero at point *O*

$\vec{B}$ due to side *AB* and *BC* will be equal so

$$\vec{B_1} = 2\left[\frac{\mu_0 i}{4\pi b}(\sin 45^\circ + 0)\right] = \frac{\mu_0 i}{2\sqrt{2}\pi b} \otimes$$

$\vec{B}$ due to circular part

$$\vec{B_2} = \frac{\mu_0 i}{2a}\left[\frac{\left(\frac{3\pi}{2}\right)}{2\pi}\right] = \frac{3\mu_0 i}{8a} \otimes$$

$$\vec{B_{\text{net}}} = \vec{B_1} + \vec{B_2} = \mu_0 i\left[\frac{3}{8a} + \frac{1}{2\sqrt{2}\pi b}\right] = \frac{\mu_0 i}{4\pi}\left[\frac{3\pi}{2a} + \frac{\sqrt{2}}{b}\right]$$

23. If an electron revolves around a nucleus in a circular orbit of radius *R* with frequency *n*, then the magnetic field produced at the centre of the nucleus will be

(1) $\frac{\mu_0 en}{2R}$ (2) $\frac{\mu_0 en}{4\pi R}$ (3) $\frac{4\pi\mu_0 en}{R}$ (4) $\frac{4\pi\mu_0 e}{Rn}$

Sol. Answer (1)

Current (i) = $\frac{q}{T} = q\left(\frac{1}{T}\right) = qn$

So $\vec{B} = \frac{\mu_0 i}{2R} = \frac{\mu_0 (ne)}{2R}$

24. A thin disc of radius R and mass M has charge q uniformly distributed on it. It rotates with angular velocity ω. The ratio of magnetic moment and angular momentum for the disc is

(1) $\frac{q}{2M}$ (2) $\frac{R}{2M}$ (3) $\frac{q^2}{2M}$ (4) $\frac{2M}{q}$

Sol. Answer (1)

Standard result $\frac{|\vec{M}|}{|\vec{L}|} = \frac{q}{2M}$

25. The number of turns per unit length of a long solenoid is 10. If its average radius is 5 cm and it carries a current of 10 A, then the ratio of flux densities obtained at the centre and at the end on the axis will be

(1) 1 : 2 (2) 2 : 1 (3) 1 : 1 (4) 1 : 4

Sol. Answer (2)

$\vec{B}_{\text{centre}} = \mu_0 ni \qquad n = 10$

$\vec{B}_{\text{end}} = \frac{\mu_0 ni}{2}$

$$\frac{\vec{B}_{\text{centre}}}{\vec{B}_{\text{end}}} = \frac{\mu_0 ni}{\left(\frac{\mu_0 ni}{2}\right)} = \frac{2}{1}$$

26. In a toroid the number of turns per unit length is 1000 and current through it is $\frac{1}{4\pi}$ ampere. The magnetic field produced inside (in weber/m^2) will be

(1) 10^{-2} (2) 10^{-3} (3) 10^{-4} (4) 10^{-7}

Sol. Answer (3)

$n = 1000 \qquad I = \frac{1}{4\pi}A$

$B = \mu_0 ni = 4\pi \times 10^{-7}(1000) \times \frac{1}{4\pi}$

$B = 10^{-4}$ (T)

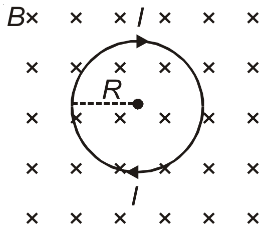
27. A conducting circular loop of radius r carries a constant current i. It is placed in uniform magnetic field B, such that B is perpendicular to the plane of the loop. The net magnetic force acting on the loop is

(1) irB (2) $2\pi riB$ (3) Zero (4) πriB

Sol. Answer (3)

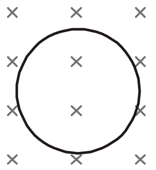
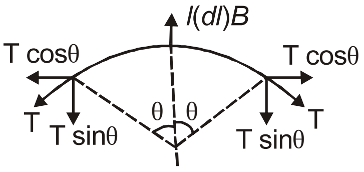
Net force on a closed loop in uniform magnetic field will always be zero.

28. A circular loop of radius R is kept in a uniform magnetic field pointing perpendicular into the plane of paper. When a current I flows in the loop, the tension produced in the loop is



(1) BIR (2) $\frac{BIR}{2}$ (3) $2BIR$ (4) Zero

Sol. Answer (1)

$\Rightarrow \quad I(dl)B = 2T\sin\theta$

$I(dl)B = 2T\,\theta$

$I\left(R(2\theta)B\right) = 2T\,\theta$

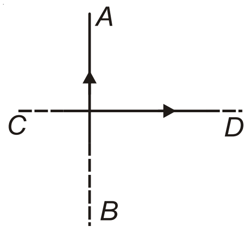
T = BIR

29. If two straight current carrying wires are kept perpendicular to each other almost touching, then the wires

(1) Attract each other (2) Repel each other

(3) Remain stationary (4) Become parallel to each other

Sol. Answer (4)



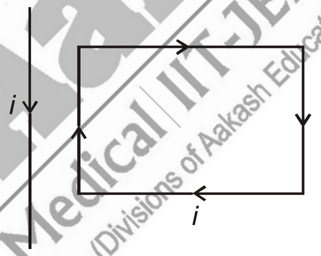
Due to wire AB, wire CD will experience torque due to which it will become parallel to AB.

30. Connecting wires carrying currents in opposite directions are twisted together in using electrical appliances in order to reduce

(1) Electrical effect (2) Magnetic effect (3) Seebeck effect (4) Peltier effect

Sol. Answer (2)

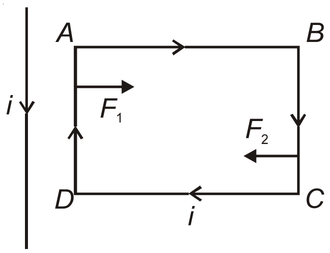
31. A rectangular loop carrying a current i is situated near a long straight wire such that the wire is parallel to one of the sides of the loop and is in the plane of the loop. If a steady current i is established in the wire, the loop will



(1) Rotate about an axis parallel to the wire (2) Move away from the wire

(3) Move towards the wire (4) Remain stationary

Sol. Answer (2)



Force on AB and CD will be zero and for AD and BC

$F_1 > F_2$

$\Rightarrow$ Loop moves away from wire.

32. A square loop of side l is kept in a uniform magnetic field B such that its plane makes an angle α with $\vec{B}$. The loop carries a current i. The torque experienced by the loop in this position is

(1) $B i l^2$ (2) $B i l^2 \sin \alpha$ (3) $B i l^2 \cos\alpha$ (4) Zero

Sol. Answer (3)

$$\tau = \vec{M} \times \vec{B}$$

$$\vec{M} = iA = il^2$$

$$\Rightarrow \quad \tau = il^2 \sin(90 - \alpha) = B i l^2 \cos\alpha$$

33. Choose the correct statement

(1) It is possible for a current loop to stay without rotating in a uniform magnetic field

(2) If a uniform magnetic field exists in a cubical region and zero outside then it is not possible to project a charged particle from outside into the field so that it describes a complete circle in the field

(3) A moving charged particle can be accelerated by a magnetic field

(4) All of these

Sol. Answer (4)

34. The effective radius of a circular coil is R and number of turns is N. The current through it is i ampere. The work done in rotating the coil by angle of 180° in an external magnetic field B will be (initially plane of coil is perpendicular to magnetic field)

(1) πNiR^2B (2) $2\pi NiR^2B$ (3) $\frac{(2NiB)}{\pi R^2}$ (4) Zero

Sol. Answer (2)

$$W = \Delta U = U_f - U_i = -Ni\pi R^2 \cos 180^\circ - \left(-Ni(\pi R^2)\cos 0^\circ\right)$$

$$= 2\pi NiR^2B$$

35. The current sensitivity of a moving coil galvanometer increases by 20% when its resistance is doubled. Calculate, by what factor does the voltage sensitivity change?

(1) Becomes $\frac{3}{5}$ times (2) Becomes $\frac{2}{5}$ times

(3) No change (4) Decreases by a factor of $\frac{7}{5}$

Sol. Answer (1)

$$S_{i_1} = \frac{NiAB}{ki} = \frac{NAB}{k}$$

$$S_{i_2} = \frac{1.2NAB}{k}$$

$$S_{v_1} = \frac{NAB}{kR} = \frac{S_{i_1}}{R}$$

$$S_{v_2} = \frac{S_{i_2}}{2R} = \frac{1.2(NAB)}{k(2R)}$$

SECTION - B

Objective Type Questions

1. A charged particle enters a uniform magnetic field perpendicular to it. The magnetic field

(1) Increases the speed of the particle

(2) Decreases the kinetic energy of the particle

(3) Changes the direction of motion of the particle

(4) Both (1) & (3)

Sol. Answer (3)

Magnetic force $\vec{F} \perp \vec{V}$

⇒ No work is done by magnetic field so speed and kinetic energy cannot be changed by magnetic field but it can deflect the particle

2. A proton and an alpha particle enter the same magnetic field which is perpendicular to their velocity. If they have same kinetic energy then ratio of radii of their circular path is

(1) 1 : 1 (2) 1 : 2 (3) 2 : 1 (4) 1 : 4

Sol. Answer (1)

$r = \frac{\sqrt{2mk}}{qB}$ here k is same, so $r \propto \frac{\sqrt{m}}{q}$

so $\frac{r_p}{r_\propto} = \sqrt{\frac{m_p}{m_\propto}} \times \frac{q_\propto}{q_p} = \sqrt{\frac{1}{4}} \times \frac{2}{1} = 1 : 1$

3. In which of the following situations, the magnetic field can accelerate a charge particle at rest?

I. When the magnetic field is uniform with respect to time as well as position

II. When the magnetic field is time varying but uniform w.r.t. position

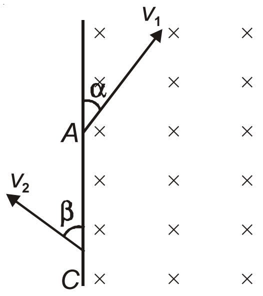
III. When the magnetic field is time independent but position dependent

(1) I, II & III (2) III only (3) II only (4) None of these

Sol. Answer (3)

When magnetic field is time varying, an induced electric field is produced which can accelerate charge.

4. A particle of charge –q and mass m enters a uniform magnetic field $\vec{B}$ at A with speed v_1 at an angle α and leaves the field at C with speed v_2 at an angle β as shown. Then



(1) $\alpha = \beta$ (2) $v_1 = v_2$

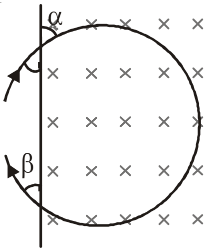
(3) Particle remains in the field for time $t = \frac{2m(\pi - \alpha)}{qB}$ (4) All of these

Sol. Answer (4)

$\beta = \alpha$

$v_1 = v_2 \ (\because F_m \perp v)$

$$T = \frac{2(\pi - \alpha)m}{qB}$$



5. A proton moving with a constant velocity, passes through a region of space without change in its velocity. If *E* & *B* represent the electric and magnetic fields respectively, this region may have

(1) $E = 0,\ B \neq 0$ (2) $E \neq 0,\ B = 0$

(3) *E* & *B* both parallel (4) *E* & *B* inclined at 45° angle

Sol. Answer (1)

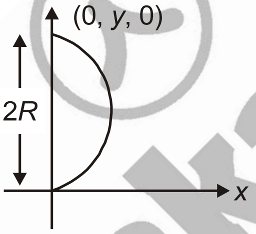
6. A particle of charge per unit mass α is released from origin with a velocity $\bar{v} = v_0\hat{i}$ in a uniform magnetic field $\bar{B} = -B_0\hat{k}$. If the particle passes through (0, *y*, 0) then *y* is equal to

(1) $-\frac{2v_0}{B_0\alpha}$ (2) $\frac{v_0}{B_0\alpha}$ (3) $\frac{2v_0}{B_0\alpha}$ (4) $-\frac{v_0}{B_0\alpha}$

Sol. Answer (3)

$$\frac{q}{m} = \alpha$$

$$y = 2R = 2\left(\frac{mv}{qB}\right) = \frac{2v_0}{\alpha B_0}$$



7. A proton is accelerating in a cyclotron where the applied magnetic field is 2 T. If the potential gap is effectively 100 kV then how much revolutions the proton has to make between the "dees" to acquire a kinetic energy of 20 MeV?

(1) 100 (2) 150 (3) 200 (4) 300

Sol. Answer (1)

Energy increased in each revolution = $2 \times 100 \times 10^3$ *eV*

= 2×10^5 *eV*

Now for energy $E = 2 \times 10^7$ *eV*

Number of revolution = $\frac{2\times10^7 eV}{2\times10^5 eV} = 100$

8. A current *i* ampere flows in a circular arc of wire which subtends an angle $\frac{3\pi}{2}$ radian at its center, whose radius is *R*. The magnetic field *B* at its center is

(1) $\frac{\mu_0 i}{R}$ (2) $\frac{3\mu_0 i}{2R}$ (3) $\frac{3\mu_0 i}{4R}$ (4) $\frac{3\mu_0 i}{8R}$

Sol. Answer (4)

$$B = \frac{\mu_0 i}{2R}\left(\frac{3\pi}{2(2\pi)}\right) = \frac{3\mu_0 i}{8R}$$

9. At what distance on the axis, from the centre of a circular current carrying coil of radius r, the magnetic field becomes 1/8th of the magnetic field at centre?

(1) $\sqrt{2}r$ (2) $2^{3/2}r$ (3) $\sqrt{3}r$ (4) $3\sqrt{2}r$

Sol. Answer (3)

$$\frac{1}{8}\frac{\mu_0 i}{2r} = \frac{\mu_0 I r^2}{2(r^2+x^2)^{3/2}} \quad \Rightarrow \quad (r^2+x^2)^{3/2} = 8r^3$$

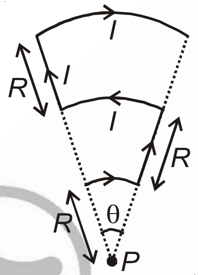
$$\Rightarrow \quad (r^2+x^2) = (8r^3)^{2/3}$$

$$\Rightarrow \quad r^2+x^2 = 4r^2$$

$$\Rightarrow \quad 3r^2 = x^2$$

$$\Rightarrow \quad x = r\sqrt{3}$$

10. Magnetic field at P due to given structure is



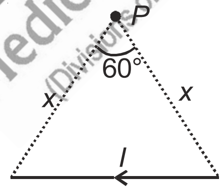
(1) $\left(\frac{\mu_0}{4\pi}\right)\frac{I\theta}{2R}$ (2) $\frac{\mu_0}{4\pi}\frac{6I\theta}{5R}$ (3) $\left(\frac{\mu_0}{4\pi}\right)\frac{5I\theta}{6R}$ (4) $\left(\frac{\mu_0}{4\pi}\right)\frac{2I\theta}{R}$

Sol. Answer (3)

$$\vec{B}_p = \frac{\mu_0 I\theta}{4\pi R} + \frac{\mu_0 I\theta}{4\pi(3R)} - \frac{\mu_0 I\theta}{4\pi(2R)}$$

$$\vec{B}_p = \frac{\mu_0 I\theta}{4\pi R}\left[1+\frac{1}{3}-\frac{1}{2}\right] = \frac{5}{6}\frac{\mu_0 I\theta}{4\pi R}$$

11. A straight wire of finite length carrying current I subtends an angle of 60° at point P as shown. The magnetic field at P is

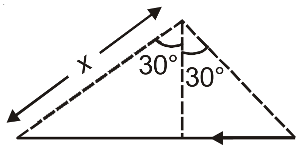


(1) $\frac{\mu_0 I}{2\sqrt{3}\pi x}$ (2) $\frac{\mu_0 I}{2\pi x}$ (3) $\frac{\sqrt{3}\mu_0 I}{2\pi x}$ (4) $\frac{\mu_0 I}{3\sqrt{3}\pi x}$

Sol. Answer (1)

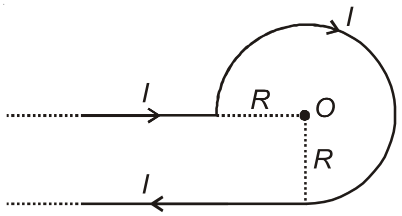
$$B = \frac{\mu_0 I}{4\pi x\cos 30^\circ}[\sin 30^\circ + \sin 30^\circ]$$

$$B = \frac{\mu_0 I}{4\pi x\left(\frac{\sqrt{3}}{2}\right)}\left(\frac{1}{2}+\frac{1}{2}\right)$$



$$= \frac{\mu_0 i}{2\sqrt{3}\pi x}$$

12. Magnetic field at the centre O due to the given structure is



(1) $\frac{\mu_0 I}{4R}\left[\frac{3}{2}+\frac{1}{\pi}\right]\odot$ (2) $\frac{\mu_0 I}{2R}\left[3+\frac{1}{\pi}\right]\otimes$ (3) $\frac{\mu_0 I}{4R}\left[\frac{3}{2}+\frac{1}{\pi}\right]\otimes$ (4) $\frac{\mu_0 I}{4R}\left[3+\frac{2}{\pi}\right]\odot$

Sol. Answer (3)

$B = B_{\text{due to circular arc}} + B_{\text{due to straight wires}}$

$$= \frac{\mu_0 i}{2R}\left(\frac{3\pi}{2.(2\pi)}\right)+\frac{\mu_0 i}{4\pi R}$$

$$\Rightarrow \quad B = \frac{\mu_0 i}{4R}\left(\frac{3}{2}+\frac{1}{\pi}\right)\otimes$$

13. A current i flows in a thin wire in the shape of a regular polygon with n sides. The magnetic induction at the centre of the polygon when $n \to \infty$ is (R is the radius of its Circumcircle)

(1) $\frac{\mu_0 n i}{2\pi R}\tan\frac{\pi}{6}$ (2) $\frac{\mu_0 n i}{2\pi R}\tan\frac{\pi}{n}$ (3) $\frac{\mu_0 i}{2R}$ (4) Zero

Sol. Answer (3)

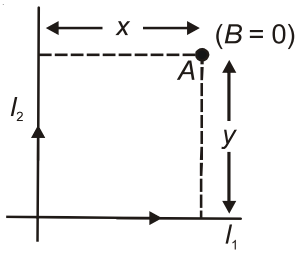
For regular polygon having n sides where $n \to \infty$ will be almost a circle

So $B = \frac{\mu_0 i}{2R}$

14. Two long straight wires are placed along x-axis and y-axis. They carry current I_1 and I_2 respectively. The equation of locus of zero magnetic induction in the magnetic field produced by them is

(1) $y = x$ (2) $y = \left(\frac{I_2}{I_1}\right)x$ (3) $y = \left(\frac{I_1}{I_2}\right)x$ (4) $y = (I_1 I_2)x$

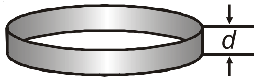
Sol. Answer (3)



On a general point A magnetic field will be zero when $\frac{\mu_0 I_2}{2\pi x} = \frac{\mu_0 I_1}{2\pi y}$

$$y = \frac{I_1}{I_2}x$$

15. Surface charge density on a ring of radius *a* and width *d* is σ as shown in the figure. It rotates with frequency *f* about its own axis. Assume that the charge is only on outer surface. The magnetic field induction at centre is(Assume that $d << a$)



(1) $\pi\mu_0 f\sigma d$ (2) $\mu_0 f\sigma d$ (3) $2\pi\mu_0 f\sigma d$ (4) $\frac{\pi^2}{2\mu_0}f\sigma d$

Sol. Answer (1)

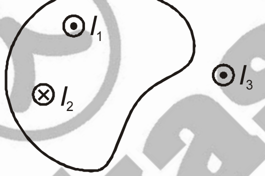
Surface charge density = σ

Total charge on the ring (q) = $\sigma(2\pi a)d$

$$\Rightarrow i = \frac{q}{T} = \sigma(2\pi a)df$$

$$\vec{B} = \frac{\mu_0 I}{2\pi a} = \frac{\mu_0(\sigma 2\pi a d f)}{2\pi a} = \pi\mu_0\sigma df$$

16. If $\vec{B}_1, \vec{B}_2$ and $\vec{B}_3$ are the magnetic field due to I_1, I_2 and I_3, then in Ampere's circuital law $\oint \vec{B}\cdot d\vec{l} = \mu_0 I, \vec{B}$ is



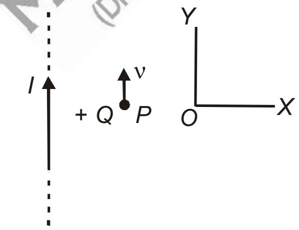
(1) $\vec{B} = \vec{B}_1 - \vec{B}_2$ (2) $\vec{B} = \vec{B}_1 + \vec{B}_2 + \vec{B}_3$ (3) $\vec{B} = \vec{B}_1 - \vec{B}_2 + \vec{B}_3$ (4) $\vec{B} = \vec{B}_3$

Sol. Answer (2)

In ampere circuital law, on amperian loop *B* is due to all the current elements either inside or outside to the amperian loop

$$\vec{B} = \vec{B}_1 + \vec{B}_2 + \vec{B}_3$$

17. A charge Q moves parallel to a very long straight wire carrying a current *I* as shown. The force on the charge is

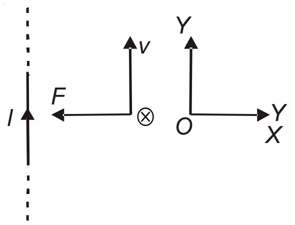


(1) Opposite to *OX* (2) Along *OX* (3) Opposite to *OY* (4) Along *OY*

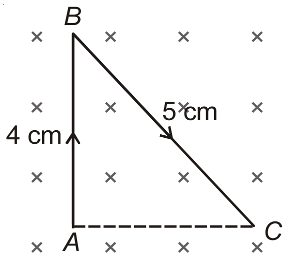
Sol. Answer (1)

$F = q(\vec{V} \times \vec{B})$

Using right hand thumb rule *F* will be opposite to *OX*.



18. A uniform conducting wire *ABC* has a mass of 10 g. A current of 2 A flows through it. The wire is kept in a uniform magnetic field *B* = 2 T. The acceleration of the wire will be

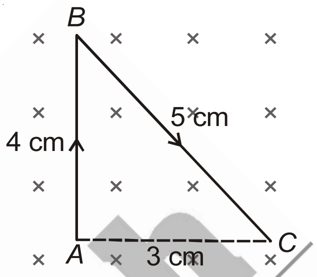


(1) Zero (2) 12 ms^{-2} (3) $1.2 \times 10^{-3}\ \text{ms}^{-2}$ (4) $0.6 \times 10^{-3}\ \text{ms}^{-2}$

Sol. Answer (2)

Force on wire *ABC* will be same as force on wire *AC*,

using $F = i(\vec{l} \times \vec{B})$

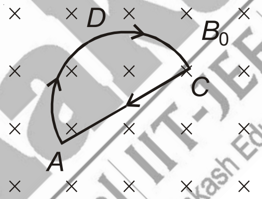


$$F = 2\left(\frac{3}{100}\right)(2)\sin 90^\circ$$

$$= 12 \times 10^{-2}\ \text{N}$$

$$a = \frac{F}{m} = \frac{12 \times 10^{-2}}{10^{-2}} = 12\ \text{m/s}^2$$

19. Figure shows a conducting loop *ADCA* carrying current *i* and placed in a region of uniform magnetic field B_0. The part *ADC* forms a semicircle of radius *R*. The magnitude of force on the semicircle part of the loop is equal to



(1) πRiB_0 (2) Zero (3) $2\pi RiB_0$ (4) $2iRB_0$

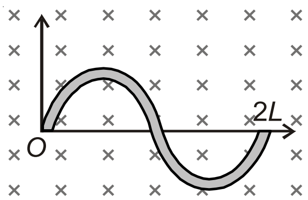
Sol. Answer (4)

The force on the semicircle part *ADC*, will be same as force on wire *CA* and force on wire *CA* = $i\,(2R)(B_0)$

(using F = *ilB*)

= $2iRB_0$

20. A wire carrying a current *i* is placed in a magnetic field in the form of the curve $y = a\sin\left(\frac{\pi x}{L}\right) 0 \le x \le 2L$. Force acting on the wire is



(1) $\frac{iBL}{\pi}$ (2) $iBL\pi$ (3) $2iBL$ (4) Zero

Sol. Answer (3)

$$|\vec{l}| = 2L$$

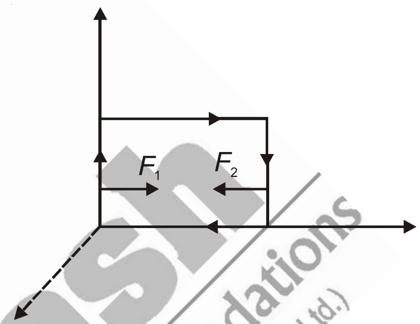
Now, using $F = ilB$

$$= i(2L)B$$

21. The magnetic field existing in a region is given by $\vec{B} = B_0\left(1+\frac{x}{l}\right)\hat{k}$. A square loop of edge l and carrying a current i, is placed with its edge parallel to the x-y axes. Find the magnitude of the net magnetic force experienced by the loop

(1) $\frac{1}{2}iB_0l$ (2) Zero (3) iB_0l (4) $2iB_0l$

Sol. Answer (3)



$$\vec{B} = B_0\left(1+\frac{x}{l}\right)\hat{k}$$

at $x = 0$, $B_1 = B_0\hat{k}$

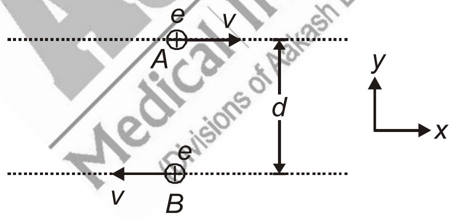
at $x = l$, $B_2 = 2B_0\hat{k}$

$$F_{\text{net}} = F_2 - F_1 = il(B_2 - B_1)$$

$$= il(2B_0 - B_0)$$

$$= ilB_0$$

22. Two protons A and B move parallel to the x-axis in opposite directions with equal speeds v. At the instant shown, the ratio of magnetic force and electric force acting on the proton A is (c = speed of light in vacuum)



(1) $\frac{v}{c}$ (2) $\frac{v^2}{c^2}$ (3) $\frac{vd^2}{c}$ (4) $\frac{2v}{c}$

Sol. Answer (2)

23. If the planes of two identical concentric coils are perpendicular and the magnetic moment of each coil is M, then the resultant magnetic moment of the two coils will be

(1) M (2) $2M$ (3) $3M$ (4) $\sqrt{2}M$

Sol. Answer (4)

$$M_{\text{net}} = \sqrt{M^2 + M^2}$$

$$= M\sqrt{2}$$

24. In a hydrogen atom, an electron of mass *m* and charge *e* revolves in an orbit of radius *r* making *n* revolutions per second. If the mass of hydrogen nucleus is *M*, the magnetic moment associated with the orbital motion of electron is

(1) $\dfrac{\pi ner^2 m}{M+m}$ (2) πner^2 (3) $\dfrac{\pi ner^2}{m}$ (4) $\dfrac{\pi ner^2 m}{M}$

Sol. Answer (2)

Magnetic moment = *NiA*

$$i = \frac{q}{T} = en$$

$$A = \pi r^2$$

and $N = 1$

$\Rightarrow$ Magnetic moment $(m) = (1)(en)(\pi r^2)$

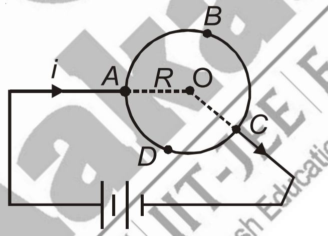
25. The phosphor bronze strip is used in a moving coil galvanometer because

(1) It is torsional constant is small (2) It is easily available

(3) It is paramagnetic (4) It is diamagnetic

Sol. Answer (1)

26. A uniform circular wire loop is connected to the terminals of a battery. The magnetic field induction at the centre due to *ABC* portion of the wire will be (length of *ABC* = l_1, length of *ADC* = l_2)



(1) $\dfrac{\mu_0}{2R}\dfrac{il_1l_2}{(l_1+l_2)^2}$ (2) $\dfrac{\mu_0}{2\pi R^2}\dfrac{il_2}{(l_1+l_2)}$ (3) $\dfrac{\mu_0}{2R}\dfrac{i(l_1+l_2)}{l_1l_2}$ (4) Zero

Sol. Answer (1)

Let current in part *ABC* is i_1

and in part *ADC* is i_2

$i = \dfrac{il_2}{l_1+l_2}$ (As *ABC* and *ADC* part are in parallel connection)

and subtended by *ABC* at centre O will be $= \left(\dfrac{2\pi}{l_1+l_2}\right)(l_1)$

so using $B = \dfrac{\mu_0 i}{2a}\left(\dfrac{\theta}{2\pi}\right)$

$$B = \frac{\mu_0}{2R}\left(\frac{il_2}{l_1+l_2}\right)\frac{2\pi}{(l_1+l_2)}\frac{(l_1)}{2\pi}$$

SECTION - C

Previous Years Questions

1. A particle of mass m, charge Q and kinetic energy T enters a transverse uniform magnetic field of induction $\vec{B}$. After 3 seconds the kinetic energy of the particle will be

(1) $4T$ (2) $3T$ (3) $2T$ (4) T

Sol. Answer (4)

$\vec{B}$ does not change kinetic energy.

2. A beam of electrons is moving with constant velocity in a region having electric and magnetic fields of strength 20 Vm^{-1} and 0.5 T at right angles to the direction of motion of the electrons. What is the velocity of the electrons?

(1) 8 ms^{-1} (2) 5.5 ms^{-1} (3) 20 ms^{-1} (4) 40 ms^{-1}

Sol. Answer (4)

$$qVB = qE$$

$$\Rightarrow \quad V = \frac{E}{B} = \frac{20}{0.5} = 40\ \text{ms}^{-1}$$

3. A 10 eV electron is circulating in a plane at right angles to a uniform field of magnetic induction 10^{-4} Wb/m^2 (= 1.0 gauss), the orbital radius of electron is

(1) 11 cm (2) 18 cm (3) 12 cm (4) 16 cm

Sol. Answer (1)

$$r = \frac{\sqrt{2mk}}{qB}$$

4. A positively charged particle moving due East enters a region of uniform magnetic field directed vertically upwards. This particle will

(1) Move in a circular path with a decreased speed

(2) Move in a circular path with a uniform speed

(3) Get deflected in vertically upward direction

(4) Move in circular path with an increased speed

Sol. Answer (2)

In uniform $\vec{B}$, if charge enters perpendicular to the magnetic field. It will execute circular motion with uniform speed.

5. An electron having mass m and kinetic energy E enters in uniform magnetic field B perpendicularly, then its frequency will be

(1) $\frac{eE}{q\nu B`}$ (2) $\frac{2\pi m}{eB}$ (3) $\frac{eB}{2\pi m}$ (4) $\frac{2m}{eBE}$

Sol. Answer (3)

$$f = \frac{eB}{2\pi m}$$

6. An electron moves in a circular orbit with a uniform speed v. It produces a magnetic field B at the centre of the circle. The radius of the circle is proportional to

(1) $\sqrt{\frac{B}{v}}$ (2) $\frac{B}{v}$ (3) $\sqrt{\frac{v}{B}}$ (4) $\frac{v}{B}$

Sol. Answer (3)

$$B = \frac{\mu_0}{4\pi}\frac{q\left(\vec{v}\times\vec{r}\right)}{r^3}$$

$$\Rightarrow \quad B = \frac{\mu_0}{4\pi}\frac{qv}{r^2}$$

$$r \propto \sqrt{\frac{v}{B}}$$

7. When a charged particle moving with velocity $\vec{v}$ is subjected to a magnetic field of induction $\vec{B}$, the force on it is non-zero. This implies that

(1) Angle between is either zero or 180°

(2) Angle between is necessarily 90°

(3) Angle between can have any value other than 90°

(4) Angle between can have any value other than zero and 180°

Sol. Answer (4)

$$F = q\left(\vec{v}\times\vec{B}\right) = qvB\sin\theta$$

$$F \neq 0\,,\ \sin\theta \neq 0\,,\ \Rightarrow\ \theta \neq 0^\circ,\ 180^\circ$$

8. Under the influence of a uniform magnetic field a charged particle is moving in a circle of radius R with constant speed v. The time period of the motion

(1) Depends on both R and v (2) Is independent of both R and v

(3) Depends on R and not on v (4) Depends on v and not on R

Sol. Answer (2)

$$T = \frac{2\pi m}{qB}$$

9. The magnetic force acting on a charged particle of charge –2 μC in a magnetic field of 2 T acting in y direction, when the particle velocity is $(2\hat{i}+3\hat{j})\times 10^6\ \text{ms}^{-1}$, is

(1) 8 N in z direction (2) 8 N in $-z$ direction (3) 4 N in z direction (4) 8 N in y direction

Sol. Answer (2)

$$q = -2\ \mu C \qquad B = 2\ T\hat{j}$$

$$\vec{V} = \left(2\hat{i}+3\hat{j}\right)\times 10^6$$

$$F = -2\ \mu C\left(\vec{V}\times\vec{B}\right)$$

$$F = -2\times 10^{-6}\begin{bmatrix}\hat{i} & \hat{j} & \hat{k}\\ 2 & 3 & 0\\ 0 & 2 & 0\end{bmatrix}10^6 = -8\hat{k}$$

10. A particle having a mass of 10^{-2} kg carries a charge of 5×10^{-8} C. The particle is given an initial horizontal velocity of 10^5 ms^{-1} in the presence of electric field $\vec{E}$ and magnetic field $\vec{B}$. To keep the particle moving in a horizontal direction, it is necessary that

(a) $\vec{B}$ should be perpendicular to the direction of velocity and $\vec{E}$ should be along the direction of velocity

(b) Both $\vec{B}$ and $\vec{E}$ should be along the direction of velocity

(c) Both $\vec{B}$ and $\vec{E}$ are mutually perpendicular and perpendicular to the direction of velocity

(d) $\vec{B}$ should be along the direction of velocity and $\vec{E}$ should be perpendicular to the direction of velocity

Which one of the following pairs of statements is possible?

(1) (a) & (c) (2) (c) & (d) (3) (b) & (c) (4) (b) & (d)

Sol. Answer (3)

$$F_m = q(\vec{V} \times \vec{B})$$

$$F_e = q\vec{E}$$

If $F_m = F_e$, particle will continuously move in horizontal direction

If $\vec{B}$ is in the direction of velocity $F_m = 0$

11. An alternating electric field, of frequency ν, is applied across the dees (radius = R) of a cyclotron that is being used to accelerate protons (mass = m). The operating magnetic field (B) used in the cyclotron and the kinetic energy (K) of the proton beam, produced by it, are given by

(1) $B = \dfrac{2\pi m\nu}{e}$ and $K = 2m\pi^2\nu^2R^2$

(2) $B = \dfrac{m\nu}{e}$ and $K = m^2\pi\nu R^2$

(3) $B = \dfrac{m\nu}{e}$ and $K = 2m\pi^2\nu^2R^2$

(4) $B = \dfrac{2\pi m\nu}{e}$ and $K = m^2\pi\nu R^2$

Sol. Answer (1)

$$R = \frac{mV}{qB} \quad \text{here } q = e \Rightarrow \quad v = \frac{eBR}{m}$$

$$\text{frequency } \nu = \frac{1}{T} = \frac{1}{\left(\dfrac{2\pi m}{eB}\right)}$$

$$\Rightarrow B = \frac{2\pi m\nu}{e}$$

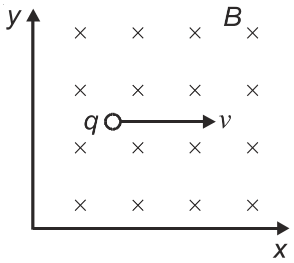
$$k = \frac{1}{2}mv^2$$

$$= \frac{1}{2}m\left(\frac{eBR}{m}\right)^2 = \frac{e^2B^2R^2}{2m}$$

$$k = \frac{e^2R^2}{2m}\left[\frac{2\pi m\nu}{e}\right]^2$$

$$= 2m\pi^2\nu^2R^2$$

12. A positive charge particle with charge q is moving with speed v in a region of uniform magnetic field B at the instant shown in figure. An external electric field is to be applied so that the charged particle follows a straight line path. The magnitude and direction of electric field required are respectively



(1) qvB, $+y$ axis (2) qvB, $-y$ axis (3) vB, $-y$ axis (4) $\frac{vB}{q}$, $-x$ axis

Sol. Answer (3)

$$F_m = qvB\hat{j}$$

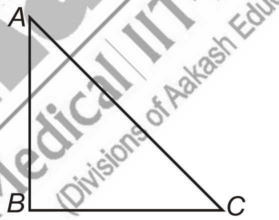
for constant velocity

$$\vec{F}_B = -\vec{F}_E$$

$$qvB\hat{j} = -q\vec{E}$$

$$\Rightarrow \vec{E} = -vB\hat{j}$$

13. A current carrying closed loop in the form of a right angle isosceles triangle ABC is placed in a uniform magnetic field acting along AB. If the magnetic force on the arm BC is $\vec{F}$, the force on the arm AC is

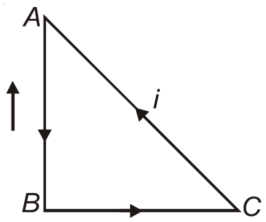


(1) $\sqrt{2}\vec{F}$ (2) $-\sqrt{2}\vec{F}$ (3) $-\vec{F}$ (4) $\vec{F}$

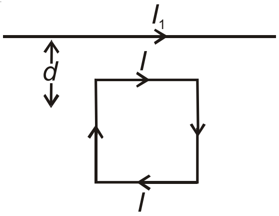
Sol. Answer (3)

Net force on the loop = 0

Force on wire AB is zero because it is along B field. Hence Foce on AC = –(Force on BC) = $-\vec{F}$



14. A square loop, carrying a steady current I, is placed in a horizontal plane near a long straight conductor carrying a steady current I_1 at a distance d from the conductor as shown in figure. The loop will experience



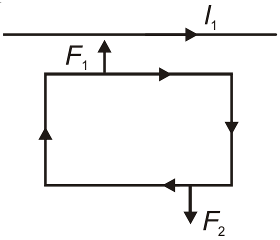
(1) A net torque acting downward normal to the horizontal plane

(2) A net attractive force towards the conductor

(3) A net repulsive force away from the conductor

(4) A net torque acting upward perpendicular to the horizontal plane

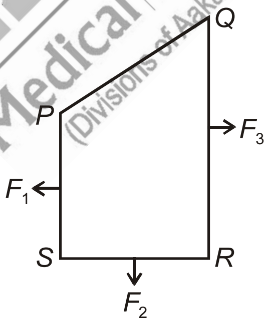
Sol. Answer (2)



$F_{\text{net}} = F_1 - F_2$

$= F_1 > F_2$

15. A closed loop $PQRS$ carrying a current is placed in a uniform magnetic field. If the magnetic forces on segments PS, SR and RQ are F_1, F_2 and F_3 respectively and are in the plane of the paper and along the directions shown, the force on the segment QP is



(1) $F_3 - F_1 + F_2$ (2) $F_3 - F_1 - F_2$ (3) $\sqrt{(F_3 - F_1)^2 + F_2^2}$ (4) $\sqrt{(F_3 - F_1)^2 - F_2^2}$

Sol. Answer (3)

Net force on loop will be zero in uniform magnetic field

So, force on QP will balance other forces

$\therefore \quad F_{QP} = \sqrt{(F_3 - F_1)^2 + F_2^2}$

16. Charge q is uniformly spread on a thin ring of radius R. The ring rotates about its axis with a uniform frequency f Hz. The magnitude of magnetic induction at the center of the ring is

(1) $\frac{\mu_0 q}{2\pi f R}$ (2) $\frac{\mu_0 q f}{2\pi R}$ (3) $\frac{\mu_0 q f}{2R}$ (4) $\frac{\mu_0 q}{2 f R}$

Sol. Answer (3)

$$B = \frac{\mu_0 q f}{2R}$$

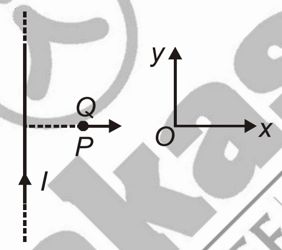
17. The magnetic field of given length of wire for single turn coil at its centre is B then its value for two turns coil for the same wire is

(1) $\frac{B}{4}$ (2) $\frac{B}{2}$ (3) $4B$ (4) $2B$

Sol. Answer (3)

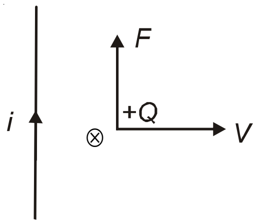
$$B = N\frac{\mu_0 i}{2R} \qquad B' = 2N\frac{\mu_0 i}{2\left(R/2\right)} = 4N\frac{\mu_0 i}{2R} = 4B$$

18. A very long straight wire carries a current I. At the instant when a charge $+Q$ at point P has velocity $\vec{v}$, as shown, the force on the charge is



(1) Along Oy (2) Opposite to Oy (3) Along Ox (4) Opposite to Ox

Sol. Answer (1)



$$\vec{F} = q(\vec{V} \times \vec{B})$$

using right hand thumb, $\vec{F}$ will be in the direction OY.

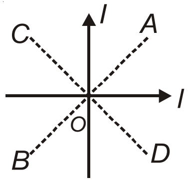
19. The magnetic field $\overrightarrow{dB}$ due to a small current element $\vec{dl}$ at a distance $\vec{r}$ and element carrying current i is

(1) $\overrightarrow{dB} = \frac{\mu_0}{4\pi} i^2 \left(\frac{\vec{dl} \times \vec{r}}{r}\right)$ (2) $\overrightarrow{dB} = \frac{\mu_0}{4\pi} i \left(\frac{\vec{dl} \times \vec{r}}{r^3}\right)$ (3) $\overrightarrow{dB} = \frac{\mu_0}{4\pi} i \left(\frac{\vec{dl} \times \vec{r}}{r}\right)$ (4) $\overrightarrow{dB} = \frac{\mu_0}{4\pi} i^2 \left(\frac{\vec{dl} \times \vec{r}}{r^2}\right)$

Sol. Answer (2)

$$\overrightarrow{dB} = \frac{\mu_0 i}{4\pi}\left(\frac{\vec{dl} \times \vec{r}}{r^3}\right)$$

20. Two equal electric currents are flowing perpendicular to each other as shown in the figure. Lines *AB* and *CD* are perpendicular to each other and symmetrically placed with respect to the currents. Where do we expect the resultant magnetic field to be zero?



(1) On *CD* (2) On *AB*

(3) On both *OD* and *BO* (4) On both *AB* and *CD*

Sol. Answer (2)

On line *AB*, as in this region magnetic field will be in opposite direction due to both the wires.

21. To convert a galvanometer into a voltmeter one should connect a

(1) High resistance in series with galvanometer (2) Low resistance in series with galvanometer

(3) High resistance in parallel with galvanometer (4) Low resistance in parallel with galvanometer

Sol. Answer (1)

22. A galvanometer having a coil resistance of 60 Ω shows full scale deflection when a current of 1.0 A passes through it. It can be converted into an ammeter to read currents upto 5.0 A by

(1) Putting in parallel a resistance of 15 Ω (2) Putting in parallel a resistance of 240 Ω

(3) Putting in series a resistance of 15 Ω (4) Putting in series a resistance of 240 Ω

Sol. Answer (1)

$$Rs = \frac{Rg}{\dfrac{i}{i_g} - 1} = \frac{60}{\dfrac{5}{1} - 1} = 15\ \Omega$$

23. A straight wire of a diameter 0.5 mm carrying a current of 1 A is replaced by another wire of 1 mm diameter carrying the same current. The strength of the magnetic field far away is

(1) One-quarter of the earlier value (2) No change

(3) Twice the earlier value (4) One-half of the earlier value

Sol. Answer (2)

For wire 1 $d = 0.5$ mm, $r = 0.25$ mm, $I = 1$A

For wire 2 $d = 1$ mm, $r = 0.5$ mm, $I = 1$A

$$B = \frac{\mu_0 i}{2\pi x} \qquad \text{as } x \to \infty \Rightarrow B = 0 \text{ (for both the cases)}$$

24. A closely wound solenoid of 2000 turns and area of cross-section 1.5 × 10^{-4} m^2 carries a current of 2.0 A. It is suspended through its centre and perpendicular to its length, allowing it to turn in a horizontal plane in a uniform magnetic field 5 × 10^{-2} tesla making an angle of 30º with the axis of the solenoid. The torque on the solenoid will be

(1) 3 × 10^{-3} N.m (2) 1.5 × 10^{-3} N.m (3) 1.5 × 10^{-2} N.m (4) 3 × 10^{-2} N.m

Sol. Answer (3)

N = 2000 $\theta = 30°$

$A = 1.5 \times 10^{-4}\ \text{m}^2$ $B = 5 \times 10^{-2}\ \text{T}$

I = 2A

$$\tau = \vec{M} \times \vec{B}$$

$$\tau = NIAB \sin 30° = 1.5 \times 10^{-2}\ \text{Nm}$$

25. When a proton is released from rest in a room, it starts with an initial acceleration a_0 towards west. When it is projected towards north with a speed v_0 it moves with an initial acceleration $3a_0$ towards west. The electric and magnetic fields in the room are respectively

(1) $\frac{ma_0}{e}$ west, $\frac{2ma_0}{ev_0}$ down

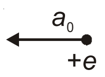
(2) $\frac{ma_0}{e}$ east, $\frac{3ma_0}{ev_0}$ up

(3) $\frac{ma_0}{e}$ east, $\frac{3ma_0}{ev_0}$ down

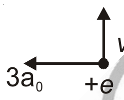
(4) $\frac{ma_0}{e}$ west, $\frac{2ma_0}{ev_0}$ up

Sol. Answer (1)

Case-I



Case-II



Now, $\vec{a_0} = \frac{e\vec{E}}{m}$ west

$\vec{E} = \frac{m\vec{a_0}}{e}$ west

Now, $F_B = m(2a_0) = ev_0 B$

$B = \frac{2ma_0}{ev_0}$ $\otimes$

26. In an ammeter 0.2% of main current passes through the galvanometer. If resistance of galvanometer is G, the resistance of ammeter will be

(1) $\frac{1}{499}G$ (2) $\frac{499}{500}G$ (3) $\frac{1}{500}G$ (4) $\frac{500}{499}G$

Sol. Answer (3)

0.2 G = 100 R_A $\therefore$ $R_A = \frac{G}{500}$

27. Two identical long conducting wires *AOB* and *COD* are placed at right angle to each other, with one above other such that *O* is their common point for the two. The wires carry I_1 and I_2 currents, respectively. Point *P* is lying at distance *d* from *O* along a direction perpendicular to the plane containing the wires. The magnetic field at the point *P* will be

(1) $\frac{\mu_0}{2\pi d}\left(\frac{I_1}{I_2}\right)$ (2) $\frac{\mu_0}{2\pi d}(I_1 + I_2)$ (3) $\frac{\mu_0}{2\pi d}(i_1^2 - I_2^2)$ (4) $\frac{\mu_0}{2\pi d}\left(I_1^2 + I_2^2\right)^{1/2}$

Sol. Answer (4)

Since the wires are perpendicular, their magnetic fields also are perpendicular. So the resultant field will be pythagoras of both the fields.

SECTION - D

Assertion-Reason Type Questions

1. A : Magnetic field lines are always perpendicular to the current producing it.

R : Magnetic field due to a straight wire varies in inverse square proportion with distance.

Sol. Answer (3)

2. A : Stationary charges do not experience a magnetic force.

R : Magnetic force is a central force.

Sol. Answer (3)

3. A : Net magnetic force experienced by a current carrying loop in a uniform magnetic field is always zero.

R : A current loop placed in a uniform magnetic field never experiences a torque.

Sol. Answer (3)

4. A : The trajectory of a charge when it is projected perpendicular to an electric field is a parabola.

R : A moving charge entering parallel to the magnetic field lines moves in a circular path.

Sol. Answer (3)

5. A : Like currents repel and unlike currents attract each other (in conductor).

R : Magnetic force acts in the direction of current.

Sol. Answer (4)

6. A : A magnetic dipole experiences maximum torque when it is placed normal to the magnetic field.

R : The minimum potential energy of magnetic dipole is zero.

Sol. Answer (4)

7. A : The relation between magnetic moment and angular momentum is true for every finite size body.

R : Ratio of magnetic dipole moment and angular momentum is just dependent on specific charge of the body.

Sol. Answer (1)

8. A : When currents vary with time, Newton's third law is valid only if momentum carried by the electromagnetic field is taken into account.

R : Magnetic field lines always form closed loops.

Sol. Answer (2)

9. A : In the expression for Lorentz force, $\vec{F} = q(\vec{v} \times \vec{B} + \vec{E})$, if one switches to a frame with instantaneous velocity $\vec{v}$.

R : There exists an appropriate electric field in the new frame.

Sol. Answer (1)

10. A : Ampere's circuital law' is not independent of the Biot-Savart's law.

R : Ampere's Circuital law can be derived from the Biot-Savart law.

Sol. Answer (1)

11. A : The work done by magnetic field on a moving charge is zero.

R : The magnetic force acting on a moving charge has no component in the direction of velocity.

Sol. Answer (1)

12. A : In any magnetic field region the line integral $\oint \vec{B}.\vec{dl}$ along a closed loop is always zero.

R : The magnetic field $\vec{B}$ in the expression $\oint \vec{B}.\vec{dl}$ is due to the currents enclosed only by the loop.

Sol. Answer (4)

13. A : The magnetic field always accelerates a moving charge if the moving charge cuts the field lines.

R : When a moving charge cuts the magnetic field lines, the magnetic force on the charge is always non zero.

Sol. Answer (1)

14. A : The magnetic moment of a current carrying planar loop does not depend on the shape of the loop.

R : The magnetic moment is a vector quantity.

Sol. Answer (2)

15. A : Magnetic field is produced by moving charge(s).

R : The magnetic field in the central region of a solenoid is uniform.

Sol. Answer (2)

16. A : In the middle to high latitudes on a dark night an aurora or the curtain of light hangs down from the sky. This curtain is local, several hundred kilometer high, several thousand kilometer long but less than 1 km thick.

R : Electrons and protons trapped in the helical terrestrial magnetic field collide with atoms and molecules of air, causing that air to emit light.

Sol. Answer (1)

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Chapter 5

Magnetism and Matter

Solutions

SECTION - A

Objective Type Questions

1. Suppose an isolated north pole is kept at the centre of a circular loop carrying a electric current *i*. The magnetic field due to the north pole at a point on the periphery of the wire is *B*. The radius of the loop is *a*. The force on the wire is

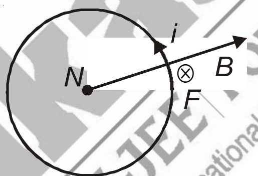
   (1) Nearly $2\pi aiB$ perpendicular to the plane of the wire

   (2) $2\pi ai$B in the plane of the wire

   (3) πaiB along the axis of the wire

   (4) Zero

Sol. Answer (1)



$dF = IdlB$

$F_{\text{total}} = i(2\pi a)B$

Perpendicular to the plane of the paper.

2. If *L* be the length of a bar magnet then separation between the two poles is nearly

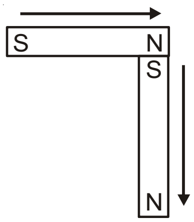
   (1) $\frac{9}{10}L$ (2) $\frac{6}{7}L$ (3) $\frac{1}{3}L$ (4) $\frac{1}{2}L$

Sol. Answer (2)

3. Two identical thin bar magnets each of length *l* and pole strength *m* are placed at right angle to each other with north pole of one touching the south pole of the other. Magnetic moment of the system is

   (1) $2\,ml$ (2) ml (3) $\sqrt{2}\,ml$ (4) $\frac{ml}{2}$

Sol. Answer (3)



$\mu = ml\sqrt{2}$

4. A solenoid of length 10 cm and radius 1 cm contains 200 turns and carries a current of 10 A. The value of pole strength of each pole is

(1) 2 Am (2) 2π Am (3) 4π Am (4) 10π Am

Sol. Answer (2)

NIA = mL $\therefore$ m = NIA/L = $200 \times \pi(10^{-2})^2 \times 10/0.1 = 2\pi$

5. A long magnetic needle of length $2L$, magnetic moment M and pole strength m units is broken into two at the mid point. The magnetic moment and pole strength of each piece will be

(1) $M/2$, $m/2$ (2) M, $m/2$ (3) $M/2$, m (4) M, m

Sol. Answer (3)

$M = m(2l)$

Pole strength does not change, on breaking the magnet but magnetic moment will become half.

6. A bar magnet of magnetic moment M is cut into two equal parts along its length. The magnetic moment of either part is

(1) $2M$ (2) M (3) $M/2$ (4) Zero

Sol. Answer (3)

$M = ml$

$$M' = \frac{m}{2}l$$

$M' = M/2$

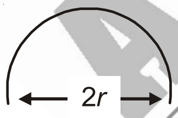
7. A steel wire of length l has a magnetic moment M. It is then bent into a semi-circular arc. The new magnetic moment is

(1) M (2) $\frac{2M}{\pi}$ (3) $\frac{M}{\pi}$ (4) $2M\pi$

Sol. Answer (2)

$l = \pi r$

$$r = \frac{l}{\pi}$$



$M = ml$

$M' = m2r$

$$M' = m\frac{2l}{\pi} \Rightarrow M' = \frac{2M}{\pi}$$

8. Points A and B are situated perpendicular to the axis of a small bar magnet at large distances x and $3x$ from its centre on opposite sides. The ratio of the magnetic fields at A and B will be approximately equal to

(1) 2 : 9 (2) 1 : 9 (3) 27 : 1 (4) 9 : 1

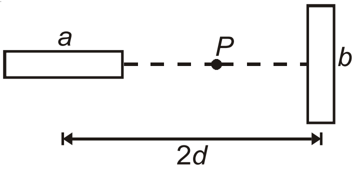
Sol. Answer (3)

$$B_A = \frac{\mu_0}{4\pi}\frac{2M}{x^3}$$

$$B_B = \frac{\mu_0}{4\pi}\frac{2M}{(3x)^3}$$

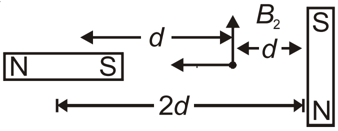
$$\frac{B_A}{B_B} = \frac{1}{27}$$

9. Figure shows two small identical magnetic dipoles *a* and *b* of magnetic moments *M* each, placed at a separation 2*d*, with their axes perpendicular to each other. The magnetic field at the point *P* mid way between the dipoles is



(1) $\frac{2\mu_0 M}{4\pi d^3}$ (2) $\frac{\mu_0 M}{4\pi d^3}$ (3) Zero (4) $\frac{\sqrt{5}\mu_0 M}{4\pi d^3}$

Sol. Answer (4)

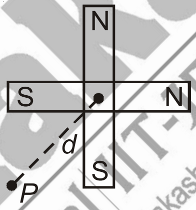


$$B_1 = \frac{\mu_0}{4\pi}\frac{2M}{d^3}$$

$$B_2 = \frac{\mu_0}{4\pi}\frac{M}{d^3}$$

$$B_{\text{net}} = \sqrt{B_1^2 + B_2^2} = \frac{\mu_0}{4\pi}\frac{M}{d^3}\sqrt{5}$$

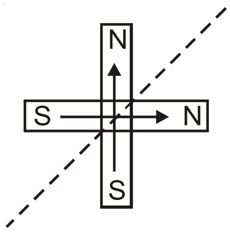
10. Two short magnets of equal dipole moments *M* are fastened perpendicularly at their centres as shown below (point *P* is in the plane of the magnets)



The magnetic field (magnitude) at *P*, distance *d* from the centre on the bisector of the right angle is

(1) $\frac{\mu_0}{4\pi}\frac{M}{d^3}$ (2) $\frac{\mu_0}{4\pi}\frac{M\sqrt{2}}{d^3}$ (3) $\frac{\mu_0}{4\pi}\frac{2M}{d^3}$ (4) $\frac{\mu_0}{4\pi}\frac{2\sqrt{2}M}{d^3}$

Sol. Answer (4)



M can be broken of both the magnets in terms of their components, one in direction of bisector and other perpendicular to it

Parallel components will be added whereas perpendicular components will be cancel out

So $\vec{B}_{\text{net}} = \frac{2\mu_0}{4\pi}\left(\frac{2M}{d^3}\right)\cos 45^\circ = \frac{\mu_0}{4\pi}\frac{2\sqrt{2}M}{d^3}$

11. Two small bar magnets are placed in a line at certain distance d apart. If the length of each magnet is negligible compared to d, the force between them will be inversely proportional to

(1) d^2 (2) d (3) d^3 (4) d^4

Sol. Answer (4)

$$F \propto \frac{\mu_0}{4\pi}\frac{M_1M_2}{d^4}$$

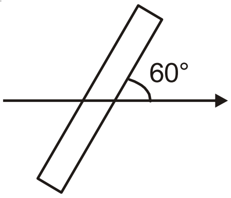
so $F \propto \dfrac{1}{d^4}$

12. A magnetic needle lying parallel to a magnetic field requires W units of work to turn it through 60°. The torque needed to maintain the needle in this position will be

(1) W (2) $\sqrt{3}W$ (3) $\dfrac{\sqrt{3}W}{2}$ (4) $2W$

Sol. Answer (2)

$$U_i = -MB\cos 0° = -MB$$



$$U_f = -MB\cos 60°$$

$$= \frac{-MB}{2}$$

$$W = U_f - U_i \;= -\frac{MB}{2} + MB = \frac{MB}{2} \;\Rightarrow\; MB = 2W$$

$$\tau = MB\sin 60°$$

$$\tau = 2W\frac{\sqrt{3}}{2} = W\sqrt{3}$$

13. Potential energy of a bar magnet of magnetic moment M placed in a magnetic field of induction B such that it makes an angle θ with the direction of B is (take $\theta = 90°$ as datum)

(1) $-MB\sin\theta$ (2) $-MB\cos\theta$ (3) $MB(1-\cos\theta)$ (4) $MB(1+\cos\theta)$

Sol. Answer (2)

$U = -MB\cos\theta$

14. A magnetic dipole is placed at right angles to the direction of lines of force of magnetic induction B. If it is rotated through an angle of 180°, then the work done is

(1) $2MB$ (2) MB (3) $-2MB$ (4) Zero

Sol. Answer (4)

$U_i = -MB\cos 90°$

$U_f = -MB\cos 90°$

$W = 0 - 0 = 0$

15. Which of the following statements regarding magnetic lines of force is correct?

(1) Total magnetic flux linked with a closed surface is always zero

(2) They need not be perpendicular to the surface from where they start or where they meet

(3) They may or may not pass through a conductor

(4) All of these

Sol. Answer (4)

16. A magnetic needle of negligible breadth and thickness compared to its length, oscillates in a horizontal plane with a period *T*. The period of oscillation of each part obtained on breaking the magnet into *n* equal parts perpendicular to the length is

(1) T/n (2) T (3) $T\,n$ (4) $1/T\,n$

Sol. Answer (1)

$$T = 2\pi\sqrt{\frac{I}{MB}}$$

$$T' = 2\pi\sqrt{\frac{I}{n^3\frac{M}{n}B}} = \frac{2\pi}{n}\sqrt{\frac{I}{MB}}$$

$$T' = \frac{T}{n}$$

17. The time period of a freely suspended magnet is 4 s. If it is broken in length into two equal parts and one part is suspended in the same way, then its time period will be

(1) 2 s (2) 4 s (3) 0.5 s (4) 0.25 s

Sol. Answer (1)

$$T' = \frac{T}{2} = 2\text{ s}$$

18. The magnetic moments of two bar magnets of same size are in the ratio 1 : 2. When they are placed one over the other with their similar poles together, then their period of oscillation in a magnetic field is 3s. If one of the magnets is reversed, then the period of oscillation in the same field will be

(1) $\sqrt{3}$s (2) $3\sqrt{3}$s (3) 3 s (4) 6 s

Sol. Answer (2)

$$T \propto \frac{1}{\sqrt{M}}$$

$$\frac{3}{T} = \sqrt{\frac{M_1 - M_2}{M_1 + M_2}} \Rightarrow \frac{3}{T} = \sqrt{\frac{2-1}{2+1}} \Rightarrow T = 3\sqrt{3}$$

19. Magnetostatic screening or shielding can be created by

(1) Super conductor (2) Soft iron ring (3) Both (1) & (2) (4) Neither (1) nor (2)

Sol. Answer (3)

20. Planets producing larger magnetic field have larger

(1) Rotational speed (2) Density (3) Mass (4) Size

Sol. Answer (1)

21. To shield an instrument from external magnetic field, it is placed inside a cabin made of

(1) Wood (2) Plastic

(3) Diamagnetic substances (4) Iron

Sol. Answer (4)

22. A dip circle lies initially in the magnetic meridian, it shows an angle of dip δ at a place. The dip circle is rotated through an angle α in the horizontal plane and then it shows an angle of dip δ'. Hence $\frac{\tan\delta'}{\tan\delta}$ is

(1) $\cos\alpha$ (2) $1/\sin\alpha$ (3) $1/\tan\alpha$ (4) $1/\cos\alpha$

Sol. Answer (4)

$$\tan\delta' = \frac{\tan\delta}{\cos\alpha}$$

$$\frac{\tan\delta'}{\tan\delta} = \frac{1}{\cos\alpha}.$$

23. If a dip circle is placed in a vertical plane at an angle of 30° to the magnetic meridian, the dip needle makes an angle of 45° with the horizontal. The real dip at that place is

(1) $\tan^{-1}(\sqrt{3}/2)$ (2) $\tan^{-1}(\sqrt{3})$ (3) $\tan^{-1}(\sqrt{3}/\sqrt{2})$ (4) $\tan^{-1}(2/\sqrt{3})$

Sol. Answer (1)

$$\tan 45^\circ = \frac{\tan\delta}{\cos 30^\circ}$$

$$1 = \frac{2\tan\delta}{\sqrt{3}}$$

$$\tan\delta = \frac{\sqrt{3}}{2} \Rightarrow \delta = \tan^{-1}\left(\frac{\sqrt{3}}{2}\right)$$

24. A dip needle free to move in a vertical plane perpendicular to the magnetic meridian will remain

(1) Horizontal (2) Vertical

(3) At an angle of 60° to the vertical (4) At an angle of 45° to the horizontal

Sol. Answer (2)

$$\tan\delta_A = \frac{\tan\delta}{\cos 90^\circ}$$

$$\Rightarrow \tan\delta_A = \infty$$

$$\Rightarrow \delta_A = 90^\circ$$

25. If ϕ_1 and ϕ_2 are the angles of dip in two vertical planes at right angles to each other and ϕ is the true angle of dip then

(1) $\cot^2\phi = \cot^2\phi_1 + \cot^2\phi_2$ (2) $\tan^2\phi = \tan^2\phi_1 + \tan^2\phi_2$

(3) $\cot\phi = \cot\phi_1 + \cot\phi_2$ (4) $\tan\phi = \tan\phi_1 + \tan\phi_2$

Sol. Answer (1)

26. How many neutral points will be obtained when a bar magnet is kept with magnetic moment parallel to earth's magnetic field?

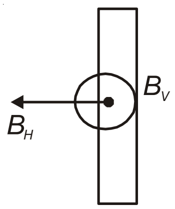
(1) One (2) Two (3) Four (4) Infinite

Sol. Answer (4)

27. Time period of oscillations of a magnet of magnetic moment M and moment of inertia I in a vertical plane perpendicular to the magnetic meridian at a place where earth's horizontal and vertical component of magnetic field are B_H and B_V respectively is

(1) $T=2\pi\sqrt{\dfrac{I}{M(B_V^2+B_H^2)^{1/2}}}$ (2) $T=2\pi\sqrt{\dfrac{I}{MB_V}}$ (3) $T=2\pi\sqrt{\dfrac{I}{MB_H}}$ (4) Infinite

Sol. Answer (2)



$$T = 2\pi\sqrt{\frac{I}{MBv}}$$

28. A magnet is suspended in such a way that it oscillates in the horizontal plane. It makes 20 oscillations per minute at a place where dip angle is 30° and 15 oscillations per minute at a place where dip angle is 60°. Ratio of the total earth's magnetic field at the two places is

(1) $3\sqrt{3}:8$ (2) $16:9\sqrt{3}$ (3) 4 : 9 (4) $2\sqrt{3}:9$

Sol. Answer (2)

$$\frac{1}{20} = 2\pi\sqrt{\frac{I}{MB_1\cos 30^\circ}}$$

$$\frac{1}{15} = 2\pi\sqrt{\frac{I}{MB_2\cos 60^\circ}}$$

$$\left(\frac{3}{4}\right)^2 = \frac{B_2}{B_1\sqrt{3}} \Rightarrow \frac{B_1}{B_2} = \frac{16}{9\sqrt{3}}$$

29. Instruments based on tangent law are most accurate when the deflection is

(1) 30° (2) 45° (3) 60° (4) Any angle

Sol. Answer (2)

30. The magnetic induction and magnetising field intensity in a sample of magnetic material are B and H respectively. The magnetic susceptibility of the material is

(1) $\dfrac{B}{\mu_0 H}$ (2) $\dfrac{B}{\mu_0 H}-1$ (3) $\dfrac{B}{H}-1$ (4) $\dfrac{\mu_0 H}{B}-1$

Sol. Answer (2)

$$B = \mu_0(I+H)$$

$$B = \mu_0\left(x_m H + H\right)$$

$$X_m = \frac{B}{\mu_0 H} - 1$$

31. A frog is levitated in a magnetic field produced by current in a vertical solenoid below the frog is

(1) Diamagnetic (2) Paramagnetic (3) Ferromagnetic (4) Ferrimagnetic

Sol. Answer (1)

32. When a ferromagnetic substance is heated to a temperature above its Curie temperature, it

(1) Behaves like a paramagnetic substance
(2) Behaves like a diamagnetic substance
(3) Remains ferromagnetic
(4) Is permanently magnetised

Sol. Answer (1)

33. Select the incorrect statement

(1) In a diamagnetic substance net magnetic moment of each atom/molecule is zero
(2) In a paramagnetic substance net magnetic moment of each atom/molecule is non-zero
(3) In a ferromagnetic material net magnetic moment of each domain is zero
(4) In a ferromagnetic material net magnetic moment of each domain is non-zero

Sol. Answer (3)

34. Soft iron is used to manufacture electromagnets because their

(1) Magnetic permeability is high and retentivity and coercive force are small
(2) Retentivity is high
(3) Coercive force is high
(4) Area of the hysteresis curve is large

Sol. Answer (1)

35. Relative permeability of superconductors is

(1) 0
(2) 1
(3) –1
(4) 0.5

Sol. Answer (1)

SECTION - B

Objective Type Questions

1. At a certain place, vertical component of earth's magnetic field is $\sqrt{3}$ times the horizontal component of earth's magnetic field. If a magnetic needle is suspended freely in air then it will incline

(1) 30° below horizontal
(2) 60° below horizontal
(3) 30° above horizontal
(4) 45° above horizontal

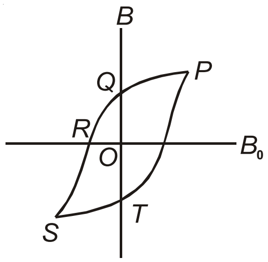
Sol. Answer (2)

$$B_V = \sqrt{3}B_H$$

$$\frac{B_V}{B_H} = \sqrt{3} = \tan\theta$$

$$\theta = 60^\circ$$

2. The figure illustrates how B, the flux density, inside a sample of ferromagnetic material varies with external magnetic field B_0. For the sample to be suitable for making a permanent magnet



(1) OQ should be large, OR should be small
(2) OQ and OR both should be large
(3) OQ should be small and OR should be large
(4) OQ and OR both should be small

Sol. Answer (2)

3. The work done in turning a magnet of magnetic moment M by an angle of 90° from the magnetic meridian is n times the corresponding work done to turn it through an angle of 60°. The value of n is

(1) 2 (2) 1 (3) $\frac{1}{3}$ (4) $\frac{1}{4}$

Sol. Answer (1)

$$U_1 = -MB\cos 0°$$

$$U_2 = -MB\cos 90°$$

$$U_3 = -MB\cos 60°$$

$$U_2 - U_1 = MB$$

$$U_3 - U_1 = \frac{MB}{2} \Rightarrow n = 2$$

4. Soft iron is used in many parts of electrical machines for

(1) Low hysteresis loss and low permeability (2) Low hysteresis loss and high permeability

(3) High hysteresis loss and low permeability (4) High hysteresis loss and high permeability

Sol. Answer (2)

5. A magnetic needle oscillates in a horizontal plane with a period T at a place where the angle of dip is 60°. When the same needle is made to oscillate in a vertical plane coinciding with the magnetic meridian, its period will be

(1) $\frac{T}{\sqrt{2}}$ (2) T (3) $\sqrt{2}T$ (4) $2T$

Sol. Answer (1)

$$T = 2\pi\sqrt{\frac{I}{MB\cos 60°}} \Rightarrow \frac{T'}{T} = \sqrt{\cos 60°}$$

$$T' = 2\pi\sqrt{\frac{I}{MB}} \Rightarrow \frac{T'}{T} = \frac{1}{\sqrt{2}} \Rightarrow \text{T}' = \frac{T}{\sqrt{2}}$$

6. Two different magnets are tied together and allowed to vibrate in a horizontal plane. When their like poles are joined, time period of oscillation is 5 s and with unlike poles joined, time period of oscillation is 15 s. The ratio of their magnetic moments is

(1) 5 : 4 (2) 1 : 3 (3) 3 : 1 (4) 2 : 5

Sol. Answer (1)

$$5 = 2\pi\sqrt{\frac{I}{M_1 + M_2}}$$

$$15 = 2\pi\sqrt{\frac{I}{M_1 - M_2}} \Rightarrow \frac{1}{3} = \sqrt{\frac{M_1 - M_2}{M_1 + M_2}}$$

$$\frac{M_1 - M_2}{M_1 + M_2} = \frac{1}{9}$$

$$\frac{M_1}{M_2} = \frac{10}{8} = \frac{5}{4}$$

7. The values of the apparent angles of dip in two planes at right angles to each other are 45° and 30° respectively. The true value of angle of dip at the place is

(1) $\cot^{-1}(1)$ (2) $\cot^{-1}(2)$ (3) $\cot^{-1}(3)$ (4) $\cot^{-1}(4)$

Sol. Answer (2)

$$\cot^2\phi = \cot^2 45° + \cot^2 30°$$

$$\cot^2\phi = 1 + 3$$

$$\cot\phi = 2 \qquad \Rightarrow \phi = \cot^{-1}(2)$$

8. A magnet is placed horizontally on ground with its north pole towards the geographic north pole of the earth. The neutral point is obtained

(1) Along the axis of the magnet

(2) On the east-west line through the centre of the magnet

(3) In only east side of the magnet

(4) In only west side of the magnet

Sol. Answer (2)

9. The value of horizontal component of earth's magnetic field at a place is 0.35×10^{-4} T. If the angle of dip is 60°, the value of vertical component of earth's magnetic field is nearly

(1) 0.1×10^{-4} T (2) 0.2×10^{-4} T (3) 0.4×10^{-4} T (4) 0.61×10^{-4} T

Sol. Answer (4)

$$B_V = B_H \tan\delta$$

$$B_H = (0.35 \times 10^{-4})\sqrt{3}$$

$$B_H = 0.61 \times 10^{-4}$$

10. The period of oscillation of a magnet of a vibration magnetometer is 2.45 s at one place and 4.9 s at the other. The ratio of the horizontal component of earth magnetic field at the two places is

(1) 1 : 4 (2) 1 : 2 (3) 2 : 1 (4) 4 : 1

Sol. Answer (4)

$$2.45 = 2\pi\sqrt{\frac{I}{MB_{H_1}}}$$

$$4.9 = 2\pi\sqrt{\frac{I}{MB_{H_2}}}$$

Dividing both the equations

$$\frac{2.45}{4.9} = \sqrt{\frac{B_{H_2}}{B_{H_1}}} \Rightarrow \frac{B_{H_1}}{B_{H_2}} = 4:1$$

11. If ϕ is latitude and δ is dip at a place then

(1) $\tan\phi = \frac{\tan\delta}{2}$ (2) $\tan\delta = \frac{\tan\phi}{2}$ (3) $\tan\delta = \frac{1}{\tan\phi}$ (4) $\tan^2\phi + \tan^2\delta = 1$

Sol. Answer (1)

12. A tangent galvanometer has 80 turns of wire. The internal and external diameters of the coil are 19 cm and 21 cm respectively. The reduction factor of the galvanometer at a place where $H = 0.32$ oersted will be (1 oersted = 80 A/m)

(1) 0.0064 (2) 0.64 (3) 0.064 (4) None of these

Sol. Answer (3)

$$\text{Reduction factor} = \frac{2RB_h}{\mu_0 N} = \frac{2\times 0.1\times 0.32\times 80}{80} = 0.064$$

13. Magnetic susceptibility for a diamagnetic substance is

(1) Large and positive (2) Large and negative (3) Small and positive (4) Small and negative

Sol. Answer (4)

14. Area of B-H curve measures the energy loss

(1) By the specimen (2) Per unit volume of the specimen

(3) Per unit volume per cycle of the specimen (4) Per cycle of the specimen

Sol. Answer (3)

15. A wire of length l m carrying a current I ampere, is bent in the form of a circle. The magnetic moment is

(1) $\frac{4\pi I}{l^2}$ (2) $\frac{2Il^2}{\pi}$ (3) $\frac{Il^2}{\pi}$ (4) $\frac{Il^2}{4\pi}$

Sol. Answer (4)

$$l = 2\pi r$$

$$r = \frac{l}{2\pi}$$

$$M = I\pi\left(\frac{l}{2\pi}\right)^2 \Rightarrow M = \frac{Il^2}{4\pi}$$

16. Bohr magneton is given by (symbols have their usual meanings)

(1) $\frac{4\pi m_e}{eh^2}$ (2) $\frac{4\pi m_e}{eh}$ (3) $\frac{eh^2}{4\pi m_e}$ (4) $\frac{eh}{4\pi m_e}$

Sol. Answer (4)

$$B_m = \frac{eh}{4\pi m}$$

17. The unit of magnetic susceptibility is

(1) weber (2) weber per metre (3) henry (4) Dimensionless

Sol. Answer (4)

18. One weber is equal to

(1) 10^2 maxwell (2) 10^4 maxwell (3) 10^6 maxwell (4) 10^8 maxwell

Sol. Answer (4)

19. If the number of turns and radius of cross section of the coil of a tangent galvanometer are doubled, then the reduction factor K will become

(1) K (2) $2K$ (3) $4K$ (4) $\frac{K}{4}$

Sol. Answer (1)

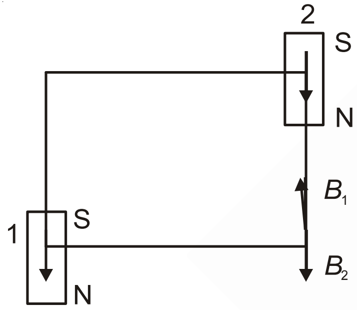
$$K = \frac{2RB_H}{\mu_0 N}$$

$$\therefore \quad K \propto = \frac{R}{N} \text{ and } K' \propto = \frac{2R}{2N} = K$$

20. Two short bar magnets of magnetic moments 'M' each are arranged at the opposite corners of a square of side 'd', such that their centres coincide with the corners and their axes are parallel to one side of the square. If the like poles are in the same direction, the magnetic induction at any of the other corners of the square is

(1) $\frac{\mu_0}{4\pi}\frac{M}{d^3}$ (2) $\frac{\mu_0}{4\pi}\frac{2M}{d^3}$ (3) $\frac{\mu_0}{2\pi}\frac{M}{d^3}$ (4) $\frac{\mu_0}{2\pi}\frac{2M}{d^3}$

Sol. Answer (1)

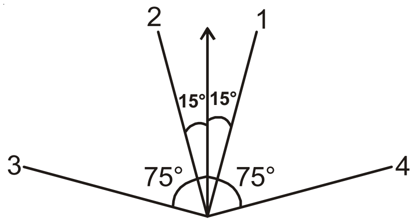


$$B_{net} = B_2 - B_1$$

$$= \frac{\mu_0}{4\pi}\left(\frac{2M}{d^3}\right) - \frac{\mu_0}{4\pi}\left(\frac{M}{d^3}\right)$$

$$= \frac{\mu_0}{4\pi}\frac{M}{d^3}$$

21. If declination at a place is known to be 15° E. And a compass needle points as shown, then geographic north is represented by the direction numbered.

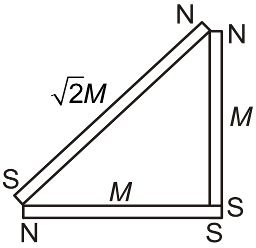


(1) 1 (2) 2 (3) 3 (4) 4

Sol. Answer (2)

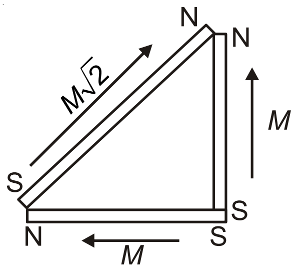
Geographic north will be 15° west of the direction in which the magnetic needle is pointing.

22. The magnetic moment of the arrangement shown in the figure is



(1) Zero (2) $2\sqrt{2}M$ (3) $2M$ (4) M

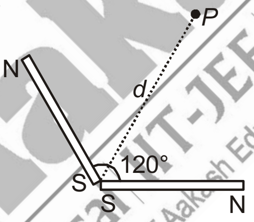
Sol. Answer (3)



Resultant of these three dipole moments will be

$$M_{\text{net}} = \sqrt{\left(M\sqrt{2}\right)^2 + \left(M\sqrt{2}\right)^2} = 2M$$

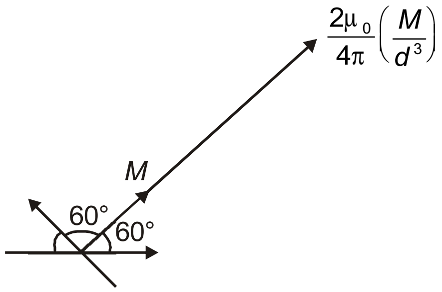
23. Two identical short bar magnets are placed at 120° as shown in the figure. The magnetic moment of each magnet is *M*. Then the magnetic field at the point *P* on the angle bisector is given by



(1) $\frac{\mu_0}{4\pi}\cdot\frac{M}{d^3}$ (2) $\frac{\mu_0}{4\pi}\cdot\frac{2M}{d^3}$ (3) $\frac{\mu_0}{4\pi}\cdot\frac{2\sqrt{2}M}{d^3}$ (4) Zero

Sol. Answer (2)

Since two equal vectors *M* are inclined at 120°, their resultant will also be *M* and along its angular bisector. So point *P* is on axial line of resultant moment *M*.



$$B_{\text{net}} = \frac{2\mu_0 M}{4\pi d^3}$$

24. The work done in rotating a bar magnet of magnetic moment M from its unstable equilibrium position to its stable equilibrium position in a uniform magnetic field B is

(1) $2MB$ (2) MB (3) $-MB$ (4) $-2MB$

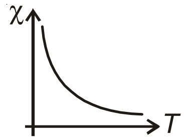
Sol. Answer (4)

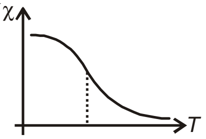
$U_i = MB$

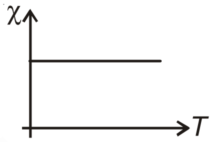
$U_f = -MB$

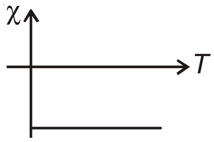
$\Delta U = -2MB$

25. The variation of magnetic susceptibility (χ) with absolute temperature (T) for a ferromagnetic material is

(1)


(2)


(3)


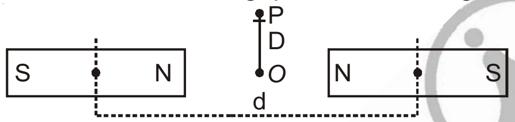
(4)


Sol. Answer (2)

SECTION - C

Previous Years Questions

1. Two identical bar magnets are fixed with their centres at a distance d apart. A stationary charge Q is placed at P in between the gap of the two magnets at a distance D from the centre O as shown in the figure



The force on the charge Q is

(1) Zero (2) Directed along OP

(3) Directed along PO (4) Directed perpendicular to the plane of paper

Sol. Answer (1)

If charge is stationary then

Using $F_m = q(\vec{v} \times \vec{B})$

as $v = 0$, $F_m = 0$

2. A magnetic needle suspended parallel to a magnetic field requires $\sqrt{3}$ J of work to turn it through 60°. The torque needed to maintain the needle in this position will be

(1) $2\sqrt{3}$ J (2) 3 J (3) $\sqrt{3}$ J (4) $\frac{3}{2}$ J

Sol. Answer (2)

$$W = \frac{MB}{2}$$

$$\sqrt{3} = \frac{MB}{2} \Rightarrow MB = 2\sqrt{3}$$

$$\tau = MB\sin 60^\circ$$

$$\tau = MB\frac{\sqrt{3}}{2}$$

$$\tau = 2\sqrt{3}\frac{\sqrt{3}}{2} = 3 \text{ J}$$

3. A bar magnet having a magnetic moment of 2×10^4 JT^{-1} is free to rotate in a horizontal plane. A horizontal magnetic field $B = 6 \times 10^{-4}$ T exists in the space. The work done in taking the magnet slowly from a direction parallel to the field to a direction 60° from the field is

(1) 2 J (2) 0.6 J (3) 12 J (4) 6 J

Sol. Answer (4)

$$W = \frac{MB}{2} = \frac{2\times10^4\times6\times10^{-4}}{2} = 6 \text{ J}$$

4. A short bar magnet of magnetic moment 0.4 JT^{-1} is placed in a uniform magnetic field of 0.16 T. The magnet is in stable equilibrium when the potential energy is

(1) – 0.082 J (2) 0.064 J (3) – 0.064 J (4) Zero

Sol. Answer (3)

$$U = -\vec{M}.\vec{B}$$

$$= -(0.4)(0.16)$$

$$= -0.064 \text{ J}$$

5. A magnet oscillates, in earth's magnetic field, with a time-period T. If its mass is quadrupled, then its new time-period will be

(1) $\frac{T}{2}$, motion remaining S.H.M. (2) Unaffected but motion is not S.H.M.

(3) $4T$, motion remaining S.H.M. (4) $2T$, motion remaining S.H.M.

Sol. Answer (4)

$$T = 2\pi\sqrt{\frac{I}{MB}} \qquad T' = 2\pi\sqrt{\frac{4I}{MB}}$$

$\frac{T}{T'} = \frac{1}{2} \Rightarrow T' = 2T$ and motion will be SHM.

6. A bar magnet of magnetic moment $\vec{M}$, is placed in a magnetic field of induction $\vec{B}$, The torque exerted on it is

(1) $\vec{M}\times\vec{B}$ (2) $-\vec{M}\cdot\vec{B}$ (3) $\vec{M}\cdot\vec{B}$ (4) $\vec{B}\times\vec{M}$

Sol. Answer (1)

$$\tau = \vec{M}\times\vec{B}$$

7. Tangent galvanometer is used to measure

(1) Potential difference (2) Current (3) Resistance (4) Charge

Sol. Answer (2)

8. The magnetic moment of a diamagnetic atom is

(1) Much greater than one (2) Equal to one

(3) Between zero and one (4) Equal to zero

Sol. Answer (4)

9. The work done in turning a magnet of magnetic moment *M* by an angle of 90° from the magnetic meridian is *n* times the corresponding work done to turn it through an angle of 60°. The value of *n* is

(1) 2 (2) 1 (3) $\frac{1}{3}$ (4) $\frac{1}{4}$

Sol. Answer (1)

$$W_{0\to 90} = nW_{0\to 60}$$

$$MB = \frac{nMB}{2}$$

$n = 2$

10. A compass needle which is allowed to move in a horizontal plane is taken to a geomagnetic pole. It

(1) Will stay in north-south direction only (2) Will stay in east-west direction only

(3) Will become rigid showing no movement (4) Will stay in any position

Sol. Answer (4)

Because here earth's magnetic field has vertical component only.

11. Due to earth's magnetic field, the charged cosmic rays particles

(1) Can never reach the pole

(2) Can never reach the equator

(3) Require greater kinetic energy to reach the equator than pole

(4) Require less kinetic energy to reach the equator than pole

Sol. Answer (2)

They will move in helical path while trapped in earth's magnetic field and will eventually move towards poles.

12. There are four light-weight-rod samples, *A*, *B*, *C*, *D* separately suspended by threads. A bar magnet is slowly brought near each sample and the following observations are noted

(i) *A* is feebly repelled

(ii) *B* is feebly attracted

(iii) *C* is strongly attracted

(iv) *D* remains unaffected

Which one of the following is true?

(1) *A* is of a non-magnetic material (2) *B* is of a paramagnetic material

(3) *C* is of a diamagnetic material (4) *D* is of a ferromagnetic material

Sol. Answer (2)

13. Curie temperature is the temperature above which

(1) Ferromagnetic material becomes diamagnetic material

(2) Ferromagnetic material becomes paramagnetic material

(3) Paramagnetic material becomes diamagnetic material

(4) Paramagnetic material becomes ferromagnetic material

Sol. Answer (2)

14. For protecting a sensitive equipment from the external magnetic field, it should be

(1) Surrounded with fine copper sheet

(2) Placed inside an iron can

(3) Wrapped with insulation around it when passing current through it

(4) Placed inside an aluminium can

Sol. Answer (2)

Because stationary magnetic field is zero inside soft ring.

15. If a diamagnetic substance is brought near north or south pole of a bar magnet, it is

(1) Repelled by north pole and attracted by the south pole

(2) Repelled by the poles

(3) Attracted by the poles

(4) Attracted by the north pole and repelled by the south pole

Sol. Answer (2)

16. Two bar magnets having same geometry with magnetic moments M and $2M$, are firstly placed in such a way that their similar poles are same side then its time period of oscillation is T_1. Now the polarity of one of the magnet is reversed then time period of oscillation is T_2, then

(1) $T_1 < T_2$ (2) $T_1 = T_2$ (3) $T_1 > T_2$ (4) $T_2 = \infty$

Sol. Answer (1)

$$T_1 = 2\pi\sqrt{\frac{I}{3MB}}$$

$$T_2 = 2\pi\sqrt{\frac{I}{MB}}$$

$$\frac{T_1}{T_2} = \frac{1}{\sqrt{3}} \Rightarrow T_2 = T_1\sqrt{3} \Rightarrow T_2 > T_1$$

17. According to Curie's law, the magnetic susceptibility of a substance at an absolute temperature T is proportional to

(1) $\frac{1}{T}$ (2) T (3) $\frac{1}{T^2}$ (4) T^2

Sol. Answer (1)

$$\chi_m \propto \frac{1}{T}$$

18. A diamagnetic material in a magnetic field moves

(1) From stronger to the weaker parts of the field (2) From weaker to the stronger parts of the field

(3) Perpendicular to the field (4) In none of the above directions

Sol. Answer (1)

19. If the magnetic dipole moment of an atom of diamagnetic material, paramagnetic material and ferromagnetic material are denoted by μ_d, μ_p. and μ_f, respectively, then

(1) $\mu_d = 0$ and $\mu_p \neq 0$ (2) $\mu_d \neq 0$ and $\mu_p = 0$

(3) $\mu_p = 0$ and $\mu_f \neq 0$ (4) $\mu_d \neq 0$ and $\mu_f \neq 0$

Sol. Answer (1)

$$\mu_d = 0,\ \mu_p \neq 0,\ \mu_f \neq 0$$

20. Nickel shows ferromagnetic property at room temperature. If the temperature is increased beyond Curie temperature, then it will show

(1) Anti ferromagnetism (2) No magnetic property (3) Diamagnetism (4) Paramagnetism

Sol. Answer (4)

21. Electromagnets are made of soft iron because soft iron has

(1) High retentivity and low coercive force (2) Low retentivity and high coercive force

(3) High retentivity and high coercive force (4) Low retentivity and low coercive force

Sol. Answer (4)

22. A current loop in a magnetic field

(1) Can be in equilibrium in one orientation

(2) Can be in equilibrium in two orientations, both the equilibrium states are unstable

(3) Can be in equilibrium in two orientations, one stable while the other is unstable

(4) Experience a torque whether the field is uniform or non-uniform in all orientations

Sol. Answer (3)

23. A coil is the shape of an equilateral triangle of side l is suspended between the pole pieces of a permanent magnet such that B is in the plane of coil. If due to a current i in the triangle a torque τ acts on it, the side l of the triangle is

(1) $\frac{2}{\sqrt{3}}\left(\frac{\tau}{Bi}\right)^{\frac{1}{2}}$ (2) $2\left(\frac{\tau}{\sqrt{3}Bi}\right)^{\frac{1}{2}}$ (3) $\frac{2}{\sqrt{3}}\left(\frac{\tau}{Bi}\right)$ (4) $\frac{1}{\sqrt{3}}\left(\frac{\tau}{Bi}\right)$

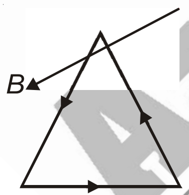
Sol. Answer (2)

$$\tau = MB$$

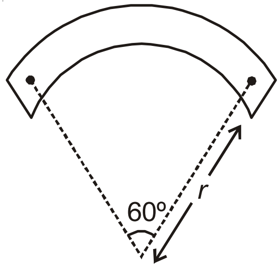
$$= iAB$$

$$= i\frac{\sqrt{3}}{4}l^2B$$

$$l = \left(\frac{4\tau}{\sqrt{3}iB}\right)^{\frac{1}{2}}$$



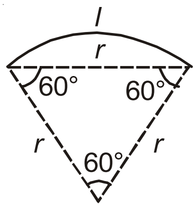
24. A bar magnet of length l and magnetic dipole moment M is bent in the form of an arc as shown in figure. The new magnetic dipole moment will be



(1) $\frac{3}{\pi}M$ (2) $\frac{2}{\pi}M$ (3) $\frac{M}{2}$ (4) M

Sol. Answer (1)

$$\frac{\pi}{3}=\frac{l}{r}$$



$$l=\frac{r\pi}{3}$$

or $r=\dfrac{3l}{\pi}$

$M = ml$

$M' = mr$

$$=M\left(\frac{3l}{\pi}\right)=\frac{3M}{\pi}$$

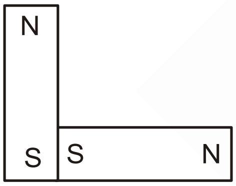
25. An iron nail near a bar magnet experiences

(1) Only torque
(2) Torque and force of attraction
(3) Only force
(4) Torque and force of repulsion

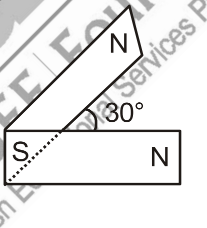
Sol. Answer (2)

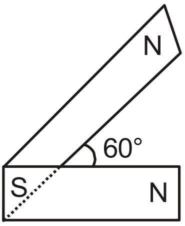
Field is non-uniform.

26. Following figures show the arrangement of bar magnets in different configurations. Each magnet has magnetic dipole moment $\vec{m}$. Which configuration has highest net magnetic dipole moment?

a.


b.


c.


d.


(1) a (2) b (3) c (4) d

Sol. Answer (3)

Resultant dipole moment = $\sqrt{M^2+M^2+2M^2\cos\theta}$

SECTION - D

Assertion-Reason Type Questions

1. A : If a bar magnet is cut into two equal halves then magnetic dipole moment of each part is half that of the original magnet.

R : Magnetic dipole moment is the product of pole strength and magnetic length.

Sol. Answer (1)

2. A : A magnetized needle in a uniform magnetic field experiences a torque but no net force, however, an iron nail near a bar magnet experiences a force of attraction as well as torque.

R : Bar magnet creates non-uniform magnetic field.

Sol. Answer (1)

3. A : Every magnetic configuration need not have a north pole and south pole.

   R : North pole, south pole exists only if the source of the field has net magnetic dipole moment.

Sol. Answer (1)

4. A : If different ends of two identical looking iron bars are brought closer and they always attract each other then one of the bars is not magnetized.

   R : Repulsion is the sure check of presence of magnetization of both the bars.

Sol. Answer (1)

5. A : The magnetic field lines also represent the lines of force on a moving charged particle at every point.

   R : Force on a moving charge acts parallel to the magnetic field.

Sol. Answer (4)

6. A : Magnetic field lines can be entirely confined within the core of a toroid.

   R : Magnetic field lines cannot be entirely confined within the core of a straight solenoid.

Sol. Answer (2)

7. A : A bar magnet does not exert a torque on itself due to its own field.

   R : One element of a current-carrying non-straight wire exert a force on another element of the same wire.

Sol. Answer (2)

8. A : A system can have magnetic moments even though its net charge is zero.

   R : Magnetic moment is created by charges in motion.

Sol. Answer (1)

9. A : The earth's magnetic field not only varies from point to point in space, it also changes with time.

   R : The earth's core is known to contain iron yet geologists do not regard this as a source of the earth's magnetism.

Sol. Answer (2)

10. A : The earth may have even reversed the direction of its field several times during its history of 4 to 5 billion years.

    R : Earth's magnetic field gets weakly 'recorded' in certain rocks during solidification.

Sol. Answer (4)

11. A : The earth's field departs from its dipole shape substantially at large distances (greater than about 30,000 km).

    R : At large distances, the field gets modified due to the field of ions in motion in the ionosphere which is sensitive to extra-terrestrial disturbances such as, the solar wind.

Sol. Answer (1)

12. A : Paramagnetic sample displays greater magnetisation (for the same magnetizing field) when cooled.

    R : The tendency to disrupt the alignment of dipoles (with the magnetising field) arising from random thermal motion is reduced at lower temperatures.

Sol. Answer (1)

13. A : Diamagnetism is almost independent of temperature.

R : The induced dipole moment in a diamagnetic sample is always opposite to the magnetising field irrespective of what the internal motion of the atom is.

Sol. Answer (1)

14. A : If a toroid uses bismuth for its core, then the field in the core will be slightly less than when the core is empty.

R : Bismuth is paramagnetic.

Sol. Answer (3)

15. A : Permeability of a ferromagnetic material is independent of the magnetising field.

R : Permeability is given by the area under a hysteresis loop.

Sol. Answer (4)

16. A : The maximum possible magnetization of a paramagnetic sample is of the same order of magnitude as the magnetization of a ferromagnet.

R : Saturation of paramagnetic substances requires impractically high magnetising fields.

Sol. Answer (1)

17. A : A system displaying a hysteresis loop such as a ferromagnet, is a device for storing memory.

R : Magnetisation of a ferromagnet is not a single valued function of the magnetising field rather it depends both on the field and also on history of magnetization.

Sol. Answer (1)

18. A : Ceramics (specially treated barium iron oxides) also called **ferrites** are used for coating magnetic tapes in a cassette player, or for building 'memory stores' in a modern computer.

R : A certain region of space surrounded by soft iron rings is approximately shielded from magnetic fields.

Sol. Answer (2)

19. A : Magnetic field lines are continuous and form closed loops.

R : Magnetic monopoles do not exist.

Sol. Answer (1)

20. A : Superconductors are perfect diamagnetic.

R : Superconductors are perfect conductors.

Sol. Answer (2)

21. A : Superconducting magnets are gainfully exploited in running magnetically levitated superfast trains.

R : Superconductors are diamagnetic substances which get repelled by strong external magnetic field.

Sol. Answer (1)

22. A : Diamagnetism is exhibited by all the substances.

R : Diamagnetism is due to paired electrons.

Sol. Answer (1)

23. A : Above curie-point a ferromagnetic substance behaves as a paramagnetic substance.

R : Magnetic susceptibility of a diamagnetic substance increases with rise in temperature.

Sol. Answer (3)

24. A : Earth's magnetism protects us from many of the harmful cosmic rays.

R : Earth's magnetism is due to a large permanent magnet inside earth.

Sol. Answer (3)

25. A : In a diamagnetic substance each atom has a non-zero dipole moment but due to thermal agitation the individual dipoles remain randomly oriented and, therefore, the net dipole moment in any finite volume of the substance remains zero.

R : On increasing the temperature the magnetism inside a permanent magnet increases.

Sol. Answer (4)

26. A : The magnetic field lines have a tendency to avoid entering the body of a frog.

R : The body of a frog is diamagnetic in nature.

Sol. Answer (1)

❑ ❑ ❑

Chapter 6

Electromagnetic Induction

Solutions

SECTION - A

Objective Type Questions

1. Dimensional formula of magnetic flux is

    (1) $[M L^2 T^{-2} A^{-1}]$ (2) $[M L^1 T^{-1} A^{-2}]$ (3) $[M L^2 T^{-3} A^{-1}]$ (4) $[M L^{-2} T^{-2} A^{-2}]$

Sol. Answer (1)

$\phi = BA$

and $F = ilB \Rightarrow B = \dfrac{F}{il}$

So dimensional formula will be $ML^2T^{-2}A^{-1}$

2. An emf can be induced in stationary coil if it is kept in

    (1) Stationary uniform magnetic field (2) Stationary nonuniform magnetic field

    (3) Time varying magnetic field (4) Not possible

Sol. Answer (3)

Time varying $\vec{B}$ will induce emf as

$$\varepsilon = -\frac{d\phi}{dt}$$

3. The induced e.m.f. in a coil does not depend on

    (1) The number of turns in the coil (2) The rate of change of magnetic flux

    (3) Time of rotation (4) The resistance of the circuit

Sol. Answer (4)

ε does not depend on resistance.

4. Flux ϕ (in weber) in a closed circuit of resistance 10 ohm varies with time t (in second) according to the equation $\phi = 6t^2 - 5t + 1$. What is the magnitude of the induced current at $t = 0.25$ s?

    (1) 1.2A (2) 0.2A (3) 0.6A (4) 0.8A

Sol. Answer (2)

$$\phi = 6t^2 - 5t + 1$$

$$\varepsilon = -\frac{d\phi}{dt} = -12t + 5$$

$$I = \frac{\varepsilon}{R} = \frac{-12\left(\frac{1}{4}\right) + 5}{10} = 0.2 \text{ A}$$

5. A cylindrical magnet is kept along the axis of a circular coil. On rotating the magnet about its axis, the coil will have induced in it

(1) No current (2) A current

(3) Only an e.m.f. (4) Both an e.m.f. and a current

Sol. Answer (1)

No change in flux, so no current will be induced.

6. A magnet is brought near a coil in two ways (i) rapidly (ii) slowly. The induced charge will be

(1) More in case (i) (2) More in case (ii)

(3) Equal in both the cases (4) More or less according to the radius of the coil

Sol. Answer (3)

Induced charged is independent of speed of magnet.

7. A circular loop of flexible conducting material is kept in a magnetic field directed perpendicularly into its plane. By holding the loop at diametrically opposite points its is suddenly stretched outwards, then

(1) No current is induced in the loop (2) Anti-clockwise current is induced

(3) Clockwise current is induced (4) Only e.m.f. is induced

Sol. Answer (3)

Flux will increase by stretching outwards so by Lenz's law clockwise current will be induced to oppose the change.

8. An aeroplane is flying horizontally with a velocity of 360 km/h. The distance between the tips of the wings of aeroplane is 25 m. The vertical component of earth's magnetic field is 4×10^{-4} Wb/m^2. The induced e.m.f. is

(1) 1 V (2) 100 V (3) 1 kV (4) Zero

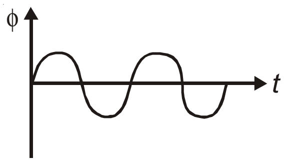
Sol. Answer (1)

$\varepsilon = Bvl$

$$= 4 \times 10^{-4} \times 360 \times \frac{5}{18} \times 25$$

= 1 V

9. The magnetic flux through a coil varies with time t as shown in the diagram. Which graph best represents the variation of the e.m.f. E induced in the coil with time t?



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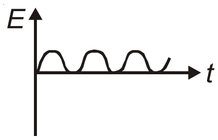

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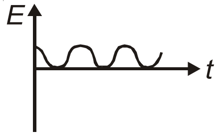

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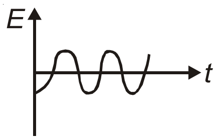

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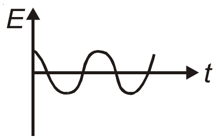
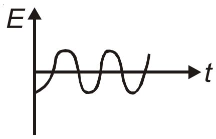


Sol. Answer (3)

$\phi = A\sin\omega t$

$$\varepsilon = -\frac{d\phi}{dt} = -A\omega\cos\omega t$$



10. A coil having 500 square loops each of side 10 cm is placed with its plane perpendicular to a magnetic field which increases at a rate of 1.0 tesla/s. The induced e.m.f. (in volts) is

(1) 0.5 (2) 0.1 (3) 1.0 (4) 5.0

Sol. Answer (4)

$$\varepsilon = NA\frac{dB}{dt}$$

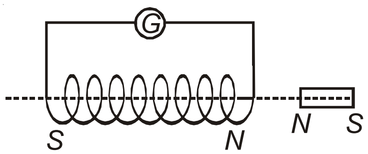
$$= (500)(0.1)^2(1) = 5 \text{ V}$$

11. The physical quantity, which is conserved on the basis of Lenz's Law is

(1) Charge (2) Momentum (3) Mass (4) Energy

Sol. Answer (4)

12. A short bar magnet passes at a steady speed right through a long solenoid. A galvanometer is connected across the solenoid. Which graph best represents the variation of the galvanometer deflection θ with time t?



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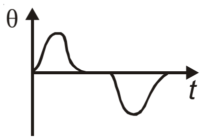

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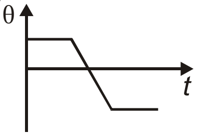

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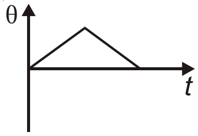

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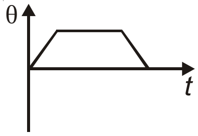


Sol. Answer (1)

Using Lenz's law

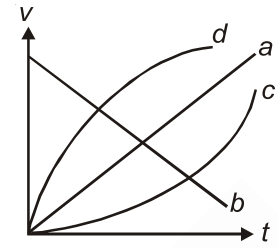
13. A metallic ring with a cut is held horizontally and a magnet is allowed to fall vertically through the ring, then the acceleration of this magnet is

(1) Equal to g (2) More than g

(3) Less than g (4) Sometimes less and sometimes more than g

Sol. Answer (1)

14. A bar magnet is made to fall through a long vertical copper tube. The speed (v) of the magnet as a function of time (t) is best represented by



(1) a (2) b (3) c (4) d

Sol. Answer (4)

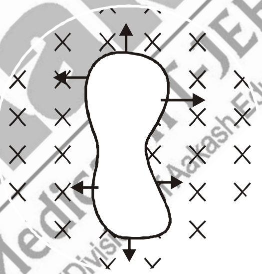
15. A loop of irregular shape made of flexible conducting wire carrying clockwise current is placed in uniform inward magnetic field, such that its plane is perpendicular to the field. Then the loop

(1) Experiences force (2) Develops induced current for a short time

(3) Changes to circular loop (4) All of these

Sol. Answer (4)

16. A loop of irregular shape of conducting wire *PQRS* (as shown in figure) placed in a uniform magnetic field perpendicular to the plane of the paper changes into a circular shape. The direction of induced current will be

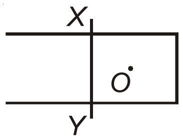


(1) Clockwise (2) Anti-clockwise (3) No current (4) None of these

Sol. Answer (2)

Using Lenz's law, inward flux is increasing. So to oppose this change current will be anticlockwise.

17. When a conducting wire *XY* is moved towards the right, a current flows in the anti-clockwise direction. Direction of magnetic field at point *O* is



(1) Parallel to motion of wire (2) Along *XY*

(3) Perpendicular outside the paper (4) Perpendicular inside the paper

Sol. Answer (3)

Using Lenz's law

18. A copper rod of length l is rotated about one end perpendicular to the uniform magnetic field B with constant angular velocity ω. The induced e.m.f. between its two ends is

(1) $B\omega l^2$ (2) $\frac{3}{2}B\omega l^2$ (3) $\frac{1}{2}B\omega l^2$ (4) $2B\omega l^2$

Sol. Answer (3)

$$\varepsilon = \frac{1}{2}B\omega l^2$$

19. A coil having number of turns N and area A is rotated in a uniform magnetic field B with angular velocity ω about its diameter. Maximum e.m.f. induced in it is given by

(1) $NAB\omega$ (2) $\frac{NAB}{\omega}$ (3) $\frac{NA\omega}{B}$ (4) $\frac{B\omega}{NA}$

Sol. Answer (1)

$$\phi = NBA\cos\theta = NBA\cos\omega t$$

$$\varepsilon = -\frac{d\phi}{dt}$$

$$\varepsilon = NBA\omega\sin\omega t$$

$$\varepsilon_{\text{max}} = NBA\omega$$

20. A flat coil of 500 turns, each of area 50 cm^2, rotates in a uniform magnetic field of 0.14 Wb/m^2 about an axis normal to the field at an angular speed of 150 rad/s. The coil has a resistance of 5 Ω. The induced e.m.f. is applied to an external resistance of 10 Ω. The peak current through the resistance is

(1) 1.5 A (2) 2.5 A (3) 3.5 A (4) 4.5 A

Sol. Answer (3)

$N = 500$, $A = 50$ cm^2, $B = 0.14$ Wb/m^2

$\omega = 150$ rad/s, $R = 5\ \Omega$

$$\varepsilon_{\text{max}} = NBA\omega$$

$$I_{\text{max}} = \frac{\varepsilon_{\text{max}}}{R} = 3.5\text{ A}$$

21. Eddy currents are induced when

(1) A metal block is kept in a changing magnetic field

(2) A metal block is kept in a uniform magnetic field

(3) A coil is kept in a uniform magnetic field

(4) Current is passed in a coil

Sol. Answer (1)

22. A motor starter

(1) Is a variable resistor (2) Offsets the back emf variations

(3) Helps start a DC motor (4) All of these

Sol. Answer (4)

23. A simple electric motor has an armature resistance of 1 Ω and runs from a d.c. source of 12 V. It draws a current of 2 A when unloaded. When a certain load is connected to it, its speed reduces by 10% of its initial value. The current drawn by the loaded motor is

(1) 3 A (2) 6 A (3) 2 A (4) 1 A

Sol. Answer (1)

24. Which of the following is possible application of an RC circuit?

(1) Windshield wipers

(2) Flashing red lights on roadway construction sites

(3) Heart pacemakers

(4) All of these

Sol. Answer (4)

25. The current passing through a choke coil of self inductance 5 H is decreasing at the rate of 2 A/s. The e.m.f. developed across the coil is

(1) 10 V (2) – 10 V (3) – 2.5 V (4) 2.5 V

Sol. Answer (1)

$$L = 5\text{ H},\quad \frac{di}{dt} = 2\text{ A/s}$$

$$\varepsilon = \frac{Ldi}{dt} = 5(2) = 10\text{ V}$$

26. When the number of turns in a solenoid are doubled without any change in the length of the solenoid, its self inductance becomes

(1) Half (2) Double (3) Four times (4) Eight times

Sol. Answer (3)

$L \propto n^2$

So if $n' = 2n$

$L' = 4L$

27. A coil of resistance 20 ohms and inductance 5 H has been connected to a 100 volt battery. The energy stored in the coil is

(1) 31.25 J (2) 62.5 J (3) 125 J (4) 250 J

Sol. Answer (2)

$$I = \frac{100}{20} = 5\text{ A}$$

$$\varepsilon = \frac{1}{2}LI^2 = \frac{1}{2}5(5)^2 = 62.5\text{ J}$$

28. The magnetic energy stored in a long solenoid of area of cross-section A in a small region of length *L* is

(1) $\frac{B^2AL}{2\mu_0^2}$ (2) $\frac{AL}{2\mu_0}$ (3) $\frac{1}{2}\mu_0 B^2 AL$ (4) $\frac{B^2AL}{2\mu_0}$

Sol. Answer (4)

$$\frac{\text{Energy}}{\text{Volume}} = \frac{B^2}{2\mu_0} \Rightarrow \text{ Energy} = \frac{B^2(AL)}{2\mu_0}$$

29. An inductor is connected to a direct voltage source through a switch. Now

(1) Very large emf is induced in inductor when switch is closed

(2) Larger emf is induced when switch is opened

(3) Large emf is induced whether switch is closed or opened

(4) No emf is induced whether switch is closed or opened

Sol. Answer (2)

30. A long solenoid has self inductance *L*. If its length is doubled keeping total number of turns constant then its new self inductance will be

(1) $\frac{L}{2}$ (2) $2L$ (3) L (4) $\frac{L}{4}$

Sol. Answer (1)

$$L = \mu_0 n^2 Al$$

$$L = \mu_0\left(\frac{N}{l}\right)^2 Al$$

$$L = \frac{\mu_0 N^2}{l}A \Rightarrow L \propto \frac{1}{l}$$

$$\Rightarrow L' = \frac{L}{2}$$

31. If *L* and *R* denote inductance and resistance respectively, then the dimension of *L*/*R* is

(1) $[M^0L^0T^{-1}]$ (2) $[M^0L^0T^1]$ (3) $[M^0L^0T^2]$ (4) $[MLT^2]$

Sol. Answer (2)

$\tau = \frac{L}{R}$ represents time constant hence will have dimension of time.

32. A solenoid has 2000 turns wound over a length of 0.3 m. The area of its cross section is 1.2×10^{-3} m^2. Around its central section a coil of 300 turns is wound. If an initial current of 2 A is reversed in 0.25 s, the e.m.f. induced in the coil is equal to

(1) 6×10^{-4} V (2) 4.8×10^{-2} V (3) 2.4×10^{-2} V (4) 48 kV

Sol. Answer (2)

$$\phi = NBA \Rightarrow \varepsilon = \frac{d\phi}{dt} \Rightarrow \varepsilon = NA\frac{dB}{dt} = \left(NA\mu_0 n\frac{\Delta i}{\Delta t}\right)$$

$$\frac{\Delta i}{\Delta t} = \frac{4}{0.25}, \text{ So } \varepsilon = 4.8 \times 10^{-2} \text{ V}$$

33. With the decrease of current in the primary coil from 2 A to zero in 0.01s, the e.m.f. generated in the secondary coil is 1000 V. The mutual inductance of the two coil is

(1) 1.25 H (2) 2.50 H (3) 5.00 H (4) 10.00 H

Sol. Answer (3)

$\phi = Mi$

$$\frac{d\phi}{dt} = \frac{Mdi}{dt}$$

$$1000 = \frac{M(2)}{0.01}$$

$$M = \frac{1}{2}(10) = 5.00 \text{ H}$$

34. Two coaxial coils are very close to each other and their mutual inductance is 5 mH. If a current 50 sin 500*t* is passed in one of the coils then the peak value of induced e.m.f. in the secondary coil will be

(1) 5000 V (2) 500 V (3) 150 V (4) 125 V

Sol. Answer (4)

$\phi = Mi$

$$\frac{d\phi}{dt} = \frac{Mdi}{dt}$$

$$\varepsilon = 5 \times 10^{-3}(50)(500)\cos\omega t$$

ε_{max} = 125 V

35. The coefficient of self induction of two inductor coils are 20 mH and 40 mH respectively. If the coils are connected in series so as to support each other and the resultant inductance is 80 mH then the value of mutual inductance between the coils will be

(1) 5 mH (2) 10 mH (3) 20 mH (4) 40 mH

Sol. Answer (2)

L_1 = 20 mH, L_2 = 40 mH

$L = L_1 + L_2 \pm 2$ M

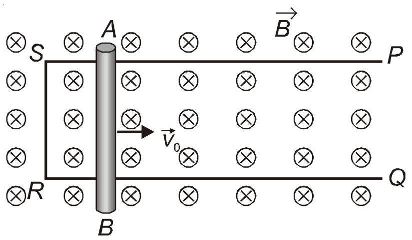
80 = 20 + 40 + 2 M

M = 10 mH

SECTION - B

Objective Type Questions

1. A conducting rod AB of length l is projected on a frictionless frame $PSRQ$ with velocity v_0 at any instant. The velocity of the rod after time t is

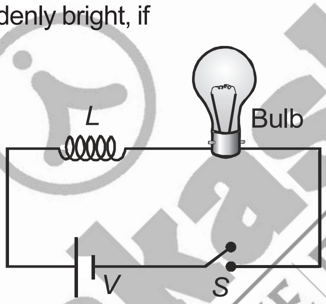


(1) $v = v_0$ (2) $v > v_0$ (3) $v < v_0$ (4) None of these

Sol. Answer (3)

The rod will experience magnetic force in the direction opposite to initial force. So velocity will decrease with time.

2. In the given circuit, bulb will become suddenly bright, if



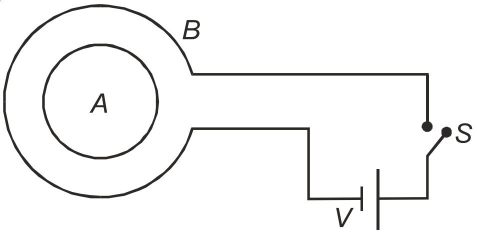
(1) Switch is closed or opened (2) Switch is closed

(3) Switch is opened (4) None of these

Sol. Answer (3)

Sudden decrease in current due to circuit breaking (opening) will be compensated by sudden induced current flow (as per Lenz's law) and hence sudden brightness.

3. What will be the direction of current in the coil A as the switch S is closed?



(1) Clockwise (2) Anticlockwise

(3) Anticlockwise and then clockwise (4) Clockwise and then anticlockwise

Sol. Answer (1)

Using Lenz's law, current in A will be clockwise.

4. The armature of a generator of resistance 1 Ω is rotated at its rated speed and produces 125 V without load and 115 V with full load. The current in the armature coil is

(1) 240 A (2) 10 A (3) 1 A (4) 2 A

Sol. Answer (2)

$$I = \frac{125-115}{1} = 10\text{ A}$$

5. A copper disc of radius 0.1 m is rotated about its centre with 10 rev/s in a uniform magnetic field of 0.1T with its plane perpendicular to field. The emf induced across the radius of disc is

(1) $\frac{\pi}{10}$ volt (2) $\frac{\pi}{100}$ volt (3) $\frac{\pi}{1000}$ volt (4) Zero

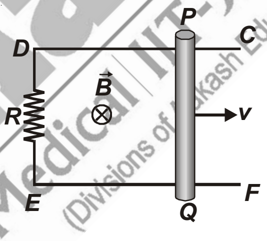
Sol. Answer (2)

$$\varepsilon = \frac{1}{2}B\omega R^2,\ R = 0.1\text{ m},\ B = 0.1\text{ T},\ W = 20\frac{\pi}{s}$$

$$\varepsilon = \frac{1}{2}(0.1)(0.1)^2(20\pi)$$

$$= \frac{\pi}{100}\text{ volt}$$

6. A frame *CDEF* is placed in a region where a magnetic field $\vec{B}$ is present. A rod of length one metre moves with constant velocity 20 m/s and strength of magnetic field is one tesla. The power spent in the process is (take *R* = 0.2 Ω and all other wires and rod have zero resistance)



(1) 1 kW (2) 2 kW (3) 3 kW (4) 4 kW

Sol. Answer (2)

$$P = F.V = \frac{B^2l^2v^2}{R}$$

$$= \frac{1(1)^2(20)^2}{0.2}$$

$$= 2\text{ kW}$$

7. An ideal solenoid of cross-sectional area 10^{-4} m^2 has 500 turns per metre. At the centre of this solenoid, another coil of 100 turns is wrapped closely around it. If the current in the coil changes from 0 to 2 A in 3.14 ms, the emf developed in the second coil is

(1) 1 mV (2) 2 mV (3) 3 mV (4) 4 mV

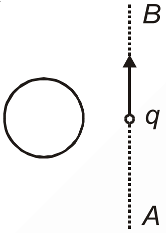
Sol. Answer (4)

$$M = \mu_0 n_1 n_2 A$$

$$= 4\pi \times 10^{-7}(500)(100) \times 10^{-4}$$

$$\varepsilon = -\frac{Mdi}{dt} = \frac{M(2)}{3.14} = 4 \text{ mV}$$

8. A positive charge *q* moves along the line *AB*, which lies in the same plane as a circular loop of conducting wire as shown in the figure. The direction of current induced in the loop is



(1) Clockwise (2) First anticlockwise then clockwise

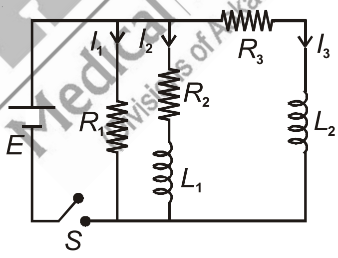
(3) First clockwise then anticlockwise (4) No current is induced

Sol. Answer (3)

$$B = \frac{\mu_0}{4\pi}\frac{qv}{r^2}$$

when *q* approaches the loop '*r*' decreases when *q* goes away from the loop '*r*' increases so using Lenz law induced current will be first clockwise then anticlockwise.

9. Figure shows an L-R circuit. When the switch *S* is closed, the current through resistor R_1, R_2 and R_3 are I_1, I_2 and I_3 respectively. The value of I_1, I_2 and I_3 at t = 0 s is



(1) $I_1 = I_2 = I_3 = 0$ (2) $I_1 = \frac{E}{R_1}, I_2 = I_3 = 0$

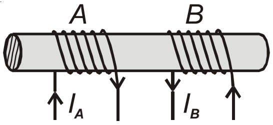
(3) $I_1 = 0, I_2 = \frac{E}{R_2}, I_3 = \frac{E}{R_3}$ (4) $I_1 = \frac{E}{R_1}, I_2 = \frac{E}{R_2 + L_1}, I_3 = \frac{E}{R_3 + L_3}$

Sol. Answer (2)

At t = 0, inductor offers infinite resistance

So , $I_1 = \frac{E}{R_1}$, $I_2 = I_3 = 0$

10. Two coils A and B are wound on the same iron core as shown in figure. The number of turns in the coil A and B are N_A and N_B respectively. Identify the correct statement



(1) Both the coils have same magnitude of magnetic flux

(2) The magnetic flux linked are in the ratio $\frac{\phi_A}{\phi_B} = \frac{N_A}{N_B}$

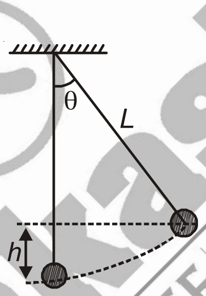
(3) The induced emf across each coil are in the ratio $\frac{E_A}{E_B} = \left(\frac{N_A}{N_B}\right)^2$

(4) Both the coils have same magnitude of induced emf

Sol. Answer (2)

$$\frac{\phi_A}{\phi_B} = \frac{N_A}{N_B}$$

11. A simple pendulum with bob of mass m and conducting wire of length L swings under gravity through an angle 2θ. The earth's magnetic field component in the direction perpendicular to swing is B. The maximum potential difference induced across the pendulum is



(1) $2BL\sin\left(\frac{\theta}{2}\right).\sqrt{gL}$ (2) $BL\sin\left(\frac{\theta}{2}\right)\sqrt{(gl)}$ (3) $BL\sin\left(\frac{\theta}{2}\right).(gL)^{3/2}$ (4) $BL\sin\left(\frac{\theta}{2}\right).(gL)^2$

Sol. Answer (2)

Using conservation of energy

$$mgl(1-\cos\theta) = \frac{1}{2}I\omega^2$$

$$mgl(1-\cos\theta) = \frac{1}{2}ml^2\omega^2$$

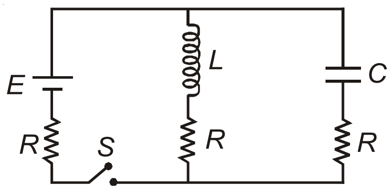
$$2gl\left(2\sin^2\left(\frac{\theta}{2}\right)\right) = l^2\omega^2$$

$$\omega = 2\sqrt{\frac{g}{l}}\sin\frac{\theta}{2}$$

$$\varepsilon = \frac{1}{2}B\omega l^2 = \frac{1}{2}\times\left(2\sqrt{\frac{g}{l}}\sin\frac{\theta}{2}\right)l^2\times B$$

$$\varepsilon = Bl\sin\frac{\theta}{2}\sqrt{gl}$$

12. The switch shown in the circuit is closed at t = 0. The current drawn from the battery by the circuit at t = 0 and $t = \infty$ are in the ratio



(1) 2 : 1 (2) 1 : 2 (3) 1 : 1 (4) 1 : 4

Sol. Answer (3)

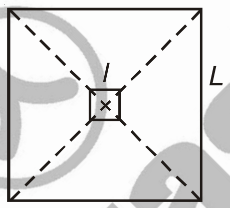
At t = 0, L offers infinite resistance

At $t \to \infty$, C offers infinite resistance

So, in both the cases, $I = \frac{\varepsilon}{2R}$

Hence ratio is 1 : 1.

13. A small square loop of wire of side l is placed inside a large square loop of wire of side L (>>l). The loops are coplanar and their centres coincide. The mutual inductance of the system is



(1) $\frac{2\sqrt{2}\mu_0 L}{\pi l}$ (2) $\frac{2\sqrt{2}\mu_0 L^2}{\pi l}$ (3) $\frac{2\sqrt{2}\mu_0 l}{\pi L}$ (4) $\frac{2\sqrt{2}\mu_0 l^2}{\pi L}$

Sol. Answer (4)

$$M = \frac{\phi}{i}$$

ϕ due to outer loop in the smaller loop will be due to magnetic field Vector sum of all the four sides of bigger square.

So $M = \frac{2\sqrt{2}\mu_0 l^2 i}{\pi L(i)}$

14. A uniform magnetic field exists in the region given by $\vec{B} = 3\hat{i} + 4\hat{j} + 5\hat{k}$. A rod of length 5 m placed along y-axis is moved along x-axis with constant speed 1 ms^{-1}. Then induced e.m.f. in the rod is

(1) Zero (2) 25 V (3) 5 V (4) 10 V

Sol. Answer (2)

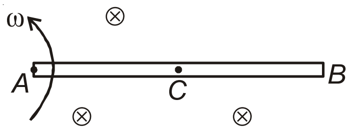
$$\varepsilon = (\vec{v} \times \vec{B}).\vec{l}$$

$$= \left[(1\hat{i}) \times (3\hat{i} + 4\hat{j} + 5\hat{k})\right].5\hat{j}$$

$$= \left[4\hat{k} - 5\hat{j}\right].5\hat{j}$$

= 25 V

15. A copper rod *AB* of length *l*, pivoted at one end *A*, rotates at constant angular velocity ω, at right angles to a uniform magnetic field of induction *B*. The emf, developed between the mid point *C* of the rod and end *B* is



(1) $\frac{B\omega l^2}{8}$ (2) $\frac{3}{4}B\omega l^2$ (3) $\frac{B\omega l^2}{4}$ (4) $\frac{3}{8}B\omega l^2$

Sol. Answer (4)

$$\varepsilon = \int_{l/2}^{l} B\omega x\,dx$$

$$= B\omega\left(\frac{x^2}{2}\right)_{l/2}^{l}$$

$$= \frac{B\omega}{2}\left(l^2 - l^2/4\right)$$

$$= \frac{3}{8}B\omega l^2$$

16. Radius of a circular loop placed in a perpendicular uniform magnetic field is increasing at a constant rate of r_0 ms^{-1}. If at any instant radius of the loop is *r*, then emf induced in the loop at that instant will be

(1) $-2Brr_0$ (2) $-2B\pi r$ (3) $-B\pi r_0 r$ (4) $-2B\pi r_0 r$

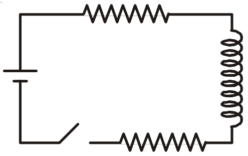
Sol. Answer (4)

$$\frac{dr}{dt} = r_0 \Rightarrow \phi = B\pi r^2$$

$$\varepsilon = \frac{-d\phi}{dt} = -B\pi(2r)\frac{dr}{dt}$$

$$\varepsilon = -2\pi Brr_0$$

17.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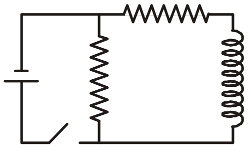
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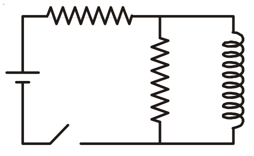

3

The figure shows three circuits with identical batteries, inductors and resistances. Rank the circuits according to the currents through the battery just after the switch is closed, greatest first

(1) $I_2 > I_3 > I_1$ (2) $I_2 > I_1 > I_3$ (3) $I_1 > I_2 > I_3$ (4) $I_1 > I_3 > I_2$

Sol. Answer (1)

$$I_1 = 0,\ I_2 = \frac{\varepsilon}{R},\ I_3 = \frac{\varepsilon}{2R}$$

$$\Rightarrow\ I_2 > I_3 > I_1$$

18. In an inductor, the current I varies with time t as $I = 5A + 16\ (\text{A/s})\ t$. If induced emf in the inductor is 5 mV, the self inductance of the inductor is

(1) 3.75×10^{-3} H (2) 3.75×10^{-4} H (3) 3.125×10^{-3} H (4) 3.125×10^{-4} H

Sol. Answer (4)

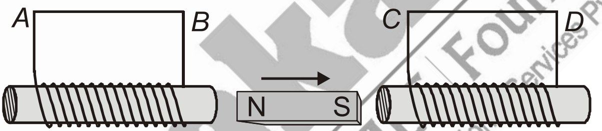
$$I = 5 + 16t\ \Rightarrow \frac{di}{dt} = 16$$

$$\varepsilon = 5 \times 10^{-3}\ \text{V}$$

$$|\varepsilon| = \frac{Ldi}{dt} = L(16) = 5 \times 10^{-3}$$

So, $L = 3.125 \times 10^{-4}$ H

19. A magnet is moved in the direction indicated by an arrow between two coils AB and CD as shown in figure. The direction of induced current in the straight wire is



(1) A to B and C to D (2) B to A and C to D (3) A to B and D to C (4) B to A and D to C

Sol. Answer (3)

Using Lenz's law

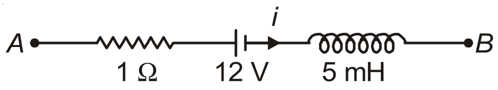
20. Two coils of self inductance L_1 and L_2 are placed near each other so that the total flux in one coil is completely linked with the other. Their mutual inductance (M) will be given by

(1) $M = L_1 L_2$ (2) $M = \sqrt{L_1 L_2}$ (3) $M < \sqrt{L_1 L_2}$ (4) $M > L_1 L_2$

Sol. Answer (2)

$$M = \sqrt{L_1 L_2}$$

21. The network shown in figure is a part of a complete circuit. If at a certain instant, the current i is 4 A and is increasing at a rate of 10^3 A/s. Then $V_B - V_A$ will be



(1) –11 V (2) 11 V (3) –21 V (4) 21 V

Sol. Answer (3)

$$\frac{di}{dt} = +10^3$$

So, $V_A - (4)(1) - 12 - 5 \times 10^{-3}(10^3) = V_B$

$$\Rightarrow V_B - V_A = -21\text{ V}$$

22. The magnetic flux through a stationary loop with resistance R varies during interval of time T as $\phi = at(T - t)$. The heat generated during this time neglecting the inductance of loop will be

(1) $\frac{a^2T^3}{3R}$ (2) $\frac{a^2T^2}{3R}$ (3) $\frac{a^2T}{3R}$ (4) $\frac{a^3T^2}{3R}$

Sol. Answer (1)

$$\phi = at(T - t) = aTt - at^2$$

$$\varepsilon = -\frac{d\phi}{dt} = -(aT - 2at)$$

$$P = -\frac{\varepsilon^2}{R} = \frac{(aT - 2at)^2}{R}$$

$$H = \int_0^T Pdt = \int_0^T \frac{(aT - 2at)^2}{R}$$

$$= \frac{a^2T^3}{3R}$$

23. A short-circuited coil is placed in a time-varying magnetic field. Electrical power is dissipated due to the current induced in the coil. If the number of turns were to be quadrupled and the wire radius halved, the electric power dissipated would be

(1) Halved (2) The same (3) Doubled (4) Quadrupled

Sol. Answer (2)

$$\varepsilon = nB\pi r^2 \frac{dB}{dt}$$

$$\varepsilon' = 4nB\pi\left(\frac{r}{2}\right)^2 \frac{dB}{dt}$$

$$\varepsilon' = nB\pi r^2 \frac{dB}{dt} = \varepsilon$$

$$P' = \frac{(\varepsilon')^2}{R} = \frac{\varepsilon^2}{R}$$

24. A small square loop of wire of side *l* is placed inside a large circular loops of radius *r*. The loop are coplanar and their centre coincide. The mutual inductance of the system is proportional to

(1) $\frac{l^2}{r}$ (2) $\frac{l^2}{r^2}$ (3) $\frac{r}{l^2}$ (4) $\frac{r^2}{l}$

Sol. Answer (1)

Using $\phi = Mi$

$$M = \frac{\phi}{i} = \left(\frac{\mu_0 i}{2r}\right).\frac{l^2}{i} \propto \frac{l^2}{r}$$

SECTION - C

Previous Years Questions

1. A coil of resistance 400 Ω is placed in a magnetic field. If the magnetic flux ϕ (wb) linked with the coil varies with time *t* (sec) as $\phi = 50t^2 + 4$. The current in the coil at *t* = 2 second is

(1) 2 A (2) 1 A (3) 0.5 A (4) 0.1 A

Sol. Answer (3)

$$\phi = 50t^2 + 4$$

$$|\varepsilon| = \left|\frac{d\phi}{dt}\right| = 100t$$

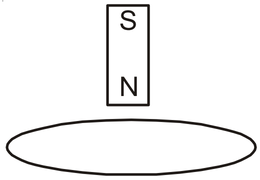
$$\varepsilon\big|_{t=2} = 100(2) = 200 \text{ V}$$

$$I = \frac{\varepsilon}{R} = \frac{200}{400} = 0.5 \text{ A}$$

2. A metal ring is held horizontally and a bar magnet is dropped through the ring with its length along the axis of the ring. The acceleration of the falling magnet is

(1) More than *g* (2) Equal to *g* (3) Less than *g* (4) Either (1) or (3)

Sol. Answer (3)



due to Lenz's law $a < g$

3. The magnetic flux through a circuit of resistance *R* changes by an amount $\Delta\phi$ in a time Δt. Then the total quantity of electric charge *Q* that passes any point in the circuit during the time Δt is represented by

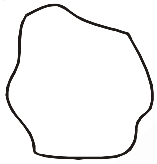
(1) $Q = \frac{1}{R}.\frac{\Delta\phi}{\Delta t}$ (2) $Q = \frac{\Delta\phi}{R}$ (3) $Q = \frac{\Delta\phi}{\Delta t}$ (4) $Q = R.\frac{\Delta\phi}{\Delta t}$

Sol. Answer (2)

$$I = \frac{\Delta\phi}{\Delta t R} \Rightarrow \frac{\Delta Q}{\Delta t} = \frac{\Delta\phi}{\Delta t R}$$

$$\Rightarrow \Delta Q = \frac{\Delta\phi}{R}$$

4. As a result of change in the magnetic flux linked to the closed loop as shown in the figure, an e.m.f V volt is induced in the loop. The work done (in joule) in taking a charge Q coulomb once along the loop is



(1) QV (2) $2QV$ (3) $\frac{QV}{2}$ (4) Zero

Sol. Answer (1)

$W = QV$

(By the defination of e.m.f)

5. A rectangular, a square, a circular and an elliptical loop, all in the (x-y) plane, are moving out of a uniform magnetic field with a constant velocity $\vec{V} = v\hat{i}$. The magnetic field is directed along the negative z-axis direction. The induced emf, during the passage of these loops, out of the field region, will not remain constant for

(1) Any of the four loops (2) The rectangular, circular and elliptical loops

(3) The circular and the elliptical loops (4) Only the elliptical loop

Sol. Answer (3)

For circular and elliptical loop, area coming out from the field per unit time is not constant

i.e. $\frac{dA}{dt} \neq$ constant

6. A conducting circular loop is placed in a uniform magnetic field, B = 0.025 T with its plane perpendicular to the loop. The radius of the loop is made to shrink at a constant rate of 1 mms^{-1}. The induced emf when the radius is 2 cm is

(1) $2\ \mu V$ (2) $2\ \pi\mu V$ (3) $\pi\mu V$ (4) $\frac{\pi}{2}\mu V$

Sol. Answer (3)

B = 0.025 T

$\frac{dr}{dt} = 1$ mm/s $\Rightarrow r = 2$ cm

$\varepsilon = B(2\pi r)\frac{dr}{dt}$

So, $\varepsilon = \pi \times 10^{-6}$ V

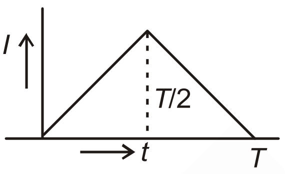
7. A conductor of 3 m length is moving perpendicular to its length as well as a magnetic field of 10^{-3} T with a speed of 10^2 m/s, then the force required to move it with this constant speed is

(1) 0. 3 N (2) 0.9 N (3) 0 (4) 3×10^{-3} N

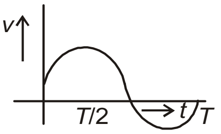
Sol. Answer (3)

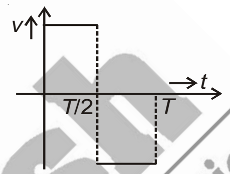
Motional emf will induce ($\varepsilon = Bvl$). But loop is not closed so no current will flow, hence no magnetic field force will act upon it.

8. The current (I) in the inductance is varying with time according to the plot shown in figure.



Which one of the following is the correct variation of magnitude of voltage with time in the coil?

(1)


(2)


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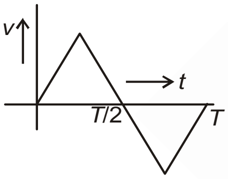

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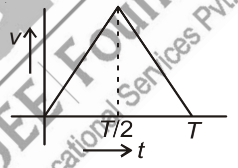


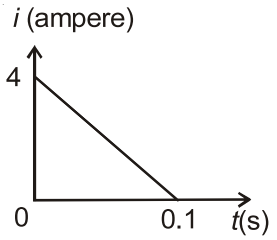
Sol. Answer (2)

Use $|\varepsilon| = \frac{Ldi}{dt}$

for 0 to $\frac{T}{2}$, $\frac{di}{dt}$ is constant and positive

and from $\frac{T}{2}$ to T, $\frac{di}{dt}$ is constant and negative.

9. In a coil of resistance 10 Ω, the induced current developed by changing magnetic flux through it, is shown in figure as a function of time. The magnitude of change in flux through the coil in weber is



(1) 8 (2) 2 (3) 6 (4) 4

Sol. Answer (2)

$$I = \left(\frac{\Delta\phi}{\Delta t.R}\right)$$

$$\Delta\phi = I\Delta tR$$

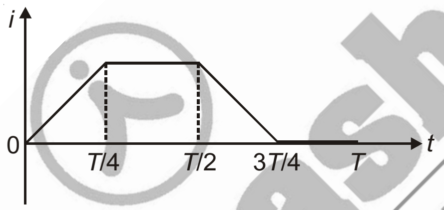
or $d\phi = (Idt)R$

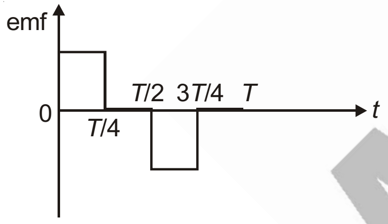
Total flux $\phi = R\int Idt$

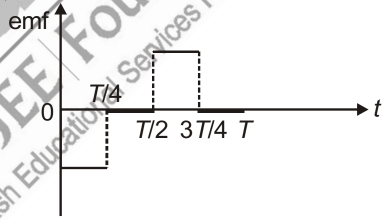
$\int idt$ represents area under $i - t$ curve

So $\phi = R\left[\frac{1}{2}(0.1)(4)\right] = 2$

10. The current i in a coil varies with time as shown in the figure. The variation of induced emf with time would be



(1)


(2)


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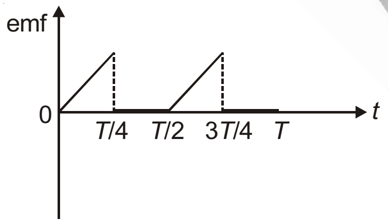

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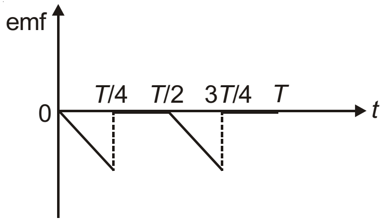


Sol. Answer (2)

$$\varepsilon = \frac{-Ldi}{dt}$$

$\frac{di}{dt}$ is slope of $I - t$ curve.

11. A long solenoid has 500 turns. When a current of 2 ampere is passed through it, the resulting magnetic flux linked with each turn of the solenoid is 4×10^{-3} Wb. The self-inductance of the solenoid is

(1) 4.0 henry (2) 2.5 henry (3) 2.0 henry (4) 1.0 henry

Sol. Answer (4)

$N = 500,\ I = 2$

$$L = \frac{N\phi}{i} = \frac{500\left(4\times10^{-3}\right)}{2}$$

12. In a circular conducting coil, when current increases from 2 A to 18 A in 0.05 s, the induced emf is 20 V. The self inductance of the coil is

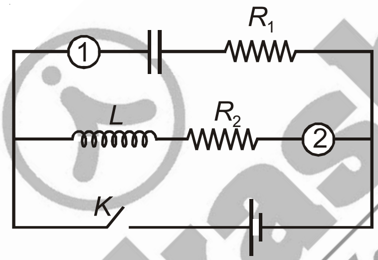
(1) 62.5 mH (2) 6.25 mH (3) 50 mH (4) 0

Sol. Answer (1)

$$\varepsilon = \left|\frac{Ldi}{dt}\right| = \frac{L(18-2)}{0.05} = 20$$

So $L = 62.5 \times 10^{-3}$ H

13. In the circuit given in figure, 1 and 2 are ammeters. Just after key K is pressed to complete the circuit, the reading will be



(1) Zero in 1, maximum in 2 (2) Maximum in both 1 and 2

(3) Zero in both 1 and 2 (4) Maximum in 1, zero in 2

Sol. Answer (4)

At $t = 0$, C offers zero resistance

L offers infinite resistance

So reading of Ammeter (1) → max

Ammeter (2) → Zero

14. For a coil having $L = 2$ mH, current flowing through it is $I = t^2 e^{-t}$ then the time at which emf become zero

(1) 2 s (2) 1 s (3) 4 s (4) 3 s

Sol. Answer (1)

$$\varepsilon = \frac{Ldi}{dt}$$

When $\frac{di}{dt}$ becomes zero, ε will becom zero.

$$\frac{di}{dt} = -t^2\left(e^{-t}\right) + e^{-t}(2t) = 0$$

$\Rightarrow t = 2$

15. When the number of turns and the length of a solenoid both are doubled, its self inductance becomes

(1) Four times (2) Doubled (3) Halved (4) Unchanged

Sol. Answer (2)

$$L = \mu_0 n^2 Al$$

$$L = \mu_0 \frac{N^2}{l^2} Al = \frac{\mu_0 N^2 A}{l}$$

So, on doubling N and l

$$L' = \frac{\mu_0 (2N)^2 A}{2l} = \frac{2\mu_0 N^2 A}{l}$$

$\Rightarrow L' = 2L$

16. The time constant of L-R circuit is doubled if

(1) Both L and R become two times

(2) L becomes four times and R becomes two times

(3) L becomes two times and R becomes four times

(4) L becomes two times and R becomes eight times

Sol. Answer (2)

$$\tau = \frac{L}{R}$$

$$\tau' = 2\tau = \frac{4L}{2R}$$

17. Two neighbouring coils A and B have a mutual inductance of 20 mH. The current flowing through A is given by, $i = 3t^2 - 4t + 6$. The induced emf at $t = 2$ s is

(1) 160 mV (2) 200 mV (3) 260 mV (4) 300 mV

Sol. Answer (1)

M = 20 mH

$$I = 3t^2 - 4t + 6$$

$$\frac{di}{dt} = 6t - 4$$

$$\varepsilon = \left.\frac{Mdi}{dt}\right|_{t=2} = 20 \times 10^{-3}\left(6(2) - 4\right) = 160 \text{ mV}$$

18. The self inductance L of a solenoid depends on the number of turns per unit length 'n' as

(1) $L \propto n$ (2) $L \propto n^2$ (3) $L \propto n^{-1}$ (4) $L \propto n^{-2}$

Sol. Answer (2)

19. Two coils have a mutual inductance 0.005 H. The current changes in the first coil according to equation $I = I_0 \sin \omega t$, where I_0 = 10 A and $\omega = 100\pi$ radian per second. The maximum value of e.m.f. (in volt) in the second coil is

(1) π (2) 5π (3) 2π (4) 4π

Sol. Answer (2)

M = 0.005 H

$I = I_0 \sin\omega t = 10\sin\omega t$

$\omega = 1\omega\pi$ rad/s

$$\varepsilon = \frac{Mdi}{dt}$$

$$= (0.005)[(10)(100\pi)\cos\omega t]$$

$$= (0.005)(1000\pi)$$

$$= 5\pi$$

20. A transformer has 500 primary turns and 10 secondary turns. If the secondary has resistive load of 15 Ω, the currents in the primary and secondary respectively, are

(1) 0.16 A, 3.2×10^{-3} A (2) 3.2×10^{-3} A, 0.16 A

(3) 0.16 A, 0.16 A (4) 3.2×10^{-3} A, 3.2×10^{-3} A

Sol. Answer (2)

Use $\frac{i_P}{i_S} = \frac{n_P}{n_S}$

21. Two coils of self inductance 2 mH and 8 mH are placed so close together that the effective flux in one coil is completely linked with the other. The mutual inductance between these coils is

(1) 16 mH (2) 10 mH (3) 6 mH (4) 4 mH

Sol. Answer (4)

L_1 = 2mH, L_2 = 8 mH

$M = \sqrt{L_1 L_2} = \sqrt{16} = 4$ mH

22. A wire loop is rotated in a magnetic field. The frequency of change of direction of the induced e.m.f. is

(1) Twice per revolution (2) Four times per revolution

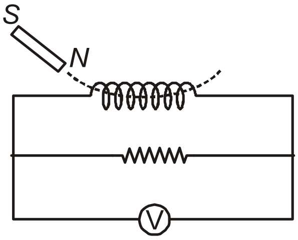
(3) Six times per revolution (4) Once per revolution

Sol. Answer (1)

$\phi = BA\cos\omega t$

$$\varepsilon = \frac{d\phi}{dt} = BA\omega\sin\omega t$$

23. A magnet is made to oscillate with a particular frequency through a coil as shown in figure. The time variation of magnitude of emf generated across the coil during one cycle is



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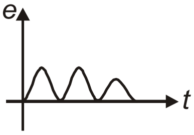

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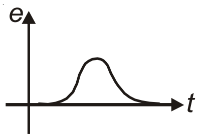

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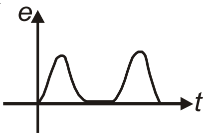

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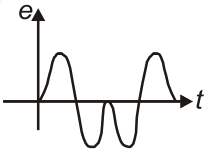


Sol. Answer (3)

emf induced will be zero when magnet will be inside coil. Use Lenz's law.

24. Two coils have self inductance L_1 = 4 mH and L_2 = 1 mH respectively. The currents in the two coils are increased at the same rate. At a certain instant of time both coils are given the same power. If I_1 and I_2 are the currents in the two coils, at that instant of time respectively, then the value of $\frac{I_1}{I_2}$ is

(1) $\frac{1}{8}$ (2) $\frac{1}{4}$ (3) $\frac{1}{2}$ (4) 1

Sol. Answer (2)

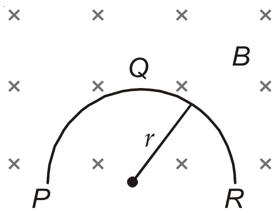
$L_1 = 4$ mH, $L_2 = 1$ mH

$$\frac{di_1}{dt} = \frac{di_2}{dt}$$

$$\frac{I_1}{I_2} = \frac{\varepsilon_2}{\varepsilon_1} \quad \left(\because\ P = \varepsilon i \Rightarrow \frac{\varepsilon_1}{\varepsilon_2} = \frac{I_2}{I_1}\right)$$

$$\frac{I_1}{I_2} = \frac{L_2\frac{di_2}{dt}}{L_1\frac{di_1}{dt}} \Rightarrow \frac{I_1}{I_2} = \frac{L_2}{L_1} = \frac{1}{4}$$

25. A thin semicircular conducting ring (*PQR*) of radius *r* is falling with its plane vertical in a horizontal magnetic field *B,* as shown in figure. The potential difference developed across the ring when its speed is *v,* is



(1) Zero

(2) $Bv\pi r^2/2$ and *P* is at higher potential

(3) πrBv and *R* is at higher potential

(4) $2rBv$ and *R* is at higher potential

Sol. Answer (4)

SECTION - D

Assertion-Reason Type Questions

1. A : Total induced emf in a loop is not confined to any particular point but it is distributed around the loop in direct proportion to the resistances of its parts.

   R : In general when there is no change in magnetic flux, no induced emf is produced.

Sol. Answer (2)

2. A : The induced current flows so as to oppose the cause producing it.

   R : Lenz's law is based on energy conservation.

Sol. Answer (1)

3. A : Faraday's law is an experimental law.

   R : Time varying magnetic field cannot generate induced emf.

Sol. Answer (3)

4. A : Unlike electrostatic field the lines of induced field form closed loop.

   R : Electrostatic field is conservative unlike induced fields.

Sol. Answer (1)

5. A : The mutual induction between the two coils infinitely apart is zero.

   R : If the mutual induction between the two coils is zero, it means that their self inductances are also zero.

Sol. Answer (3)

6. A : An inductor is called the inertia of an electric circuit.

   R : An inductor tends to keep the flux constant.

Sol. Answer (1)

7. A : At any instant, if the current through an inductor is zero, then the induced emf will also be zero.

   R : In one time constant, the current flows to 37 percent of its maximum value in a series *LR* circuit.

Sol. Answer (4)

8. A : There may be an induced emf in a loop without induced current.

   R : Induced current depends on the resistance of the loop as well.

Sol. Answer (2)

9. A : When the magnetic flux through a loop is maximum, induced emf is maximum.

   R : When the magnetic flux through a loop is minimum, induced emf is minimum.

Sol. Answer (4)

10. A : When a conducting loop is kept stationary in a non-uniform magnetic field an emf is induced.

    R : As per Faraday's law, whenever flux changes, an emf is induced.

Sol. Answer (4)

11. A : When an electric motor is started, a variable resistance (that decreases with time) is used in series. This resistance is known as motor starter.

R : The back-emf in the beginning, when motor starts, is very small.

Sol. Answer (1)

12. A : When a bar magnet is dropped into a vertical long hollow metallic tube, the magnet ultimately moves with zero acceleration.

R : The magnet falling into metallic tube causes the eddy currents in the metal tube, so the motion of the magnet is damped.

Sol. Answer (1)

13. A : The power output of a practical transformer is always smaller than the power input.

R : A transformer works on the principle of mutual induction.

Sol. Answer (2)

14. A : Electrical power through transmission lines is transmitted at high voltage.

R : At high voltage theft of power is checked.

Sol. Answer (3)

15. A : The electric field induced due to changing magnetic field is non-conservative.

R : The line integral of the electric field induced due to changing magnetic field along a closed loop is always zero.

Sol. Answer (3)

❑ ❑ ❑

Chapter 7

Alternating Current

Solutions

SECTION - A

Objective Type Questions

1. Hot wire ammeters are used for measuring

(1) Both AC and DC. (2) Only AC (3) Only DC (4) Neither AC nor DC

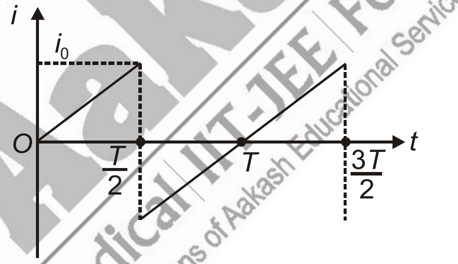
Sol. Answer (1)

2. In alternating current circuits, the a.c. meters measure

(1) r.m.s. value (2) Peak value (3) Mean value (4) Mean square value

Sol. Answer (1)

3. The mean value of current for half cycle for a current variation shown by the graph is



(1) $\frac{i_0}{2}$ (2) i_0 (3) $\frac{i_0}{\sqrt{3}}$ (4) $\frac{i_0}{3}$

Sol. Answer (1)

$$I_{\text{mean}} = \frac{\int_0^{T/2} I\,dt}{T/2}$$

From 0 to $\frac{T}{2}$ graph is straight line so the function (I) will be $= \frac{i_0}{\left(T/2\right)}.t = \frac{2i_0}{T}t$

$$\text{So } I_{\text{mean}} = \frac{2}{T}\int_0^{T/2}\frac{2i_0}{T}t\,dt = \frac{2}{T}\left(\frac{2}{T}\right)i_0\left(\frac{t^2}{2}\right)_0^{T/2}$$

$$= \frac{4}{T^2}i_0\left(\frac{1}{2}\right)\left(\frac{T^2}{4}-0\right) = \frac{i_0}{2}$$

4. A 110 V d.c. heater is used on an a.c. source, such that the heat produced is same as it produces when connected to 110 V dc in same time-intervals. What would be the r.m.s. value of the alternating voltage?

(1) 110 V (2) 220 V (3) 330 V (4) 440 V

Sol. Answer (1)

Given that $H_{AC} = H_{DC}$

$$I^2_{\text{rms}}Rt = I^2Rt$$

$$\frac{V^2_{\text{rms}}}{R} = \frac{V^2}{R}$$

$$V_{\text{rms}} = \text{V}$$

so $V_{\text{rms}} = 110$ V

5. The peak value of an alternating e.m.f. $E = E_0 \sin \omega t$ is 10 volt and its frequency is 50 Hz. At a time $t = \frac{1}{600\,\text{s}}$, the instantaneous value of the e.m.f. is

(1) 1 volt (2) $5\sqrt{3}$ volt (3) 5 volt (4) 10 volt

Sol. Answer (3)

$E = E_0 \sin\omega t$, $E_0 = 10$ V

$\nu = 50$ Hz, $t = \frac{1}{600}$

$$E = 10\sin(2\pi)\times 50\times\frac{1}{600}$$

$$= 10\sin\frac{\pi}{6} = 10\left(\frac{1}{2}\right) = 5 \text{ volt}$$

6. The time required for a 50 Hz sinusoidal alternating current to change its value from zero to the r.m.s. value

(1) 1.5×10^{-2} s (2) 2.5×10^{-3} s (3) 10^{-1} s (4) 10^{-6} s

Sol. Answer (2)

$$I = I_0 \sin\omega t$$

$$I_{\text{rms}} = \frac{I_0}{\sqrt{2}}$$

So $\frac{I_0}{\sqrt{2}} = I_0 \sin\omega t$

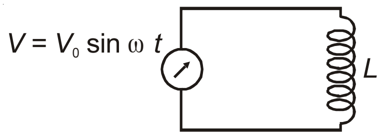
$$\sin\frac{\pi}{4} = \sin(2\pi)(50)t$$

$$\frac{\pi}{4} = 2\pi(50)t$$

$$t = \frac{1}{400} \text{ s}$$

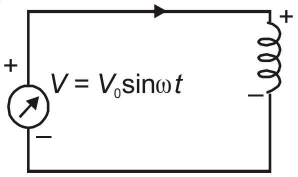
$$t = 0.25\times 10^{-2} \Rightarrow 2.5 \times 10^{-3} \text{ s}$$

7. There is no resistance in the inductive circuit. Kirchhoff 's voltage law for the circuit is



(1) $V + L\frac{di}{dt} = 0$ (2) $V = L\frac{di}{dt}$ (3) $V - L^2\frac{di}{dt} = 0$ (4) None of these

Sol. Answer (2)



Using Kirchhoff's voltage law

$$\frac{-Ldi}{dt} + V = 0$$

$$\Rightarrow V = \frac{Ldi}{dt}$$

8. A sinusoidal supply of frequency 10 Hz and r.m.s. voltage 12 V is connected to a 2.1 μF capacitor. What is r.m.s. value of current?

(1) 5.5 mA (2) 20 mA (3) 26 mA (4) 1.6 mA

Sol. Answer (4)

f = 10 Hz, V_{rms} = 12 V, C = 2.1 μF

$$I_{\text{rms}} = \frac{V_{\text{rms}}}{X_C}, \qquad X_C = \frac{1}{\omega C}$$

$\omega = 2\pi f$

Putting all values

$$I_{\text{rms}} \cong 1.6 \text{ mA}$$

9. An inductive circuit contains a resistance of 10 ohms and an inductance of 2 henry. If an alternating voltage of 120 V and frequency 60 Hz is applied to this circuit, the current in the circuit would be nearly

(1) 0.32 A (2) 0.80 A (3) 0.48 A (4) 0.16 A

Sol. Answer (4)

R = 10 Ω, L = 10 H, V_{rms} = 120 V, f = 60 Hz

$$I_{\text{rms}} = \frac{V_{\text{rms}}}{Z}$$

$$Z = \sqrt{R^2 + \omega^2 L^2} = \sqrt{(10)^2 + (2\pi \times 60 \times 2)^2}$$

$$\Rightarrow Z = 753.6\ \Omega$$

$$I_{\text{rms}} = \frac{120}{753.6} \cong 0.16 \text{ A}$$

10. A coil and a bulb are connected in series with a 12 volt direct current source. A soft iron core is now inserted in the coil. Then

(1) The intensity of the bulb remains the same (2) The intensity of the bulb decreases

(3) The intensity of the bulb increases (4) Nothing can be said

Sol. Answer (1)

Intensity of bulb remains the same because source is *DC*, so steady state current will be independent of the inductance of the inductor for *DC* circuit,

$$i_{\text{steady}} = \frac{E_{\text{source}}}{R_{\text{bulb}}}$$

11. When 100 volt d.c. is applied across a solenoid, a current of 1.0 A flows in it. When 100 volt a.c. is applied across the same coil, the current drops to 0.5 A. If the frequency of a.c. source is 50 Hz the impedance and inductance of the solenoid is

(1) 200 ohm and 0.55 henry (2) 100 ohm and 0.86 henry

(3) 200 ohm and 1.0 henry (4) 100 ohm and 0.93 henry

Sol. Answer (1)

When there is direct current, $\omega = 0$

$X_L = 0$, so only R is there

So, $V = IR$

$100 = 1(R) \Rightarrow R = 100\ \Omega$

When, $f = 50$ Hz,

$$V = IZ$$
$$100 = (0.5)^2$$

Impedance $z = 200\ \Omega$

$$Z = \sqrt{X_L^2 + R^2}$$
$$200 = \sqrt{X_L^2 + (100)^2}$$
$$40000 = X_L^2 + 10000$$
$$X_L^2 = 30{,}000$$
$$X_L = 100\sqrt{3}\ \Omega$$

Also $X_L = \omega L$

$$100\sqrt{3} = 2\pi f L$$

$$L = \frac{100\sqrt{3}}{2 \times 3.14 \times 50} = \frac{1.73}{3.14} = 0.55\ \text{H}$$

12. In an *LCR* series circuit $R = 10\ \Omega$, $X_L = 8\ \Omega$ and $X_C = 6\ \Omega$. The total impedance of the circuit is

(1) 10.2 Ω (2) 17.2 Ω (3) 10 Ω (4) None of these

Sol. Answer (1)

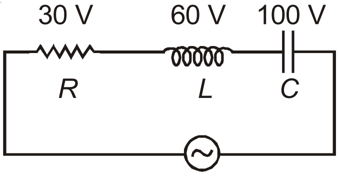
$R = 10\ \Omega$, $X_L = 8\ \Omega$ and $X_C = 6\ \Omega$

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$= \sqrt{(10)^2 + 2^2}$$

$$= \sqrt{104} \approx 10.2\ \Omega$$

13. In a series *RLC* circuit, potential differences across *R*, *L* and *C* are 30 V, 60 V and 100 V respectively as shown in figure. The e.m.f. of source (in volts) is



(1) 190 (2) 70 (3) 50 (4) 40

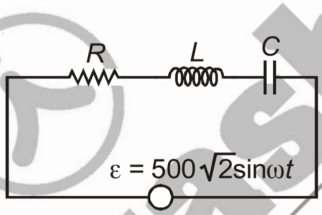
Sol. Answer (3)

$$\text{emf} = V_{\text{rms}} = \sqrt{V_R^2 + (V_L - V_C)^2}$$

$$= \sqrt{(30)^2 + (100-60)^2}$$

$$= \sqrt{(30)^2 + (40)^2} = 50 \text{ V}$$

14. In a series RLC circuit, the r.m.s. voltage across the resistor and the inductor are respectively 400 V and 700 V. If the equation for the applied voltage is $\varepsilon = 500\sqrt{2}\,\sin\omega t$, then the peak voltage across the capacitor is



(1) 1200 V (2) $1200\sqrt{2}$ V (3) 400 V (4) $400\sqrt{2}$ V

Sol. Answer (4)

$$\varepsilon = 500\sqrt{2}\,\sin\omega t$$

V_R = 400 V, V_L = 700 V

$$\varepsilon_{\text{rms}} = \frac{\varepsilon_0}{\sqrt{2}} = \frac{500\sqrt{2}}{\sqrt{2}} = 500 \text{ V}$$

$$\varepsilon_{\text{rms}} = \sqrt{V_R^2 + (V_L - V_C)^2}$$

$$(500)^2 = (400)^2 + (V_L - V_C)^2$$

$$250000 - 160000 = (V_L - V_C)^2$$

$$90000 = (V_L - V_C)^2$$

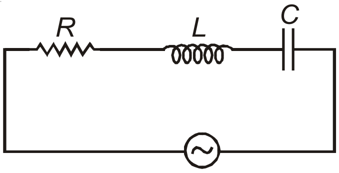
$$V_L - V_C = 300$$

$$V_C = 700 - 300$$

$$V_C = 400 \text{ V}$$

$$V_0 = V_{\text{rms}}\sqrt{2} = 400\sqrt{2} \text{ V}$$

15. In the following circuit the emf of source is $E_0 = 200$ volt, $R = 20\ \Omega$, $L = 0.1$ henry, $C = 10.6$ farad and frequency is variable then the current at frequency $f = 0$ and $f = \infty$ is



(1) Zero, 10 A (2) 10 A, zero (3) 10 A, 10 A (4) Zero, zero

Sol. Answer (4)

$E_0 = 200$ volt, $R = 20\ \Omega$, $L = 0.1$ henry, $C = 10.6$ F

When $f = 0$, $X_L = \omega L = 2\pi fL$

$X_L = 0$

When $f = \infty$, $X_L = \infty$, $X_C = 0$

In both case at least one component has value infinite. So in both cases current will be zero as they are connected in series.

16. In series LCR circuit, the phase difference between voltage across L and voltage across C is

(1) Zero (2) π (3) $\frac{\pi}{2}$ (4) 2π

Sol. Answer (2)

IN LCR circuit ⇒ angle between V_L and $V_C = 180°$ (π rad).

17. With increase in frequency of an a.c. supply, the impedance of an LCR series circuit

(1) Remains constant

(2) Decreases

(3) Increases

(4) Decreases at first, becomes minimum and then increases

Sol. Answer (4)

$$X_L = 2\pi fL, \quad X_C = \frac{1}{2\pi fC}$$

When f is increased, X_L will increase

, X_C will decrease

So $X_L - X_C$ will increase, hence z will increase

18. Mark the incorrect statement

(1) In any AC circuit, the applied instantaneous voltage equals to the algebraic sum of the instantaneous voltages across the series elements of the circuit.

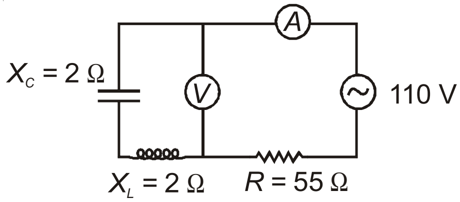
(2) For circuits used for transporting electric power, a low power factor implies large power loss in transmission

(3) Power factor can often be improved by the use of a capacitor of appropriate capacitance in the circuit

(4) The use of a capacitor is avoided in the circuit of an induction coil

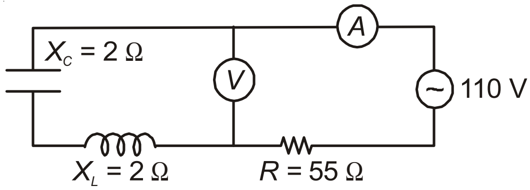
Sol. Answer (4)

19. The reading of ammeter in the circuit is



(1) 2 A (2) 3 A (3) Zero (4) 1 A

Sol. Answer (1)



$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$= \sqrt{(55)^2} = 55\ \Omega$$

$$V = I\,Z$$

$$\frac{110}{55} = I \Rightarrow I = 2\text{ A}$$

20. In an *LCR* circuit, the resonating frequency is 500 kHz. If the value of *L* is doubled and value of *C* is decreased to $\frac{1}{8}$ times of its initial values, then the new resonating frequency in kHz will be

(1) 250 (2) 500 (3) 1000 (4) 2000

Sol. Answer (3)

$f_1 = 500 \times 10^3$ Hz

$$L' \to 2L,\ \ C' \to \frac{1}{8}C$$

$$f = \frac{1}{2\pi\sqrt{LC}} \Rightarrow f \propto \frac{1}{\sqrt{CL}}$$

$$\frac{f_1}{f_2} = \frac{\sqrt{L_2C_2}}{\sqrt{L_1C_1}} = \sqrt{\frac{(2L)\left(\frac{1}{8}C\right)}{LC}}$$

$$\frac{f_1}{f_2} = \frac{1}{2} \Rightarrow f_2 = 1000\text{ kHz}$$

21. In an *LCR* circuit L = 8.0 henry, C = 0.5 μF and R = 100 ohm are in series. The resonance angular frequency is

(1) 500 rad/s (2) 600 rad/s (3) 800 rad/s (4) 1000 rad/s

Sol. Answer (1)

L = 8.0 henry, C = 0.5 μF and R = 100 Ω in series

$$\omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{8\times(0.5)\times10^{-6}}}$$

$$= \frac{1}{\sqrt{4\times10^{-6}}} = \frac{10^3}{2} = 500 \text{ rad/s}$$

22. In series *LCR* circuit voltage leads the current when (Given that ω_0 = resonant angular frequency)

(1) $\omega < \omega_0$ (2) $\omega = \omega_0$ (3) $\omega > \omega_0$ (4) None of these

Sol. Answer (3)

$$X_L = \omega L, \quad X_C = \frac{1}{\omega C}$$

If voltage leads $\Rightarrow$ $X_L > X_C$, for this condition

$\omega > \omega_0$

So it will be an inductive circuit with voltage leading current by 90°.

23. Power factor of an ideal choke coil (*i.e.*, R = 0) is

(1) Near about zero (2) Zero (3) Near about one (4) One

Sol. Answer (2)

$$\cos\phi = \frac{R}{Z} = 0$$

24. At resonance, the value of the power factor in an *LCR* series circuit is

(1) Zero (2) 1 (3) $\frac{1}{2}$ (4) Not defined

Sol. Answer (2)

At resonance, $Z = R$

$$\cos\phi = \frac{R}{Z} = 1 \text{ = Power factor.}$$

25. In an a.c. circuit, the instantaneous values of e.m.f. and current are $E = 200 \sin 314\, t$ (volt) and $i = \sin(314\, t + \pi/3)$ A. The average power consumed in watts is

(1) 100 (2) 200 (3) 50 (4) 25

Sol. Answer (3)

$$P = E_{\text{rms}} I_{\text{rms}} \cos\phi$$

$$= \frac{E}{\sqrt{2}} \frac{I}{\sqrt{2}} \left(\frac{1}{2}\right) \quad \left(\because \ \cos\phi = \frac{\pi}{3} \text{ here}\right)$$

$$= 200 \times 1 \times \frac{1}{2} \times \frac{1}{2}$$

$$= \frac{100}{2} \text{ W}$$

= 50 W

26. An a.c. of frequency f is flowing in a circuit containing only an ideal choke coil of inductance L. If V_0 and i_0 represent peak values of the voltage and the current respectively, the average power given by the source to the choke coil is equal to

(1) $\frac{1}{2} i_0 V_0$

(2) $\frac{1}{2} i_0^2 (2\pi f L)$

(3) Zero

(4) $\frac{1}{2} V_0 (2\pi f L)$

Sol. Answer (3)

For an ideal choke coil $\cos\phi = 0$

so, $P = E_{\text{rms}} I_{\text{rms}} \cos\phi$

$P = 0$

27. When a voltage $V = V_0 \cos \omega t$ is applied across a resistor of resistance R, the average power dissipated per cycle in the resistor is given by

(1) $\frac{V_0}{\sqrt{2}R}$

(2) $\frac{V_0}{\sqrt{2}\omega R}$

(3) $\frac{V_0^2}{2R}$

(4) $\frac{V_0^2}{2\omega R}$

Sol. Answer (3)

$P = E_{\text{rms}} I_{\text{rms}} \cos\phi$

$\cos\phi = \frac{R}{Z}$

$\cos\phi = 1$ for resistor

$$V_{\text{rms}} = \frac{V_0}{\sqrt{2}}$$

$$P = \frac{V_0}{\sqrt{2}}, \ \frac{V_0}{R\sqrt{2}}(1) \quad \left(\because \ I_{\text{rms}} = \frac{V_{\text{rms}}}{R} = \frac{V_0}{R\sqrt{2}}\right)$$

$$P = \frac{V_0^2}{2R}$$

28. In a series *L*-*C* circuit, if $L = 10^{-3}$ H and $C = 3\times10^{-7}$ F is connected to a 100 V-50 Hz a.c. source, the impedance of the circuit is

(1) $\frac{10^5}{3\pi} - 10\pi$ (2) $0.1\pi - 3 \times 10^{-5}\pi$ (3) $\frac{10^5}{3\pi} - \frac{\pi}{10}$ (4) None of these

Sol. Answer (3)

$L = 10^{-3}$ H and $C = 3\times10^{-7}$ F

$f = 50$ Hz, V = 100 V

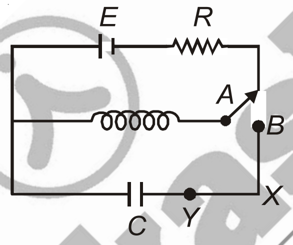
$$Z = \sqrt{(X_L - X_C)^2}$$

$$= (X_L - X_C) = \omega L - \frac{1}{\omega C}$$

Putting ω, *L* & *C*

$$Z = \left(\frac{10^5}{3\pi} - \frac{\pi}{10}\right)$$

29. Switch is in position *A* for long time. At time $t = 0$ it is shifted to position *B*. Find the maximum charge that will accumulate on capacitor



(1) $(\sqrt{LC})\frac{E}{R}$ (2) $\frac{E}{(\sqrt{LC})R}$ (3) $\left(\sqrt{\frac{L}{C}}\right)\frac{E}{R}$ (4) $\left(\sqrt{\frac{C}{L}}\right)\frac{E}{R}$

Sol. Answer (1)

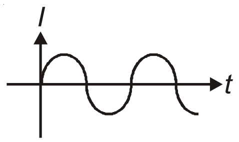
$I_{\max} = \omega_0 q_{\max}$

$I_{\max} = \frac{\varepsilon}{R}$

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

$$q_{\max} = \frac{E/R}{1/\sqrt{LC}} \Rightarrow q_{\max} = (\sqrt{LC})\frac{E}{R}$$

30. In Q.29, which of the following graphs best represents the current flowing from *X* to *Y*?

(1)


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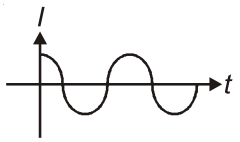

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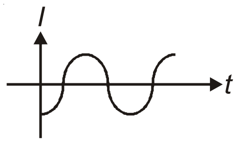

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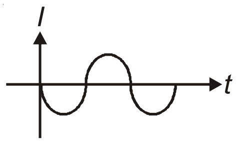


Sol. Answer (2)

At first, current will start charging the capacitor and then it will start oscillating between maximum and minimum value.

or at $t = 0$, $I = i_{\max}$

so, $I = I_0 \cos\omega t$

Hence graph will be as per $\cos\omega t$ with time t.

31. In oscillating LC circuit, the total stored energy is U and maximum charge upon capacitor is Q. When the charge upon the capacitor is $\frac{Q}{2}$, the energy stored in the inductor is

(1) $\frac{U}{2}$ (2) $\frac{U}{4}$ (3) $\frac{4}{3}U$ (4) $\frac{3U}{4}$

Sol. Answer (4)

Initial energy = total energy = $\frac{Q^2}{2C} = U$

$$U' = \frac{Q^2}{4(2C)} \quad \left(\text{as } Q' = \frac{Q}{2}\right)$$

$$= \frac{Q^2}{8C}$$

$$U_{\text{inductor}} = U_{\text{total}} - U_{\text{capacitor}}$$

$$= \frac{Q^2}{2C} - \frac{Q^2}{8C}$$

$$= \frac{3Q^2}{8C} = \frac{3}{4}U$$

SECTION - B

Objective Type Questions

1. The virtual current of 4 A and 50 Hz flows in an AC circuit containing a coil. The power consumed in the coil is 240 W. If the virtual voltage across the coil is 100 V, then its resistance will be

(1) $\frac{1}{3\pi}\,\Omega$ (2) $\frac{1}{5\pi}\,\Omega$ (3) $15\ \Omega$ (4) $\frac{1}{\pi}\,\Omega$

Sol. Answer (3)

$V_{\text{rms}} = I_{\text{rms}}Z$

$100 = 4Z$

$Z = 25\ \Omega$

$P = VI\cos\phi$

$240 = (100)(4)\cos\phi$

$$\cos\phi = \frac{3}{5} = \frac{R}{Z}$$

$$\frac{3}{5} = \frac{R}{25}$$

$R = 15\ \Omega$

2. For an AC circuit the potential difference and current are given by $V = 10\sqrt{2}\sin\omega t$ (in V) and $I = 2\sqrt{2}\cos\omega t$ (in A) respectively. The power dissipated in the instrument is

(1) 20 W (2) 40 W (3) $40\sqrt{2}$ W (4) Zero

Sol. Answer (4)

Here phase difference $\phi = \frac{\pi}{2}$

So, $P = V_{\text{rms}} I_{\text{rms}} \cos\frac{\pi}{2} = 0$

3. If the power factor in an AC circuit changes from $\frac{1}{3}$ to $\frac{1}{9}$ then by what percent reactance will change (approximately), if resistance remains constant?

(1) Increase by 200% (2) Decrease by 200% (3) Increase by 100% (4) Decrease by 100%

Sol. Answer (1)

Power factor $\cos\phi = \frac{R}{Z}$

$$\frac{R}{\sqrt{R^2 + X^2}} = \frac{1}{3} \quad \text{...(1)}$$

$$\frac{R}{\sqrt{R^2 + (X')^2}} = \frac{1}{9} \quad \text{...(2)}$$

Using (1) and (2)

$$X = R\sqrt{8}$$

$$X' = R\sqrt{80}$$

$$\frac{X'}{X} = \sqrt{10}$$

$$\frac{X' - X}{X} = \left(\sqrt{10} - 1\right)$$

so percentage change $= \left(\sqrt{10} - 1\right) \times 100$

$\cong 200\%$

4. A step-up transformer operates on 220 V line and supplies 2.2 A. The ratio of primary and secondary winding is 11 : 50. The output voltage in the secondary is

(1) 220 V (2) 100 V (3) 1000 V (4) 0 V

Sol. Answer (3)

$$\frac{N_P}{N_S} = \frac{V_P}{V_S}$$

$$V_S = \frac{N_S V_P}{N_P}$$

$$= \frac{50}{11}(220) = 1000 \text{ V}$$

5. An alternating power supply of 220 V is applied across a series circuit of resistance $10\sqrt{3}\ \Omega$, capacitive reactance 40 Ω and inductive reactance 30 Ω. The respective currents in the circuit for zero and infinite frequencies are

(1) 2 A, $\frac{1}{2}$ A (2) 0 A, 10 A (3) 10 A, 0 A (4) 0 A, 0 A

Sol. Answer (4)

For $f = 0$, $X_L = 0$ and $f \to \infty$, $X_C = 0$

6. In L-C oscillation, maximum charge on capacitor can be Q. If at any instant, electric energy and magnetic energy associated with circuit is equal, then charge on capacitor at that instant is

(1) $\frac{Q}{\sqrt{2}}$ (2) $\frac{Q}{2}$ (3) $\sqrt{3}\frac{Q}{2}$ (4) $\frac{3Q}{2}$

Sol. Answer (1)

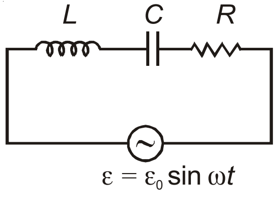
$$\text{Magnetic energy} = \frac{\text{Total energy}}{2}$$

$$\text{Electric energy} = \frac{\text{Total energy}}{2}$$

$$\frac{1}{2}\left(\frac{Q^2}{2C}\right) = \frac{(Q')^2}{2C}$$

$$Q' = \frac{Q}{\sqrt{2}}$$

7. A series *LCR* circuit consists of an inductor *L* a capacitor *C* and a resistor *R* connected across a source of emf $\varepsilon = \varepsilon_0 \sin \omega t$. When $\omega L = \frac{1}{\omega C}$ the current in the circuit is I_0 and if angular frequency of the source is changed to ω', the current in the circuit becomes $\frac{I_0}{2}$, then the value of $\left|\omega' L - \frac{1}{\omega' C}\right|$ is



(1) *R* (2) $\sqrt{3}R$ (3) $\sqrt{15}R$ (4) Zero

Sol. Answer (2)

$$I_0 = \frac{E_0}{R}$$

$$\Rightarrow \quad \frac{I_0}{2} = \frac{E_0}{\sqrt{R^2 + \left(W'L - \frac{1}{W'C}\right)^2}} \quad \text{...(i)}$$

$$R = \frac{E_0}{I_0}$$

So in (i)

$$R^2 + \left(W'L - \frac{1}{W'C}\right) = 4R^2$$

$$\left(W'L - \frac{1}{W'C}\right)^2 = 3R^2$$

$$W'L - \frac{1}{W'C} = R\sqrt{3}$$

8. A direct current of 10 A is superimposed on an alternating current $I = 40 \cos \omega t$ (A) flowing through a wire. The effective value of the resulting current will be

(1) $10\sqrt{2}$ A (2) $20\sqrt{2}$ A (3) $20\sqrt{3}$ A (4) 30 A

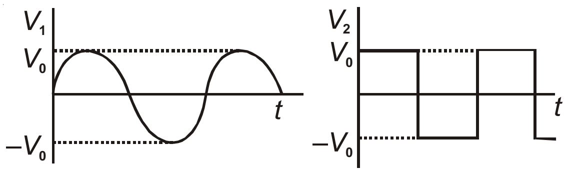
Sol. Answer (4)

$$I_{\text{net}} = \sqrt{(10)^2 + \left(\frac{40}{\sqrt{2}}\right)^2}$$

$$I_{\text{net}} = \sqrt{100 + 800}$$

$$= \sqrt{900} = 30 \text{ A}$$

9. The sinusoidal potential difference V_1 shown in figure applied across a resistor R produces heat at a rate W. What is the rate of heat dissipation when the square wave potential difference V_2 as shown in figure is applied across the resistor?



(1) $\frac{W}{2}$ (2) W (3) $\sqrt{2}W$ (4) $2W$

Sol. Answer (4)

Power (P) = $\frac{V_{\text{rms}}^2}{R}$

According to the problem

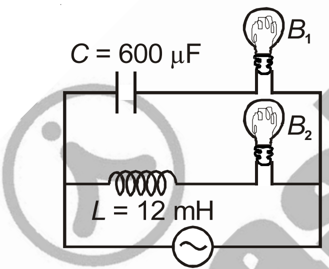
$$w = \frac{\left(\frac{V_0}{\sqrt{2}}\right)^2}{R}$$

for square wave $V_{\text{rms}} = V_0$

$$W' = \frac{V_0^2}{R}$$

$$\frac{W'}{W} = 2, \quad W' = 2W$$

10. In the circuit shown in figure, if both the bulbs B_1 and B_2 are identical then



(1) Both bulbs have equal brightness

(2) B_2 will be brighter than B_1

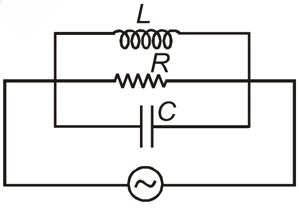
(3) As the frequency is increased, brightness of B_1 will increase and that of B_2 will decrease

(4) As the frequency is decreased, the brightness of B_1 will increase and that of B_2 will decrease

Sol. Answer (3)

As frequency is increased, X_C will decrease and X_L will increase, so brightness of B, will increase and that of B_2 will decrease.

11. In the following circuit rms current through inductor is 0.8 A, the rms current through capacitor is 0.4 A and rms current through resistor is 0.3 A, the current delivered by a.c. source is



(1) 0.7 A (2) 1.5 A (3) 0.5 A (4) Approximately 1 A

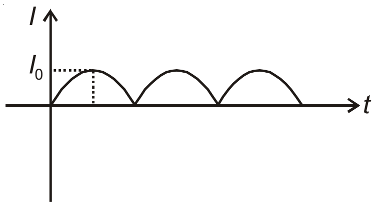
Sol. Answer (3)

$$I = \sqrt{I_R^2 + (I_L - I_C)^2}$$

$$= \sqrt{(0.3)^2 + (0.8 - 0.4)^2}$$

$$= \sqrt{(0.3)^2 + (0.4)^2} = 0.5 \text{ A}$$

12. The output current versus time curve for a rectifier is shown in the figure. The average value of output current in this case is



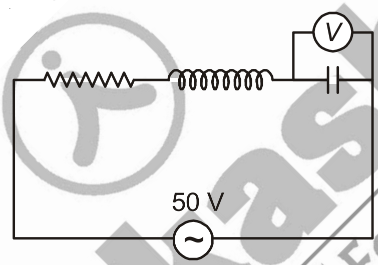
(1) 0 (2) $\frac{I_0}{2}$ (3) $\frac{2I_0}{\pi}$ (4) I_0

Sol. Answer (3)

$$I_{\text{avg}} = \frac{\int I dt}{\int dt}$$

So $I_{\text{avg}} = \frac{2I_0}{\pi}$

13. If reading of voltmeter V shown in the figure at resonance is 200 V, then the quality factor of the circuit is



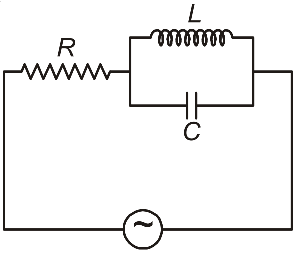
(1) 2 (2) 4 (3) 1 (4) 3

Sol. Answer (2)

$$Q = \frac{\omega L}{R} = \frac{X_L}{R}\left(\frac{i}{i}\right)$$

So Q can be written as $Q = \frac{V_L}{V_R} = \frac{200}{50} = 4$

14. In the given A.C. circuit, the instantaneous current through inductor and capacitor are 0.8 A and 0.4 A respectively. The instantaneous current through resistor is



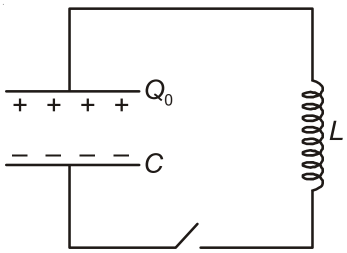
(1) 1.2 A (2) 0.6 (3) 0.4 (4) $\sqrt{0.8}$ A

Sol. Answer (3)

$I_R = i_L - i_C$

$I_R = 0.4$

15. A capacitor of capacitance C has initial charge Q_0 and connected to an inductor of inductance L as shown. At $t = 0$ switch S is closed. The current through the inductor when energy in the capacitor is three times the energy of inductor is



(1) $\dfrac{Q_0}{2\sqrt{LC}}$ (2) $\dfrac{Q_0}{\sqrt{LC}}$ (3) $\dfrac{2Q_0}{\sqrt{LC}}$ (4) $\dfrac{4Q_0}{\sqrt{LC}}$

Sol. Answer (1)

$$E_{\text{total}} = E_i + E_c = \frac{Q_0^2}{2C}$$

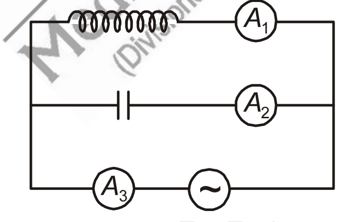
$$4E_i = \frac{Q_0^2}{2C}$$

$$E_i = \frac{Q_0^2}{8C} = \frac{1}{2}Li^2$$

$$i^2 = \frac{Q_0^2}{4LC}$$

$$i = \frac{Q_0}{2\sqrt{LC}}$$

16. An inductor L and a capacitor C ac connected in the circuit as shown in the figure. The frequency of source is equal to resonance frequency of the circuit. Which ammeter will read zero ampere?



$E = E_0 \sin \omega t$

(1) A_1 (2) A_3 (3) A_2 (4) None of these

Sol. Answer (2)

Given that $\omega L = \dfrac{1}{\omega C}$

So net current $I_L - I_C = 0$ $(\because\ I_L = I_C)$

So A_3 reads zero ampere.

17. Average energy loss due to inductance (L) of circuit is (symbols have their usual meaning)

(1) i_{rms}^2 (2) $\dfrac{V_{\text{rms}}^2}{X_L}$ (3) $i_0^2 X_L$ (4) Zero

Sol. Answer (4)

No energy will be lost as there is no resistor (inductor only stores energy).

18. The virtual current of 4 A and 50 Hz flows in an ac circuit containing a coil. The power consumed in the coil is 240 W. If the virtual voltage across the coil is 100 V, then its resistance will be

(1) $\dfrac{1}{3\pi}\,\Omega$ (2) $\dfrac{1}{5\pi}\,\Omega$ (3) $15\ \Omega$ (4) $\dfrac{1}{\pi}\,\Omega$

Sol. Answer (3)

$$P = VI\cos\phi$$

$$240 = 4(100)\cos\phi$$

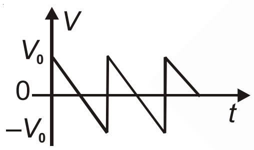
$$\frac{3}{5} = \cos\phi = \frac{R}{Z} \qquad \text{...(i)}$$

and $4Z = 100 \Rightarrow Z = 25\ \Omega$

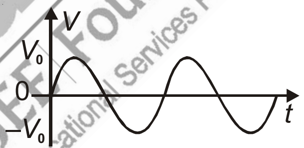
So in (i) $\dfrac{3}{5} = \dfrac{R}{25} \Rightarrow R = 15\ \Omega$

19. Different alternating voltages are given below. In which case the peak value and rms value are same?

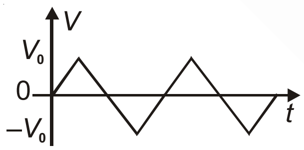
(a)



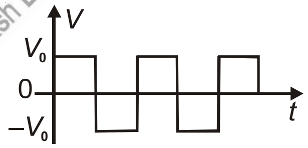
(b)



(c)



(d)



(1) (c) only (2) (d) only (3) (a), (b) & (c) (4) (b) & (c)

Sol. Answer (2)

For square pulse

$V_{\text{rms}} = V_{\text{peak}}$

20. Two cables of copper are of equal lengths. One of them has a single wire of area of cross-section A, while other has 10 wires of cross-sectional area $\dfrac{A}{10}$ each. Give their suitability for transporting A.C. and D.C.

(1) Only multiple strands for A.C, either for D.C.

(2) Only multiple strands for A.C, only single strand for D.C.

(3) Only single strand for D.C, either for A.C.

(4) Only single strand for A.C, either for D.C.

Sol. Answer (1)

21. An AC source is rated 222 V, 60 Hz. The average voltage is calculated in a time interval of 16.67 ms. It

(1) Must be zero (2) May be zero (3) Is never zero (4) Is $(111\sqrt{2})$ V

Sol. Answer (1)

$$T=\frac{2\pi}{W}=\frac{2\pi}{2\pi(60)}=16.67 \text{ ms}$$

$\Rightarrow$ for time interval 16.67 ms (which is time period) average volatge will always be zero.

22. In India electricity is supplied for domestic use at 220 V. It is supplied at 110 V in USA. If the resistance of a 60 W bulb for use in India is *R*, the resistance of a 60 W bulb for use in USA will be

(1) R (2) $2R$ (3) $\frac{R}{4}$ (4) $\frac{R}{2}$

Sol. Answer (3)

$$R=\frac{V^2}{P}$$

$$R=\frac{(220)^2}{60}$$

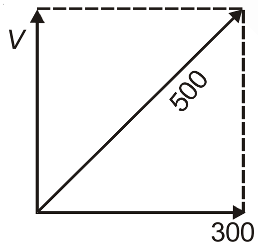
$$R'=\frac{(110)^2}{60}$$

$$\frac{R}{R'}=4\Rightarrow R'=\frac{R}{4}$$

23. An electric bulb of 100 W – 300 V is connected with an AC supply of 500 V and $\frac{150}{\pi}$ Hz. The required inductance to save the electric bulb is

(1) 2 H (2) $\frac{1}{2}$ H (3) 4 H (4) $\frac{1}{4}$ H

Sol. Answer (3)



$$V^2+(300)^2=(500)^2$$

$$V^2=(400)^2$$

V = 400

and $I=\frac{100}{300}=\frac{1}{3}$ A

$$V=IX_L$$

$$400=\left(\frac{1}{3}\right)X_L$$

$$X_L=1200\ \Omega$$

$$(2\pi f)L=1200\ \Omega$$

So L = 4 H

24. In a RLC circuit capacitance is changed from C to $2C$. For the resonant frequency to remain unchanged, the inductance should be changed from L to

(1) $4\,L$ (2) $2\,L$ (3) $\frac{L}{2}$ (4) $\frac{L}{4}$

Sol. Answer (3)

$$W = \frac{1}{\sqrt{LC}}$$

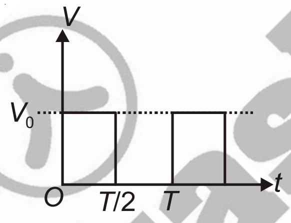
$$\sqrt{LC} = \sqrt{L'2C}$$

$$\Rightarrow L' = \frac{L}{2} \Rightarrow L' = \frac{L}{2}$$

SECTION - C

Previous Years Questions

1. The r.m.s. value of potential difference V shown in the figure is



(1) $\frac{V_0}{2}$ (2) $\frac{V_0}{\sqrt{3}}$ (3) V_0 (4) $\frac{V_0}{\sqrt{2}}$

Sol. Answer (4)

$$I_{\text{rms}} = \sqrt{\frac{\int I^2 dt}{\int dt}}$$

$$V_{\text{rms}} = \sqrt{\frac{\int V^2 dt}{\int dt}}$$

from $O \rightarrow \frac{T}{2}$, $V = V_0$ and $\frac{T}{2} \rightarrow T$, $V = 0$

So $V_{\text{rms}} = \sqrt{\frac{V_0^2 \, T/2}{T}} = \frac{V_0}{\sqrt{2}}$

2. In an ac circuit an alternating voltage $e = 200\sqrt{2}\sin 100t$ volts is connected to capacitor of capacity 1 μF. The r.m.s. value of the current in the circuit is

(1) 20 mA (2) 10 mA (3) 100 mA (4) 200 mA

Sol. Answer (1)

$$X_C = \frac{10^6}{100 \times 1} = 10^4$$

$$I_{\text{rms}} = \frac{V_{\text{rms}}}{X_C}$$

$$I_{\text{rms}} = \frac{200}{10^4} = 0.02 \text{ A} = 20 \text{ mA}$$

3. In an A.C. circuit, I_{rms} and I_0 are related as

(1) $I_{\text{rms}} = \pi I_0$ (2) $I_{\text{rms}} = \sqrt{2}\, I_0$ (3) $I_{\text{rms}} = \frac{I_0}{\pi}$ (4) $I_{\text{rms}} = \frac{I_0}{\sqrt{2}}$

Sol. Answer (4)

4. The electric current in a circuit is given by $i = 3 \sin \omega t + 4 \cos \omega t$. The rms current is

(1) $\frac{5}{\sqrt{2}}$ (2) 5 (3) $\frac{4}{\sqrt{2}}$ (4) $\frac{3}{\sqrt{2}}$

Sol. Answer (1)

$$I = 3\sin\omega t + 4\cos\omega t$$

$$= 3\sin\omega t + 4\cos\left(\omega t + \frac{\pi}{2}\right)$$

$$I_0 = \sqrt{I_1^2 + I_2^2 + 2I_1I_2\cos\frac{\pi}{2}}$$

I_1 is max of $I_1 = 3$

and $I_2 = 4$

$$I_0 = \sqrt{(3)^2 + (4)^2 + 2(3)(4)\cos\frac{\pi}{2}}$$

$= 5$

$$I_{\text{rms}} = \frac{I_0}{\sqrt{2}} = \frac{5}{\sqrt{2}}$$

5. The instantaneous values of alternating current and voltages in a circuit are given as

$i = \frac{1}{\sqrt{2}}\sin(100\pi t)$ ampere

$e = \frac{1}{\sqrt{2}}\sin\left(100\pi t + \frac{\pi}{3}\right)$ volt

The average power in watts consumed in the circuit is

(1) $\frac{1}{4}$ (2) $\frac{\sqrt{3}}{4}$ (3) $\frac{1}{2}$ (4) $\frac{1}{8}$

Sol. Answer (4)

$$P = V_{\text{rms}} I_{\text{rms}} \cos\phi$$

$$I_{\text{rms}} = \frac{I_0}{\sqrt{2}} = \frac{1}{(\sqrt{2})(\sqrt{2})} = \frac{1}{2}$$

$$V_{\text{rms}} = \frac{V_0}{\sqrt{2}} = \frac{1}{(\sqrt{2})(\sqrt{2})} = \frac{1}{2}$$

So, $P = \left(\frac{1}{2}\right)\left(\frac{1}{2}\right)\cos\frac{\pi}{3} = \left(\frac{1}{4}\right)\left(\frac{1}{2}\right) = \frac{1}{8}$ W

6. In an a.c. circuit the e.m.f. (*e*) and the current (*i*) at any instant are given respectively by

$$e = E_0 \sin\omega t$$
$$i = I_0 \sin(\omega t - \phi)$$

The average power in the circuit over one cycle of a.c. is

(1) $E_0 I_0$ (2) $\frac{E_0 I_0}{2}$ (3) $\frac{E_0 I_0}{2}\sin\phi$ (4) $\frac{E_0 I_0}{2}\cos\phi$

Sol. Answer (4)

$$P_{\text{avg}} = \frac{E_0 I_0}{2}\cos\phi$$

7. In an electrical circuit *R*, *L*, *C* and an *a.c.* voltage source are all connected in series. When *L* is removed from the circuit, the phase difference between the voltage and the current in the circuit is $\frac{\pi}{3}$. If instead, *C* is removed from the circuit, the phase difference is again $\frac{\pi}{3}$. The power factor of the circuit is

(1) 1 (2) $\frac{\sqrt{3}}{2}$ (3) $\frac{1}{2}$ (4) $\frac{1}{\sqrt{2}}$

Sol. Answer (1)

Magnitude of phase difference is constant ⇒ $X_L = X_C$

So $\cos\phi = \frac{R}{Z} = \frac{R}{R} = 1$

8. An ac voltage is applied to a resistance *R* and inductor *L* in series. If *R* and the inductive reactance are both equal to 3 Ω, the phase difference between the applied voltage and the current in the circuit is

(1) Zero (2) $\frac{\pi}{6}$ (3) $\frac{\pi}{4}$ (4) $\frac{\pi}{2}$

Sol. Answer (3)

$\cos\phi = \frac{R}{\sqrt{R^2 + X_L^2}} \Rightarrow \cos\phi = \frac{3}{3\sqrt{2}}$, So ϕ = 45°

9. A coil has resistances 30 ohm and inductive reactance 20 ohm at 50 Hz frequency. If an AC source, of 200 volt, 100 Hz is connected across the coil, the current in the coil will be

(1) $\frac{20}{\sqrt{13}}$ A (2) 2.0 A (3) 4.0 A (4) 8.0 A

Sol. Answer (3)

$$20 = 100\,\pi L$$

$$\frac{1}{5\pi} = L$$

$$X_L = \omega L = 2\pi(100)\left(\frac{1}{5\pi}\right) = 40\ \Omega$$

and $R = 30\ \Omega$

$$\Rightarrow\quad Z = \sqrt{R^2 + X_L{}^2} = \sqrt{(30)^2 + (40)^2} = 50\ \Omega$$

So $I = \frac{200}{50} = 4$ A

10. An *L*-*C*-*R* circuit is connected to a source of A.C. current. At resonance, the phase difference between the applied voltage and the current in the circuit, is

(1) π (2) Zero (3) $\frac{\pi}{4}$ (4) $\frac{\pi}{2}$

Sol. Answer (2)

$\phi = 0$ at resonance

11. The value of quality factor is

(1) $\frac{\omega L}{R}$ (2) $\frac{1}{\omega^2 RC}$ (3) $\sqrt{LC}$ (4) $\frac{L}{R}$

Sol. Answer (1)

$$Q = \frac{\omega L}{R}$$

12. A capacitor of capacity *C* has reactance *X*. If capacitance and frequency become double then reactance will be

(1) 4*X* (2) $\frac{X}{2}$ (3) $\frac{X}{4}$ (4) 2*X*

Sol. Answer (3)

$$X = \frac{1}{2\pi fC},\quad X' = \frac{1}{2\pi(2f)(2C)}$$

$$\Rightarrow\quad \frac{X}{X'} = 4,\quad \text{So } X' = \frac{X}{4}$$

13. For a series LCR circuit the power loss at resonance is

(1) $\dfrac{V^2}{\left[\omega L - \dfrac{1}{\omega C}\right]}$ (2) $I^2L\omega$ (3) I^2R (4) $\dfrac{V^2}{C\omega}$

Sol. Answer (3)

Power loss = I^2R

14. In a circuit L, C and R are connected in series with an alternating voltage source of frequency f. The current leads the voltage by 45°. The value of C is

(1) $\dfrac{1}{\pi f(2\pi f\ L - R)}$ (2) $\dfrac{1}{2\pi f(2\pi f\ L - R)}$ (3) $\dfrac{1}{\pi f(2\pi f\ L + R)}$ (4) $\dfrac{1}{2\pi f(2\pi f\ L + R)}$

Sol. Answer (2)

$$\cos 45^\circ = \frac{R}{\sqrt{R^2 + \left(\omega L - \dfrac{1}{\omega C}\right)^2}}$$

$$R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2 = 2R^2$$

$$\omega L - \frac{1}{\omega C} = R$$

$$\omega C = \frac{1}{\omega L - R}$$

$$C = \frac{1}{\omega(\omega L - R)} = \frac{1}{2\pi f\,(2\pi f L - R)}$$

15. A coil of inductive reactance 31 Ω has a resistance of 8 Ω. It is placed in series with a condenser of capacitative reactance 25 Ω. The combination is connected to an a.c. source of 110 V. The power factor of the circuit is

(1) 0.33 (2) 0.56 (3) 0.64 (4) 0.80

Sol. Answer (4)

$$\cos\phi = \frac{R}{Z}$$

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

X_L = 31 Ω, X_C = 25 Ω

So $Z = \sqrt{8^2 + (31 - 25)^2} = 10$

So $\cos\phi = \dfrac{8}{10} = \dfrac{4}{5} = 0.8$

16. Power dissipated in an *LCR* series circuit connected to an a.c. source of emf ε is

(1) $\dfrac{\varepsilon^2 R}{\sqrt{R^2+\left(L\omega-\dfrac{1}{C\omega}\right)^2}}$ (2) $\dfrac{\varepsilon^2 R}{\left[R^2+\left(L\omega-\dfrac{1}{C\omega}\right)^2\right]}$

(3) $\dfrac{\varepsilon^2\sqrt{R^2+\left(L\omega-\dfrac{1}{C\omega}\right)^2}}{R}$ (4) $\dfrac{\varepsilon^2\left[R^2+\left(L\omega-\dfrac{1}{C\omega}\right)^2\right]}{R}$

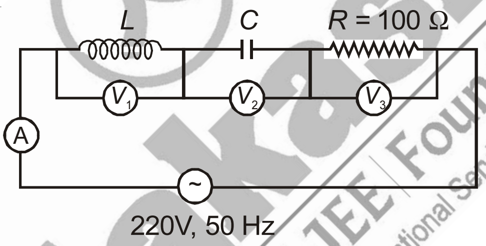
Sol. Answer (2)

$$P=\left(\frac{V_{\text{rms}}^2}{Z}\right)\cos\phi$$

now in problem

$$P=\frac{\varepsilon^2}{Z}\cdot\frac{R}{Z}=\frac{\varepsilon^2 R}{Z^2}=\frac{\varepsilon^2 R}{\sqrt{R^2+\left(\omega L-\dfrac{1}{\omega C}\right)^2}}$$

17. In the given circuit the reading of voltmeter V_1 and V_2 are 300 volts each. The reading of the voltmeter V_3 and ammeter *A* are respectively



(1) 100 V, 2.0 A (2) 150 V, 2.2 A (3) 220 V, 2.2 A (4) 220 V, 2.0 A

Sol. Answer (3)

Potential drop on L & C is same ⇒ Circuit is at resonance

So V_3 = 220 V

and $I=\dfrac{220}{R}=\dfrac{220}{100}=2.2$ A

18. A capacitor and a bulb are connected in series with a source of alternating emf. If a dielectric slab is inserted between the plates of the capacitor, then

(1) The brightness of the bulb decreases (2) The brightness of the bulb increases

(3) The brightness of the bulb remains same (4) The brightness of the bulb becomes zero

Sol. Answer (2)

$$i=\frac{E}{\sqrt{R^2+\left(\dfrac{1}{\omega C}\right)^2}}$$

$\dfrac{1}{\omega C}$ will decrease, so *i* will increase. Hence the brightness of the bulb increases.

19. The primary winding of a transformer has 500 turns whereas its secondary has 5000 turns. The primary is connected to an A.C. supply 20 V, 50 Hz. The secondary will have an output of

(1) 2 V, 50 Hz (2) 2 V, 5 Hz (3) 200 V, 50 Hz (4) 200 V, 500 Hz

Sol. Answer (3)

$$\frac{N_P}{N_S}=\frac{V_P}{V_S}$$

$$\frac{500}{20}=\frac{5000}{\text{V}}$$

V = 200 V, no change in frequency.

20. The primary and secondary coils of a transformer have 50 and 1500 turns respectively. If the magnetic flux ϕ linked with the primary coil is given by $\phi = \phi_0 + 4t$ where ϕ is in weber, t is time in second and ϕ_0 is a constant, the output voltage across the secondary coil is

(1) 120 volt (2) 220 volt (3) 30 volt (4) 90 volt

Sol. Answer (1)

$$\varepsilon=\frac{d\phi}{dt}=4$$

$$\frac{N_P}{N_S}=\frac{V_P}{V_S}$$

$$\frac{50}{4}=\frac{1500}{\text{V}}\Rightarrow \text{ V = 120 V.}$$

21. A transformer is used to light a 100 W and 110 V lamp from a 220 V mains. If the main current is 0.5 A, then the efficiency of the transformer is approximately

(1) 50% (2) 90% (3) 10% (4) 30%

Sol. Answer (2)

100 = 110 I

$$I=\frac{10}{11}\text{ A}$$

22. What is the value of inductance L for which the current is maximum in a series LCR circuit with $C = 10\ \mu\text{F}$ and $\omega = 1000\ \text{s}^{-1}$?

(1) 1 mH (2) Cannot be calculated unless R is known

(3) 10 mH (4) 100 mH

Sol. Answer (4)

$X_L = X_C$ for maximum current

$$WL=\frac{1}{WC}$$

$$1000L=\frac{10}{1000\times 10}$$

$$L = 100\text{ mH}$$

23. A 220 volt input is supplied to a transformer. The output circuit draws a current of 2.0 ampere at 440 volts. If the efficiency of the transformer is 80%, the current drawn by the primary windings of the transformer is

(1) 5.0 ampere (2) 3.6 ampere (3) 2.8 ampere (4) 2.5 ampere

Sol. Answer (1)

$$\frac{P_{\text{out}}}{P_{\text{input}}} = 0.8 \quad (\text{given})$$

$$\frac{V_{\text{out}} I_{\text{out}}}{V_{\text{input}} I_{\text{input}}} = 0.8$$

$$\frac{2 \times 440}{(220) I} = 0.8$$

$$I = \frac{4}{0.8} = 5.0 \text{ A}$$

24. A step-up transformer operates on 220 V line and supplies 2.2 A. The ratio of primary and secondary winding is 11 : 50. The output voltage in the secondary is

(1) 220 V (2) 100 V (3) 1000 V (4) Zero

Sol. Answer (3)

$$\frac{N_P}{N_S} = \frac{V_P}{V_S}$$

$$\frac{11}{50} = \frac{220}{V} \Rightarrow V = 1000 \text{ V}$$

25. A coil of self inductance L is connected in series with a bulb and an A.C. source. Brightness of the bulb decreases when

(1) Number of turns in the coil is reduced

(2) A capacitance of reactance $X_C = X_L$ is included in the same circuit

(3) An iron rod is inserted in the coil

(4) Frequency of the A.C. source is decreased

Sol. Answer (3)

$$i = \frac{E^2}{\sqrt{R^2 + (WL)^2}} \qquad \text{...(1)}$$

An iron rod is inserted in the coil, L will increase hence i will decrease.

26. A condenser of capacity C is charged to a potential difference of V_1. The plates of the condenser are then connected to an ideal inductor of inductance L. The current through the inductor when the potential difference across the condenser reduces to V_2 is

(1) $\left(\frac{C(V_1 - V_2)^2}{L}\right)^{1/2}$ (2) $\frac{C(V_1^2 - V_2^2)}{L}$ (3) $\frac{C(V_1^2 + V_2^2)}{L}$ (4) $\left(\frac{C(V_1^2 - V_2^2)}{L}\right)^{1/2}$

Sol. Answer (4)

27. A transformer having efficiency of 90% is working on 200 V and 3 kW power supply. If the current in the secondary coil is 6A, the voltage across the secondary coil and the current in the primary coil respectively are

(1) 300 V, 15 A (2) 450 V, 15 A (3) 450 V, 13.5 A (4) 600 V, 15 A

Sol. Answer (2)

SECTION - D

Assertion-Reason Type Questions

1. A : Direct current is more dangerous than Alternating current of same value.

   R : An electrocuted person sticks to direct current line. while alternating current repels the person from the line.

Sol. Answer (4)

2. A : AC can be transmitted over long distances at high voltage without much power loss.

   R : The average value of AC is defined over any half cycle.

Sol. Answer (3)

3. A : An inductor and a capacitor are called low pass filter and high pass filter respectively.

   R : Reactance of an inductor is low for low frequency signals and that of a capacitor is high for high frequency signals.

Sol. Answer (3)

4. A : The chief characteristic of series resonant circuit is voltage magnification.

   R : At resonance the voltage drop across inductance (or capacitance) is Q times the applied voltage.

Sol. Answer (1)

5. A : Wires of the transmission lines carrying A.C. are made of multiple strands.

   R : A.C. flows on surface of the conductor.

Sol. Answer (1)

6. A : The ammeters and voltmeters used for measuring alternating current and voltages have non-uniform divisions on their scales.

   R : The instruments used for measuring alternating current and voltage are based on heating effect of current.

Sol. Answer (1)

7. A : A series resonant circuit is also known as an acceptor circuit.

   R : For large value of Ohmic resistance, the quality factor of a series resonant circuit is high.

Sol. Answer (3)

8. A : For a practical choke coil the power factor is very small.

   R : In a practical choke coil the power dissipation reduces if frequency of the a.c. is increased.

Sol. Answer (2)

9. A : If a current has both ac and dc components, then a dc ammeter used to measure this current will measure the average value of the total current.

   R : The scale of a dc ammeter is uniformly divided.

Sol. Answer (2)

❑ ❑ ❑

Chapter 8

Electromagnetic Waves

Solutions

SECTION - A

Objective Type Questions

1. According to modified Ampere's circuital law

(i_D = displacement current)

(1) $\oint \vec{B} \cdot \vec{dl} = \mu_0\left(i_C + \varepsilon_0 \frac{d\phi_E}{dt}\right)$ (2) $\oint \vec{B} \cdot \vec{dl} = \mu_0\ \varepsilon_0 \frac{d\phi_E}{dt}$

(3) $\oint \vec{B} \cdot \vec{dl} = \mu_0\, i$ (4) $\oint \vec{B} \cdot \vec{d\,l} = \mu_0\left(i_C \frac{d\phi_E}{dt} + i_D\right)$

Sol. Answer (1)

According to modified Ampere's circuital law.

$$\oint \vec{B} \cdot \vec{dl} = \mu_0\left(i_C + \varepsilon_0 \frac{d\phi_E}{dt}\right)$$

2. Displacement current is set up between the plates of a capacitor when the potential difference across the plates is

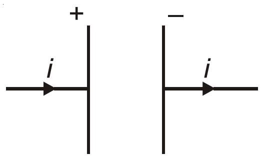
(1) Maximum (2) Zero (3) Minimum (4) Varying

Sol. Answer (4)

Displacement current, $I_d = A\varepsilon_0 \frac{dE}{dt}$

So, the potential difference has to change with time

3. A parallel plate capacitor with circular plates of radius R is being charged as shown. At the instant shown, the displacement current in the region between the plates enclosed between $\frac{R}{2}$ and R is given by



(1) $\frac{3}{4}i$ (2) $\frac{1}{4}i$ (3) $3\,i$ (4) $\frac{4}{3}i$

Sol. Answer (1)

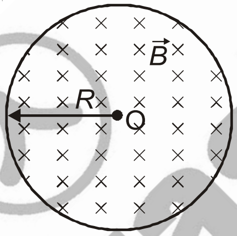
$$I_d = \varepsilon_0 A\frac{dE}{dt} = \varepsilon_0\left(\pi R^2\right)\frac{dE}{dt} = i$$

$$I'_d = \varepsilon_0\left(\pi R^2 - \frac{\pi R^2}{4}\right)\frac{dE}{dt}$$

$$= \frac{3}{4}\varepsilon_0 \pi R^2 \frac{dE}{dt}$$

$$I'_d = \frac{3}{4}i$$

4. Figure shows a circular region of radius R in which uniform magnetic field B exists. The magnetic field is increasing at a rate $\frac{dB}{dt}$. The induced electric field at a distance r from the centre for $r < R$ is



(1) $\frac{dB}{dt}\frac{r}{2}$ (2) Zero (3) $\frac{dB}{dt}$ (4) $\frac{dB}{dt}\frac{R^2}{2r}$

Sol. Answer (1)

Rate of increase of $B = \frac{dB}{dt}$

$$E_{in} \times 2\pi r = -\frac{d\phi}{dt}$$

or $$E \times 2\pi r = -A\frac{dB}{dt}$$

$$E \times 2\pi r = -\pi r^2\frac{dB}{dt}$$

$$\therefore \quad E = \frac{-r}{2}\frac{dB}{dt}$$

5. The speed of electromagnetic waves depends upon

(1) Wavelength (2) Frequency

(3) Intensity (4) Medium, in which it travels

Sol. Answer (4)

Speed of wave $= \dfrac{I}{\sqrt{\mu\varepsilon}}$

$= \dfrac{I}{\sqrt{\mu_0\mu_r\varepsilon_0\varepsilon_r}}$

It depends upon the medium.

6. If $\vec{E}$ and $\vec{B}$ represent the electric and magnetic field vectors of an electromagnetic wave, then the direction of propagation of the electromagnetic wave is in the direction of

(1) $\vec{E}$ (2) $\vec{B}$ (3) $\vec{E}\times\vec{B}$ (4) $\vec{B}\times\vec{E}$

Sol. Answer (3)

Direction of propagation is given by $\vec{E}\times\vec{B}$

7. If an electromagnetic wave propagating through vacuum is described by $E_y = E_0 \sin (kx - \omega t)$; $B_z = B_0 \sin (kx - \omega t)$, then

(1) $E_0 k = B_0 \omega$ (2) $E_0 B_0 = \omega k$ (3) $E_0 \omega = B_0 k$ (4) $E_0B_0 = \dfrac{\omega}{k}$

Sol. Answer (1)

Speed of wave $= \dfrac{E_0}{B_0} = \dfrac{\omega}{k}$

$\therefore \quad kE_0 = \omega B_0$

8. Electromagnetic wave is deflected by

(1) Electric field (2) Magnetic field

(3) Both (1) & (2) (4) Neither electric field nor magnetic field

Sol. Answer (4)

Electromagnetic wave consists of unchanged particle called photons which are neither deflected by electric field nor by magnetic field.

9. Out of the following, choose the ray which does not travel with the velocity of light

(1) X-ray (2) Microwave (3) γ-rays (4) β-rays

Sol. Answer (4)

β-rays do not travel with speed of light, as they are not *em* waves.

10. Red light differs from blue light in its

(1) Speed (2) Frequency (3) Intensity (4) Amplitude

Sol. Answer (2)

Frequency is different for each light as they have different wavelengths.

11. Which of the following has the largest wavelength?

(1) Radio wave (2) X-ray (3) Ultraviolet ray (4) Infra-red ray

Sol. Answer (1)

Radio waves : 10^{-2} m to 10^{4} m.

12. Velocity of electromagnetic waves in a medium is

(1) $(\varepsilon_0\mu_0)^{-1/2}$ (2) $(\varepsilon_0\varepsilon_r\mu_0\mu_r)^{-1/2}$ (3) 3×10^8 m/s (4) $\left(\frac{\varepsilon_0\varepsilon_r}{\mu_0\mu_r}\right)^{+1/2}$

Sol. Answer (2)

Speed of light in medium $= \frac{1}{\sqrt{\mu\varepsilon}} = \frac{1}{\sqrt{\mu_0\mu_r\varepsilon_0\varepsilon_r}}$

$= (\mu_0\mu_r\varepsilon_0\varepsilon_r)^{-\frac{1}{2}}$

13. Which of the following is incorrect about a plane electromagnetic wave?

(1) The electric field and magnetic field have equal average values

(2) The electric energy and the magnetic energy have equal average values

(3) The electric field and magnetic field both oscillate in same phase

(4) The electric field and magnetic field oscillate in opposite phase

Sol. Answer (4)

$\vec{E}$ and $\vec{B}$ are in the same phase but oscillate in different planes which are perpendicular to each other.

14. In a plane electromagnetic wave, which of the following has/ have zero average value in one complete cycle?

(a) Magnetic field (b) Magnetic energy

(c) Electric field (d) Electric energy

(1) (a), (c) (2) (b), (c) (3) (a), (d) (4) All of these

Sol. Answer (1)

Both $\vec{E}$ and $\vec{B}$ are sinusoidal, so over a complete cycle, its value will be zero.

15. An electromagnetic wave is propagating in vacuum along z-axis, the electric field component is given by $E_x = E_0 \sin(kz - \omega t)$, then magnetic component is

(1) $B_x = \frac{E_0}{C}\sin(kz - \omega t)$ (2) $B_y = \frac{B_0}{C}\sin(kz - \omega t)$

(3) $B_y = \frac{E_0}{C}\sin(kz - \omega t)$ (4) $B_y = B_0 C \sin(kz - \omega t)$

Sol. Answer (3)

Direction of propagation → Z

$E_x = E_0 \sin(kZ - \omega t)$

$\vec{B}$ → will be in the y-direction

$\therefore B_y = B_0 \sin(kZ - \omega t)$

$\therefore \frac{E_0}{B_0} = c$

$B_0 = \frac{E_0}{c}$

So, $B_y = \frac{E_0}{c}\sin(kZ - \omega t)$

16. The speed of electromagnetic wave in a medium (whose dielectric constant is 2.25 and relative permeability is 4) is equal to

(1) 0.5×10^8 m/s (2) 0.25×10^8 m/s (3) 0.75×10^8 m/s (4) 1×10^8 m/s

Sol. Answer (4)

$E_r = 2.25,\ \mu_r = 4$

$$V = \frac{1}{\sqrt{\mu_0 \mu_r \varepsilon_0 \varepsilon_r}}$$

$$= \frac{1}{\sqrt{\mu_0 \varepsilon_0}} \times \frac{1}{\sqrt{2.25 \times 4}}$$

$$= \frac{3 \times 10^8}{1.5 \times 2}$$

$V = 10^8$ m/s

17. The magnetic field in a plane electromagnetic wave is given by = $2 \times 10^{-7}\sin(0.5 \times 10^3 x + 1.5 \times 10^{11} t)$. This electromagnetic wave is

(1) Visible light (2) Infrared (3) Microwave (4) Radiowave

Sol. Answer (4)

$$B = 2 \times 10^{-7} \sin\left(0.5 \times 10^{-3} x + 1.5 \times 10^{11} t\right)$$

$$f = \frac{c}{\lambda}, \quad k = 0.5 \times 10^{-3}$$

$$\omega = 1.5 \times 10^{11}$$

$$V = \frac{\omega}{k} = \frac{1.5 \times 10^{11}}{0.5 \times 10^{-3}} = 3 \times 10^{14}$$

$$\frac{\omega}{k} = f\lambda$$

$$k = \frac{2\pi}{\lambda}$$

$$\therefore \quad \lambda = \frac{2\pi}{k} = \frac{2 \times 22}{7 \times 0.5 \times 10^{-3}} = \underset{\text{Radio waves}}{1.25 \times 10^4 \text{ m}}$$

18. The dimensional formula of $\frac{1}{2}\varepsilon_0 E^2$ is

(E = electric field)

(1) $[\text{M L T}^{-1}]$ (2) $[\text{M L}^2 \text{T}^{-2}]$ (3) $[\text{M L}^{-1} \text{T}^{-2}]$ (4) $[\text{M L}^2 \text{T}^{-1}]$

Sol. Answer (3)

$$\frac{1}{2}\varepsilon_0 E^2 = \text{Energy density} = \frac{E}{V} = \frac{[\text{ML}^2\text{T}^{-2}]}{[\text{L}^3]}$$

$$= [\text{ML}^{-1}\text{T}^{-2}]$$

19. Which of the following represents an infra-red wavelength?

(1) 10^{-4} cm (2) 10^{-5} cm (3) 10^{-6} cm (4) 10^{-7} cm

Sol. Answer (1)

10^{-6} m or 10^{-4} cm ⇒ Infrared

20. Which of the following is not transported by electromagnetic waves?

(1) Energy (2) Momentum (3) Charge (4) Information

Sol. Answer (3)

Only energy, momentum and information can be transferred with the help of *em* waves, not any matter.

21. Hertz experiment is used for

(1) Production of electromagnetic wave (2) Detection of electromagnetic wave

(3) Both (1) & (2) (4) None of these

Sol. Answer (3)

Hertz was the scientist who produced and detected the *em* waves.

22. Electromagnetic waves are produced due to

(1) A charge at rest (2) A moving charge

(3) An accelerated charge (4) None of these

Sol. Answer (3)

Em waves are produced by accelerated charged particles.

23. Ozone layer blocks the radiation of wavelength

(1) Less than 4×10^{-7} m (2) Between 4×10^{-7} m to 8×10^{-7} m

(3) More than 8×10^{-7}m (4) None of these

Sol. Answer (1)

Radiation having wavelength less than 4×10^{-7} m are blocked by ozone layer

24. Which of the following can be used in cancer treatment?

(1) X-rays (2) UV-rays (3) γ-rays (4) Both (1) & (3)

Sol. Answer (4)

Both X-rays and γ-rays are used for the treatment of cancer.

25. The following can be arranged in decreasing order of wave number

A. AM radio B. TV and FM radio

C. Microwave D. Short radio wave

(1) A > B > D > C (2) C > D > B > A (3) A > B > C > D (4) D > C > B > A

Sol. Answer (2)

Decreasing order of wave number

Microwave > short radiowave > TV and FM radio > AM radio.

SECTION - B

Objective Type Questions

1. If the electric field and magnetic field of an electromagnetic wave are related as $B = \frac{E}{c}$ where the symbols have their usual meanings and the energy in a given volume of space due to the electric field part is U, then the energy due to the magnetic field part will be

(1) $\frac{U}{c}$ (2) $\frac{U}{c^2}$ (3) $\frac{U}{2}$ (4) U

Sol. Answer (4)

$$B=\frac{E}{C}$$

Energy due to $E=\frac{1}{2}\varepsilon_0 E^2$

Energy due to $B=\frac{{B_0}^2}{2\mu_0}$

$$E_{\text{part}}=\frac{U}{2} \qquad B_{\text{part}}=\frac{U}{2}$$

$$E_{\text{part}}=B_{\text{part}}$$

2. The direction of poynting vector represents

(1) The direction of electric field

(2) The direction of magnetic field

(3) The direction of propagation of EM wave

(4) The direction opposite to the propagation of EM wave

Sol. Answer (3)

$$\vec{S}=\frac{\vec{E}\times\vec{B}}{\mu_0}$$

$\vec{E}\times\vec{B}\Rightarrow$ direction of wave propagation

3. A plane electromagnetic wave is incident on a plane surface of area *A* normally, and is perfectly reflected. If energy *E* strikes the surface in time *t* then average pressure exerted on the surface is (*c* = speed of light)

(1) Zero (2) $\frac{E}{Atc}$ (3) $\frac{2E}{Atc}$ (4) $\frac{E}{c}$

Sol. Answer (3)

$P=\frac{2I}{c}$ [Perfect reflection]

$$=\frac{2\times E}{Atc}$$

$$\therefore \quad P=\frac{2E}{Atc}$$

4. 5% of the power of 100 W bulb is converted to visible radiation. Average intensity of visible radiation at a distance of 10 m from the bulb is

(1) $\frac{5}{2\pi(10)^2}$ watt/m² (2) $\frac{5}{4\pi(10)^2}$ watt/m² (3) $\frac{5}{\pi(10)^2}$ watt/m² (4) $\frac{5}{8\pi(10)^2}$ watt/m²

Sol. Answer (2)

$$I=\frac{E}{At}=\frac{P}{A}$$

$$=\frac{P}{4\pi r^2}=\frac{\frac{5}{100}\times 100}{4\pi(10)^2}=\frac{5}{400\pi}\text{ watt/m}^2$$

5. Which of the following physical quantities contained in a small volume oscillates at double the frequency of passing electromagnetic wave?

(1) Electric field (2) Magnetic field (3) Magnetic energy (4) All of these

Sol. Answer (3)

The electric and magnetic energy oscillate at double the frequency as compared to electric and magnetic field.

6. A capacitor is connected across a battery which delivers a current of 1 A at an instant in the capacitor. Displacement current through the capacitor at that instant is

(1) 1 A (2) 0 A (3) 2 A (4) $\frac{1}{2}$A

Sol. Answer (2)

$I = 1$ A

$I_d = 1$ A

7. The magnetic field in a plane electromagnetic wave is given by, $B = 3.01 \times 10^{-7} \sin(6.28 \times 10^2 x + 2.2 \times 10^{10} t)$ T.

[where x in cm and t in second]. The wavelength of the given wave is

(1) 1 cm (2) 628 cm (3) 1.129 cm (4) 314 cm

Sol. Answer (1)

$$\vec{B} = 3.01\times10^{-7}\sin\left(6.28\times10^{2}x+2.2\times10^{10}t\right)\ \text{T}$$

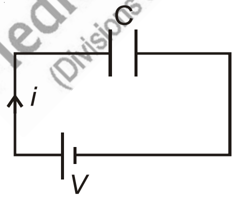
$$k = 6.28\times10^{2}$$

$$\omega = 2.2\times10^{10}$$

$$k = \frac{2\pi}{\lambda}$$

$$\therefore\quad \lambda = \frac{2\pi}{6.28\times10^{2}} = 10^{-2}\ \text{m}$$

8. At a particular instant the current in the circuit given below is i. The displacement current between the plates of the capacitor shown below is



(1) Zero (2) i (3) $\frac{i}{2}$ (4) $\frac{i}{4}$

Sol. Answer (2)

Displacement current $i_d = i$

9. To establish an instantaneous displacement current of I ampere in the space between the plates of a parallel plate capacitor of $\frac{1}{2}$ farad, the value of $\frac{dV}{dt}$ is

(1) $2I$ (2) $\frac{I}{2}$ (3) $\frac{1}{2I}$ (4) I

Sol. Answer (1)

$$I_d = \frac{A\varepsilon_0}{d}\frac{dE}{dt} \times d$$

$$I = \frac{1}{2}\frac{dE}{dt} \times d$$

$$I = \frac{1}{2}\frac{dV}{dt} \times \frac{1}{d}.d$$

$$\frac{dV}{dt} = 2I$$

10. A plane electromagnetic wave of frequency 28 MHz travels in free space along the positive *x*-direction. At a particular point in space and time, electric field is 9.3 V/m along positive *y*-direction. The magnetic field (in T) at that point is

(1) 3.1×10^{-8} along positive *z*-direction
(2) 3.1×10^{-8} along negative *z*-direction
(3) 3.2×10^{7} along positive *z*-direction
(4) 3.2×10^{7} along negative *z*-direction

Sol. Answer (1)

$f = 28\times10^6$ Hz

E = 9.3 V/m $(+\hat{j})$

$Bc = E$

$$B = \frac{9.3}{3\times10^8}$$

$B = 3.1 \times 10^{-8}$ along positive *z*-direction

SECTION - C

Previous Years Questions

1. The ratio of amplitude of magnetic field to the amplitude of electric field for an electromagnetic wave propagating in vacuum is equal to

(1) The speed of light in vacuum
(2) Reciprocal of speed of light in vacuum
(3) The ratio of magnetic permeability to the electric susceptibility of vacuum
(4) Unity

Sol. Answer (2)

$$\frac{E_0}{B_0} = C$$

$$\therefore \quad \frac{B_0}{E_0} = \frac{1}{C}$$

2. The electric and the magnetic field, associated with an e.m. wave, propagating along the +*z*-axis, can be represented by

(1) $\left[\vec{E} = E_0\hat{j}, \vec{B} = B_0\hat{k}\right]$ (2) $\left[\vec{E} = E_0\hat{i}, \vec{B} = B_0\hat{j}\right]$ (3) $\left[\vec{E} = E_0\hat{k}, \vec{B} = B_0\hat{i}\right]$ (4) $\left[\vec{E} = E_0\hat{j}, \vec{B} = B_0\hat{i}\right]$

Sol. Answer (2)

If wave is propagating in +z direction then $\vec{E}$ and $\vec{B}$ will be in x-y plane.

Also, $\vec{E}\times\vec{B}$ = direction of propagation

$$\vec{E} = E_0\hat{i},\ \vec{B} = B_0\hat{j}$$

3. The decreasing order of wavelength of infrared, microwave, ultraviolet and gamma rays is

(1) Infrared, microwaves, ultraviolet, gamma rays (2) Microwaves, infrared, ultraviolet, gamma rays

(3) Gamma rays, ultraviolet, infrared, microwaves (4) Microwaves, gamma rays, infrared, ultraviolet

Sol. Answer (2)

Maximum wavelength = microwaves

Minimum wavelength = γ-rays

4. For a medium with permittivity ε and permeability μ, the velocity of light is given by

(1) $\sqrt{\frac{\mu}{\varepsilon}}$ (2) $\sqrt{\mu\varepsilon}$ (3) $\frac{1}{\sqrt{\mu\varepsilon}}$ (4) $\sqrt{\frac{\varepsilon}{\mu}}$

Sol. Answer (3)

Speed of light in vacuum $C = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$

in any other medium, $V = \frac{1}{\sqrt{\mu\varepsilon}}$

5. The velocity of electromagnetic radiation in a medium of permittivity ε_0 and permeability μ_0 is given by

(1) $\sqrt{\frac{\mu_0}{\varepsilon_0}}$ (2) $\sqrt{\frac{\varepsilon_0}{\mu_0}}$ (3) $\sqrt{\mu_0\varepsilon_0}$ (4) $\frac{1}{\sqrt{\mu_0\varepsilon_0}}$

Sol. Answer (4)

$$C = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$$

6. Which of the following electromagnetic radiations have the smallest wavelength?

(1) X-rays (2) γ-rays (3) UV waves (4) Microwaves

Sol. Answer (2)

γ-rays → minimum wavelength.

7. If ε_0 and μ_0 are the electric permittivity and magnetic permeability in a free space, ε and μ are the corresponding quantities in medium, the index of refraction of the medium is

(1) $\sqrt{\frac{\varepsilon_0\mu_0}{\varepsilon\,\mu}}$ (2) $\sqrt{\frac{\varepsilon\mu}{\varepsilon_0\mu_0}}$ (3) $\sqrt{\frac{\varepsilon_0\,\mu}{\varepsilon\mu_0}}$ (4) $\sqrt{\frac{\varepsilon}{\varepsilon_0}}$

Sol. Answer (2)

Refractive index = $\frac{C}{V}$

$\therefore \quad V = \frac{1}{\sqrt{\mu\varepsilon}}$

$C = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$

$\therefore \quad \eta = \sqrt{\frac{\mu\varepsilon}{\mu_0\varepsilon_0}}$

8. Which is having minimum wavelength?

(1) X-ray (2) Ultraviolet rays (3) γ-rays (4) Cosmic ray

Sol. Answer (4)

Cosmic rays

9. What is the cause of "Greenhouse effect"?

(1) Infra-red rays (2) Ultraviolet rays (3) X-rays (4) Radiowaves

Sol. Answer (1)

Green house effect is mainly due to the infrared radiation, methane gas, SO_2 etc.

10. The velocity of electromagnetic wave is parallel to

(1) $\vec{B}\times\vec{E}$ (2) $\vec{E}\times\vec{B}$ (3) $\vec{E}$ (4) $\vec{B}$

Sol. Answer (2)

$\vec{E}\times\vec{B}$ $\Rightarrow$ Direction of wave propagation

perpendicular to the plane of $\vec{E}$ and $\vec{B}$.

11. If λ_v, λ_x and λ_m represent the wavelengths of visible light. X-rays and microwaves respectively, then

(1) $\lambda_m > \lambda_x > \lambda_v$ (2) $\lambda_m > \lambda_v > \lambda_x$ (3) $\lambda_v > \lambda_x > \lambda_m$ (4) $\lambda_v > \lambda_m > \lambda_x$

Sol. Answer (2)

12. The electric field part of an electromagnetic wave in a medium is represented by $E_x = 0$; $E_y = 2.5\frac{\text{N}}{\text{C}}\cos\left[\left(2\pi\times10^6\frac{\text{rad}}{\text{s}}\right)t - \left(\pi\times10^{-2}\frac{\text{rad}}{\text{m}}\right)x\right]$ $E_z = 0$. The wave is

(1) Moving along x direction with frequency 10^6 Hz and wavelength 200 m

(2) Moving along y direction with frequency $2\pi \times 10^6$ Hz and wavelength 200 m

(3) Moving along x direction with frequency 10^6 Hz and wavelength 100 m

(4) Moving along x direction with frequency 10^6 Hz and wavelength 200 m

Sol. Answer (4)

$E_x = 0$

$$E_y = 2.5\frac{N}{C} \text{ as } \left(2\pi\times10^{6}t-\pi\times10^{-2}x\right)$$

$E_z = 0$

$$f=\frac{w}{2\pi}=\frac{2\pi\times10^{6}}{2\pi}=10^{6}\ \text{s}^{-1}$$

$$\lambda=\frac{2\pi}{\lambda}=\frac{2\pi}{\pi\times10^{-2}}=200\ \text{m}\ .$$

13. Light with an energy flux of 25 × 10^4 Wm^{-2} falls on a perfectly reflecting surface at normal incidence. If the surface area is 15 cm^2, the average force exerted on the surface is

(1) 1.25 × 10^{-6} N (2) 2.50 × 10^{-6} N (3) 1.20 × 10^{-6} N (4) 3.0 × 10^{-6} N

Sol. Answer (2)

SECTION - D

Assertion-Reason Type Questions

1. A : Different electromagnetic waves differ considerably in their mode of interaction with matter.

   R : Different electromagnetic waves have different wavelength or frequency.

Sol. Answer (2)

2. A : All electromagnetic waves travel through vacuum with same speed but they have different wavelength or frequency.

   R : The wavelength of the electromagnetic waves is often correlated with the characteristic size of the system that produces and radiates them.

Sol. Answer (1)

3. A : High frequency electromagnetic waves are detected by some means based on the physical effects they produce on interacting with matter.

   R : The oscillating fields of an electromagnetic wave can accelerate charges and can produce oscillating currents therefore, an apparatus designed to detect EM waves is based on this fact.

Sol. Answer (1)

4. A : Infrared waves are often called heat waves.

   R : Infrared waves vibrate not only the electrons, but entire atoms or molecules of a substance which increases the internal energy and temperature of the substance.

Sol. Answer (1)

5. A : The centre of sensitivity of our eyes coincides with the centre of the wavelength distribution of the sun.

   R : Humans have evolved with visions most sensitive to the strongest wavelength from the sun.

Sol. Answer (1)

6. A : Long distance radio broadcasts use short-wave bands.

   R : Ionosphere reflectes waves in these bands.

Sol. Answer (1)

7. A : It is necessary to use satellites for long distance TV transmission.

R : Television signals are not properly relfected by the ionosphere therefore, relfection is effected by satellites.

Sol. Answer (1)

8. A : Optical and radiotelescopes are built on the ground but X-ray astronomy is possible only from satellites orbiting the earth.

R : Atmosphere absorbs X-rays, while visible and radiowaves can penetrate it.

Sol. Answer (1)

9. A : If the earth did not have an atmosphere, its average surface temperature would have been lower.

R : In the absence of atmosphere, the green house effect will be absent.

Sol. Answer (1)

10. A : It has been predicted that a global nuclear war on the earth would be followed by a severe 'nuclear winter' with a devastating effect on life on earth.

R : The clouds produced by global nuclear war would perhaps cover substantial parts of the sky preventing solar light from reaching many parts of the globe causing winter.

Sol. Answer (1)

11. A : In an EM wave the magnitude of the electric field vector is more than the magnitude of the magnetic field vector.

R : Energy of the EM wave is shared equally between the electric and magnetic fields.

Sol. Answer (2)

12. A : The displacement current goes through the gap between the plates of a capacitor when the charge on the capacitor does not change.

R : Displacement current arises only when the electric field is constant.

Sol. Answer (4)

13. A : When the frequency of the AC is increased, the displacement current increases.

R : The sum of the conduction current and displacement current is constant.

Sol. Answer (3)

14. A : When cooking in microwave ovens, metal containers are used.

R : Energy of the microwaves can be easily transferred to the food thorugh metal.

Sol. Answer (4)

15. A : Food is cooked faster by microwaves than by conventional gas burner.

R : Microwaves have more energy than heat waves.

Sol. Answer (3)

16. A : Microwaves are commonly used in radar to locate flying objects.

R : Microwaves have smaller wavelength than radiowaves.

Sol. Answer (1)

17. A : Environmental damage has depleted the ozone layer in the atmosphere.

R : Increase in ozone decreases the amount of UV radiation to earth.

Sol. Answer (2)

18. A : The electrical conductivity of the earth's atmosphere does not change with altitude.

R : Cosmic rays from outer space entering the earth's atmosphere do not affect it.

Sol. Answer (4)

19. A : Static crashes are heard on a radio when a lightening flash occurs.

R : Light and radiowaves are EM waves and they interfere.

Sol. Answer (1)

20. A : TV signals are affected if a low flying aircraft passes by or a petrol vehicle is started next to it.

R : Aircarft signals or vehicle's spark plug generate interfering EM waves.

Sol. Answer (1)

21. A : Light waves can be polarised.

R : All electromagnetic waves move with same speed in vacuum.

Sol. Answer (1)

22. A : In an electromagnetic wave the energy density in electric field is equal to energy density in magnetic field.

R : Electromagnetic waves are transverse in nature.

Sol. Answer (2)

23. A : The Poynting vector given as $\vec{S} = \frac{\vec{E}\times\vec{B}}{\mu_0}$ represents the instantaneous intensity at a point.

R : The velocity of an electromagnetic wave is in the direction of the vector $\vec{E}\times\vec{B}$.

Sol. Answer (2)

24. A : The radiation pressure due to light waves is maximum when the surface is a perfect reflector.

R : The momentum transfer by the photons to a perfectly reflecting surface is maximum.

Sol. Answer (1)

25. A : In a material medium the speed of a particle can be more than the speed of light in that medium.

R : In the phenomenon of green house effect, low wavelength radiation is allowed to pass but high wavelength radiation is not allowed to pass.

Sol. Answer (2)

❑ ❑ ❑

Chapter 9

Ray Optics and Optical Instruments

Solutions

SECTION - A

Objective Type Questions

1. Digital movie projectors work on the principle of

(1) Reflection from micromirrors

(2) Refraction from thin lenses

(3) Dispersion from thin prisms

(4) Total internal reflection from optical fibres

Sol. Answer (1)

Digital movie projectors need parabolic mirrors to converge all incident rays to a point.

2. Day and night settings for rearview mirrors uses

(1) Thin mirrors

(2) Thick wedge shaped mirrors

(3) Convex mirrors

(4) Concave mirrors

Sol. Answer (2)

Day and night settings for rear view mirrors.

3. When a beam of light is incident on a plane mirror, it is found that a real image is formed. The incident beam must be

(1) Converging

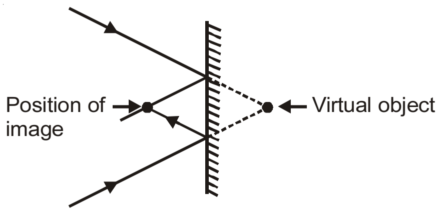
(2) Diverging

(3) Parallel

(4) Formation of real image by a plane mirror is impossible

Sol. Answer (1)

Real images are images formed from actual intersection of light rays.



In plane mirror formation of real images is shown above.

4. An object is placed symmetrically between two plane mirrors, inclined at an angle of 72°, then the total number of images observed is

(1) 5 (2) 4 (3) 2 (4) Infinite

Sol. Answer (2)

For number of images formed from plane mirror

$$m = \frac{360}{\theta} = \frac{360}{72} = 5$$

If it was at any other point the number of images (n) = m but this is not so.

Since it is placed symmetrically :

$n = m - 1$

or $n = 5 - 1$

or $n = 4$ images

5. A person 1.6 m tall is standing at the centre between two walls three metre high. What is the minimum size of a plane mirror fixed on the wall in front of him, if he is to see the full height of the wall behind him?

(1) 0.8 m (2) 1 m (3) 1.5 m (4) 2.3 m

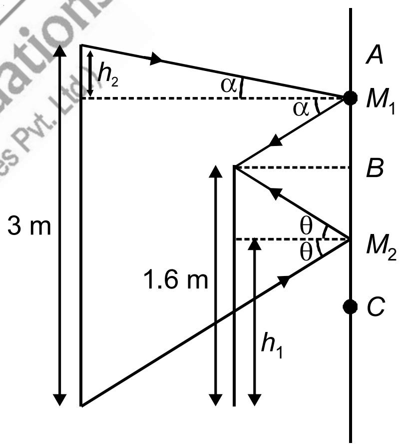
Sol. Answer (2)

$$\tan\theta = \frac{h_1}{d} = \frac{1.6 - h_1}{d/2} \quad \text{....(i)}$$

$$\tan\alpha = \frac{h_2}{d} = \frac{1.4 - h_2}{d/2} \quad \text{....(ii)}$$

$$h_1 = \frac{3.2}{3} \text{ and } h_2 = \frac{2.8}{3}$$

$$3 - h_1 - h_2 = 1 \text{ m}$$



6. While capturing solar energy for commercial purposes we use

(1) Parabolic mirrors (2) Plane mirrors (3) Convex mirrors (4) Concave mirrors

Sol. Answer (1)

While capturing solar energy for commercial purposes we use parabolic mirrors to converge the rays coming from infinity to a point.

7. A convex mirror is used to form an image of a real object. Then mark the wrong statement

(1) The image lies between the pole and focus (2) The image is diminished in size

(3) The image is erect (4) The image is real

Sol. Answer (4)

A convex mirror **always** forms a virtual image in the care of a real object.

In care of a virtual object reflected rays may intersect really to make a real image.

8. A concave mirror of focal length *f* produces an image *n* times the size of the object. If the image is real then the distance of the object from the mirror is

(1) $(n-1)f$ (2) $\left\{\frac{(n-1)}{n}\right\}f$ (3) $\left\{\frac{(n+1)}{n}\right\}f$ (4) $(n+1)f$

Sol. Answer (3)

(magnification) $m = \frac{f}{f-u}$

Focal real image $m = -n$

$$-n = \frac{-f}{-f-u}$$

$$\Rightarrow \; u = -\frac{f(n+1)}{u}$$

9. A convex mirror has a focal length *f*. A real object is placed at a distance *f* in front of it, from the pole. It produces an image at

(1) Infinity (2) f (3) $f/2$ (4) $2f$

Sol. Answer (3)

Mirror formula : $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$

Here object is real so *u* is negative

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$$

Also $(u) = f$

$$\frac{1}{v}-\frac{1}{f}=\frac{1}{f} \qquad \therefore \quad v=\frac{f}{2}$$

10. An object placed in front of a concave mirror of focal length 0.15 m produces a virtual image, which is twice the size of the object. The position of the object with respect to the mirror is

(1) –5.5 cm (2) –6.5 cm (3) –7.5 cm (4) –8.5 cm

Sol. Answer (3)

$$m = \frac{f}{f-u}$$

$f = -0.15$ m

$m = +2$ (virtual image)

$$2 = \frac{-0.15}{-0.15-u}$$

$\Rightarrow$ = –.075 m or – 7.5 cm.

11. When a light ray from a rarer medium is refracted into a denser medium, its

(1) Speed increases, wavelength increases (2) Speed decreases, wavelength increases

(3) Speed increases, wavelength decreases (4) Speed decreases, wavelength decreases

Sol. Answer (4)

When a light ray goes from a rarer to denser medium by definition of refractive index, its speed creases.

Its frequency is found to be invarant.

So, if velocity of light in a medium is v :

$v = f\lambda$ [by wave theory]

or $v \propto \lambda$

So, if v decreases, λ also decreases.

12. A narrow, paraxial beam of light is converging towards a point I on a screen. A plane parallel plate of glass of thickness t, and refractive index μ is introduced in the path of the beam. The convergence point is shifted by

(1) $t\,(1–1/\mu)$ away (2) $t\,(1 + 1/\mu)$ away (3) $t\,(1 – 1/\mu)$ nearer (4) $t\,(1 + 1/\mu)$ nearer

Sol. Answer (1)

Longitudinal shift is given by $t - \dfrac{t}{\mu}$. Hence, point of convergence shifts by the same amount.

13. The length of a vertical pole at the surface of a lake of water $\left(\mu = \dfrac{4}{3}\right)$ is 24 cm. Then to an under-water fish just below the water surface the tip of the pole appears to be

(1) 18 cm above the surface (2) 24 cm above the surface

(3) 32 cm above the surface (4) 36 cm above the surface

Sol. Answer (3)

$$\mu = \frac{\text{Apparent height}}{\text{Real height}}$$

Now, real height = 24 cm and $\mu = \dfrac{4}{3}$

$$\frac{4}{3} \times 24 = \text{ Apparent height}$$

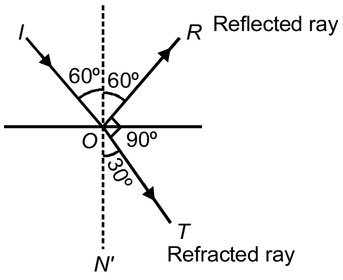
$\therefore$ Apparent height = 32 cm

14. A ray of light strikes a glass plate at an angle 60º. If the reflected and refracted rays are perpendicular to each other, the index of refraction of glass is

(1) $\sqrt{3}$ (2) 3/2 (3) $\sqrt{(3/2)}$ (4) 1/2

Sol. Answer (1)

Angle $N'OT$ = 30º this is found by geometry after putting angle between refleted and transmitted ray equal to 90º



$$\mu = \frac{\sin i}{\sin r} = \frac{\sin 60^\circ}{\sin 30^\circ}$$

or $$\mu = \frac{\sqrt{3}}{2} \times \frac{2}{1}$$

$\therefore$ $\mu = \sqrt{3}$

15. A microscope is focussed on a coin lying at the bottom of a beaker. The microscope is now raised by 1 cm. To what depth should water be poured into the beaker so that the coin is again in focus? (The refractive index of water is $\frac{4}{3}$)

(1) 1 cm (2) 4/3 cm (3) 3 cm (4) 4 cm

Sol. Answer (4)

Water should be poured such that shift in depth of image is 1 cm

$$\left(d - \frac{d}{\mu}\right) = 1$$

$$d\left(1 - \frac{3}{4}\right) = 1$$

d = 4 cm

16. Two transparent media A and B are separated by a plane boundary. The speed of light in medium A is 2.0×10^8 ms^{-1} and in medium B is 2.5×10^8 ms^{-1}. The critical angle for which a ray of light going from A to B suffers total internal reflection is

(1) $\sin^{-1}$ 1/2 (2) $\sin^{-1}$ 2/5 (3) $\sin^{-1}$ 4/5 (4) $\sin^{-1}$ 3/4

Sol. Answer (3)

$$\mu_A = \frac{3\times10^8}{2\times10^8} = 1.5\,;\ \mu_B = \frac{3\times10^8}{2.5\times10^8} = \frac{6}{5} = 1.2$$

R.I. going from A to B = $\frac{\mu_B}{\mu_A}$ or $\frac{1.2}{1.5} = 0.8$

$\mu_{AB} = 0.8 = \frac{\sin C}{\sin r}$ at critical angle $\angle r$ = 90º

$$\therefore \quad \frac{\sin C}{\sin 90^\circ} = 0.8 \qquad C = \sin^{-1}\frac{4}{5}$$

17. Which of the following phenomenon of light forms a rainbow?

(1) Reflection of light (2) Refraction

(3) Total internal reflection (4) Reflection as well as refraction

Sol. Answer (4)

Formation of a rainbow involves refraction to break white light into its constituent colours. It is also involves internal reflection in the drop.

18. Which of the following is possible application of fibre optics?

(1) Endoscopy (2) High speed internet traffic

(3) Radio, TV & Telephone signals (4) All of the above

Sol. Answer (4)

Total internal reflection is used in all of the above as they involve the use of optics fibres.

19. An object is placed at a distance of $f/2$ from a convex lens. The image will be

(1) At one of the foci, virtual and double its size
(2) At $3f/2$, real and inverted
(3) At $2f$, virtual and erect
(4) At f, real and inverted

Sol. Answer (1)

Lens formula

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$$

Object is real and placed at $-\frac{f}{2}$

$$\frac{1}{v}=\frac{1}{f}+\frac{2}{f}$$

$$\frac{1}{v}=\frac{3}{f}$$

$$v=\frac{f}{3}$$

20. The least distance between a point object and its real image formed by a convex lens of focal length F is

(1) $2F$
(2) $3F$
(3) $4F$
(4) Greater than $4F$

Sol. Answer (3)

(Distance between a point object and its real image) $d \geq 4f$

21. The plane faces of two identical plano-convex lenses, each having focal length of 40 cm, are placed against each other to form a usual convex lens. The distance from this lens at which an object must be placed to obtain a real, inverted image with magnification '–1' is

(1) 80 cm
(2) 40 cm
(3) 20 cm
(4) 160 cm

Sol. Answer (2)

It forms an equi-convex lens

$f = 0.4$ m

$$P=\frac{1}{0.4}=2.5\text{ D}$$

Power of combination = 5 D

$$f=\frac{1}{P}$$

$$f=\frac{1}{5}\text{ m}$$

or $f = 20$ cm

Therefore, object must be placed at $2f$ (= 40 cm)

22. Two thin lenses of focal lengths 20 cm and –20 cm are placed in contact with each other. The combination has a focal length equal to

(1) Infinite
(2) 50 cm
(3) 60 cm
(4) 10 cm

Sol. Answer (1)

Powers : $P_1 = \dfrac{1}{0.2}$ and $P_2 = -\dfrac{1}{0.2}$

$= 5$ D and -5 D

Net power = 0

$\therefore$ Focal length $= \dfrac{1}{0} = \infty$

23. If in a plano-convex lens, radius of curvature of convex surface is 10 cm and the focal length of lens is 30 cm, the refractive index of the material of the lens will be

(1) 1.5 (2) 1.66 (3) 1.33 (4) 3

Sol. Answer (3)

$R = 10$ cm

$f = 30$ cm

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R} - \frac{1}{\infty}\right)$$

$$\frac{1}{30} = (\mu - 1)\frac{1}{10}$$

$$\mu = \frac{4}{3}$$

24. A glass concave lens is placed in a liquid in which it behaves like a convergent lens. If the refractive indices of glass and liquid with respect to air are ${}_a\mu_g$ and ${}_a\mu_l$ respectively, then

(1) ${}_a\mu_g = 5{}_a\mu_l$ (2) ${}_a\mu_g > {}_l\mu_l$ (3) ${}_a\mu_g < {}_a\mu_l$ (4) ${}_a\mu_g = 2{}_a\mu_l$

Sol. Answer (3)

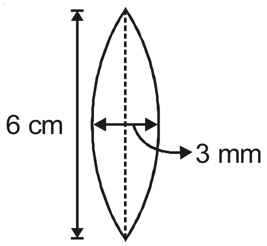
The glass lens behaves as divergent in air which has less R.I.

It will behave as convergent in a medium of higher R.I.

25. The diameter of aperture of a plano-convex lens is 6 cm and its maximum thickness is 3 mm. If the velocity of light in the material of the lens is 2×10^8 m/s, its focal length is

(1) 10 cm (2) 15 cm (3) 30 cm (4) 60 cm

Sol. Answer (3)



μ of medium $= \dfrac{C}{v}$

$$= \frac{3 \times 10^8}{2 \times 10^8} = 1.5$$

Radius of curvature of lens found using geometry

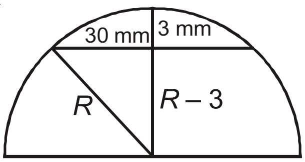
$(R - 3)^2 + (30)^2 = R^2$

$R^2 + 9 - 6R + 900 = R^2$

$909 = 6R$

$R = 151.5$ mm

or 15.15 cm



$$\frac{1}{f_0} = (\mu - 1)\left(\frac{1}{\infty} - \frac{1}{R}\right)$$

$$\frac{1}{f_0} = 0.5 \times \frac{1}{15.15}$$

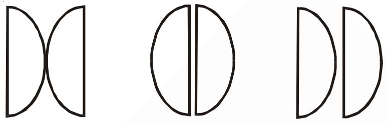
f_0 = 30.30 cm

This is distance from optical centre *O*. Distance from lens is

$f = f_0$ – thickness at principal axis = 30.3 – 0.3

$\therefore$ f = 30 cm

26. Two plano-convex lenses of equal focal lengths are arranged as shown



The ratio of the combined focal lengths is

(1) 1 : 2 : 1 (2) 1 : 2 : 3 (3) 1 : 1 : 1 (4) 2 : 1 : 2

Sol. Answer (3)

The power of lens remains the same no matter how the lenses are placed. So adding their power, the power and hence the combined focal length will remain same in all three cases.

27. When an object is at a distance u_1 and u_2 from a lens, real image and a virtual image is formed respectively having same magnification. The focal length of the lens is

(1) $u_1 - u_2$ (2) $\frac{u_1 - u_2}{2}$ (3) $\frac{u_1 + u_2}{2}$ (4) $u_1 + u_2$

Sol. Answer (3)

$$m = \frac{f}{f+u}$$

For real image For virtual image

$-m = \frac{f}{f-u_1}$, $+m = \frac{f}{f-u_1}$,

$$-\frac{f}{f-u_2} = \frac{f}{f-u_1} \Rightarrow f = \frac{u_1+u_2}{2}$$

28. A concave lens of focal length *f* produces an image (1/*x*) of the size of the object. The distance of the object from the lens is

(1) $(x - 1) f$ (2) $(x + 1)f$ (3) $\{(x - 1)/x\}f$ (4) $\{(x + 1)/x\}f$

Sol. Answer (1)

$m = \frac{f}{f+u}$ For virtual image $m = +\frac{1}{x}$

$+\frac{1}{x} = \frac{-f}{-f+u}$, $u = -f(x - 1)$

29. A thin equiconvex glass lens of refractive index 1.5 has power of 5D. When the lens is immersed in a liquid of refractive index μ, it acts as a divergent lens of focal length 100 cm. The value of μ of liquid is

(1) 4/3 (2) 3/4 (3) 5/3 (4) 8/3

Sol. Answer (3)

$\mu_g = 1.5$ $P = 5$ D

$$5 = (\mu_g - 1)\left(\frac{1}{R} + \frac{1}{R}\right)$$

$$5 \times 2 = \frac{2}{R}$$

$$R = \frac{1}{5} = 0.2 \text{ m} = 20 \text{ cm} \qquad f_l < 0$$

$$\frac{1}{f_l} = \left(\frac{\mu_g}{\mu_l} - 1\right)\left(\frac{2}{R}\right)$$

$$-\frac{1}{100} = \left(\frac{\mu_g}{\mu_l} - 1\right)\frac{2}{20}$$

$$\frac{\mu_g}{\mu_l} - 1 = -\frac{1}{10}$$

$$\frac{1.5}{\mu_l} = \frac{9}{10},\ \mu_l = \frac{5}{3}$$

30. In case of displacement method of lenses, the product of magnification in both cases is

(1) 1 (2) 2 (3) Zero (4) Infinite

Sol. Answer (1)

$m_1 m_2 = 1$ which is a fact.

Here the lens is moved between the object and the screen.

v and u interchange values between the two positions a clear image is formed on the screen.

If $m_1 = \frac{v}{u}$ and $m_2 = \frac{u}{v}$

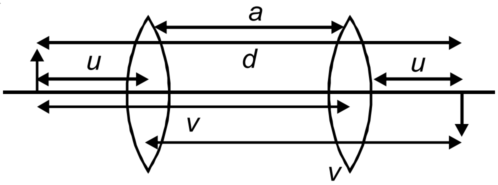
$m_1 m_2 = 1$

31. In the displacement method, a convex lens is placed in between an object and a screen. If the magnifications in the two positions are m_1 and m_2 and the displacement of the lens between the two positions is x, then the focal length of the lens is

(1) $\frac{x}{m_1 + m_2}$ (2) $\frac{x}{m_1 - m_2}$ (3) $\frac{x}{(m_1 + m_2)^2}$ (4) $\frac{x}{(m_1 - m_2)^2}$

Sol. Answer (2)

By principle of reversibility where must be symmetry in the two position



$d = u + v$ $a = v - u$

Hence, $u = \dfrac{d-a}{2}$ and $v = \dfrac{d+a}{2}$

Putting in lens equation $\dfrac{2}{d-a} + \dfrac{2}{d+a} = \dfrac{1}{f}$

$\therefore \quad f = \dfrac{d^2 - a^2}{4d}$

$m_1 = \dfrac{d+a}{d-a}$

$m_2 = \dfrac{d-a}{d+a}$

$|m_1 - m_2| = \dfrac{4\,da}{d^2 + a^2}$

$|m_1 - m_2| = \dfrac{a}{f}$. $(a = x)$

$f = \dfrac{x}{|m_1 - m_2|}$

32. The focal length of a planoconvex glass lens is 20 cm (μ_g =1.5). The plane face of it is silvered. An illuminating object is placed at a distance of 60 cm from the lens on its axis along the convex side. Then the distance (in cm) of the image is

(1) 20 (2) 30 (3) 40 (4) 12

Sol. Answer (4)

Net power of combination

$P = 2P_L + P_m$

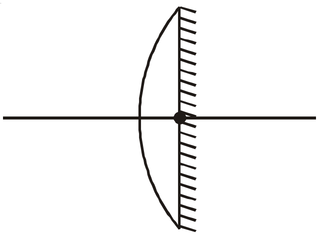
where P_L is power of lens

P_m is power of mirrors

$P_m = 0$

$P_L = \dfrac{1}{0.2}$

$\therefore \quad P = 10$ D



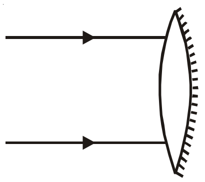
Focal length of combination (f) $= \dfrac{1}{10} = 0.1$ m or 10 cm

$\dfrac{1}{v} - \dfrac{1}{60} = \dfrac{-1}{10}$

$\dfrac{1}{v} = \dfrac{1}{60} - \dfrac{1}{10}$

$v = 12$ cm

33. Two thin similar convex glass pieces are joined together front to front with its rear portion silvered such that a sharp image is formed 20 cm from the mirror. When the air between the glass pieces is replaced by water (m_w = 4/3), then the image formed from the mirror is at a distance of



(1) 8 cm (2) 10 cm (3) 6 cm (4) 12 cm

Sol. Answer (4)

Initially it is simply a concave mirror with f = –20 cm, R = 40 cm

$\therefore$ Power of mirror $(P_m) = \frac{1}{8}$

$= \frac{1}{0.2} = 5\text{ D}$

Focal length of lens $= \frac{R}{2(\mu - 1)}$

$= \frac{40}{2 \times \left(\frac{4}{3} - 1\right)}$

= 60 cm

Power of lens $= \frac{1}{0.5}$

$= \frac{100}{50}\text{ D}$

$\therefore$ Equivalent power = $2P_L + P_m$

$P = \frac{50}{6}$

Net focal length $= \frac{1}{P}$

$= \frac{6}{50} \times 100$

= 12 cm

34. Yellow light is refracted through a prism producing minimum deviation. If i_1 and i_2 denote the angle of incidence and emergence for the prism, then

(1) $i_1 = i_2$ (2) $i_1 > i_2$ (3) $i_1 < i_2$ (4) $i_1 + i_2 = 90$

Sol. Answer (1)

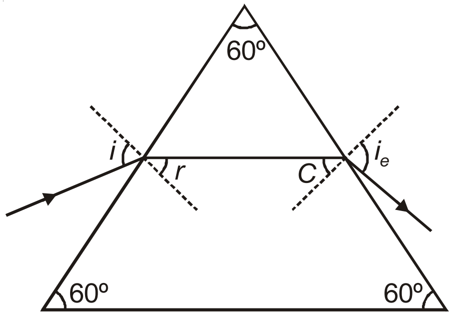
At angle of minimum deviation angle of emergence of prism is same as angle of incidence.

35. At what angle will a ray of light be incident on one face of an equilateral prism, so that the emergent ray may graze the second surface of the prism ($\mu = 2$)?

(1) 30° (2) 90° (3) 45° (4) 60°

Sol. Answer (2)

Let C by critical angle $\mu = 2 = \frac{\sin i}{\sin r}$



$i_e = 90°$

$i_e = 90°$

$60° = r + C$ from geometry

$\frac{1}{\mu} = \frac{1}{2} = \frac{\sin C}{\sin i_e}$ [At emergent interface]

$C = \sin^{-1}\frac{1}{2} = 30°$

$r = 30°$

$\frac{\sin i}{\sin r} = 2$

$\sin i = 1$

$i = \frac{\pi}{2}$

36. A prism of refractive index √2 has a refracting angle of 60°. At what angle must a ray be incident on it so that it suffers a minimum deviation?

(1) 30° (2) 45° (3) 60° (4) 75°

Sol. Answer (2)

$\mu = \sqrt{2}, A = 60°$

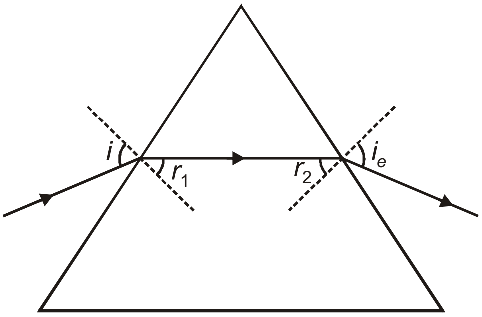
At for minimum deviation :

$i = i_e$ and $r_1 = r_2$

Also, $r_1 + r_2 = A$

or $2r = 60°$

$r = 30°$

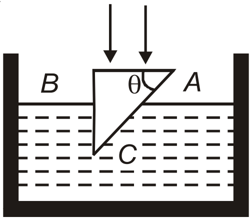


$\mu = \frac{\sin i}{\sin r}$

$\sqrt{2} = 2\sin i$ [Putting $r = 30°$]

$\sin i = \frac{1}{\sqrt{2}}$ $i = 45°$

37. A glass prism of refractive index 1.5 is immersed in water of refractive index 4/3. A light ray incident normally on face *AB* is totally reflected at face *AC* if



(1) $\sin\theta > 8/9$ (2) $\sin\theta < 2/3$ (3) $\sin\theta = \sqrt{3}/2$ (4) $2/3 < \sin\theta \le 8/9$

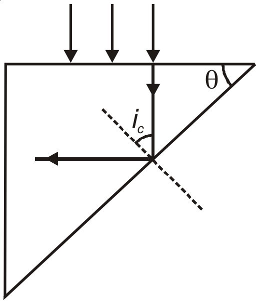
Sol. Answer (1)

μ_g (glass) = 1.5

μ_l (water) = 4/3

Rays enter and pass undeviated at first interface

For total interface reflection at 2nd interface



$$i_c > \sin^{-1}\left(\frac{\mu_e}{\mu_g}\right)$$

$$i_c > \sin^{-1}\left(\frac{4}{3}\times\frac{2}{3}\right)$$

$$i_c > \sin^{-1}\left(\frac{8}{9}\right)$$

$$\sin i_c > \frac{8}{9}$$

Since $i_c = \theta$ from geometry

$$\sin\theta > \frac{8}{9}$$

38. A person can see clearly only up to a distance of 25 cm. He wants to read a book placed at a distance of 50 cm. What kind of lens does he require for this purpose and what must be its power?

(1) Concave, – 1.0 D (2) Convex, + 1.5 D (3) Concave, – 2.0 D (4) Convex, + 2.0 D

Sol. Answer (3)

He needs to bring the image of the object closer to 25 cm

Also the image should be virtual

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$$

$$-\frac{1}{25}+\frac{1}{50}=\frac{1}{f}$$

f = –50 cm

$$P=\frac{1}{-0.5}$$

P = 2 D

39. An astronomical telescope has an objective of focal length 100 cm and an eye piece of focal length 5 cm. The final image of a star is seen 25 cm from the eyepiece. The magnifying power of the telescope is

(1) 20 (2) 22 (3) 24 (4) 26

Sol. Answer (3)

$f_0 = 100$ cm

$f_e = 5$ cm

To form image at near point

$$m = -f_0\left[\frac{1}{f_e}+\frac{1}{D}\right]$$

$$= -100\left[\frac{1}{5}+\frac{1}{25}\right]$$

$$= -100\left[\frac{6}{25}\right]$$

$m = -24$

40. When a telescope is adjusted for normal vision, the distance of the objective from the eye-piece is found to be 80 cm. The magnifying power of the telescope is 19. What are the focal lengths of the lenses?

(1) 61 cm, 19 cm (2) 40 cm, 40 cm (3) 76 cm, 4 cm (4) 50 cm, 30 cm

Sol. Answer (3)

Distance between objective and eyepiece when telescope is adjusted for normal vision is given by

$$19 = \frac{f_0}{f_e}\left(M = \frac{f_0}{f_e}\right) \qquad ....(i)$$

$$80 = f_0 + f_e.\ (L = f_0 + f_e) \qquad ....(ii)$$

Solving (i) & (ii)

$f_0 = 76$ cm, $f_0 = 4$ cm

41. The focal lengths of the objective and eye lens of a telescope are respectively 200 cm and 5 cm. The maximum magnifying power of the telescope will be

(1) – 40 (2) – 48 (3) – 60 (4) – 100

Sol. Answer (2)

Maximum magnification is at near point

Magnification at near point

$$m = -\frac{f_0}{f_e}\left(1+\frac{f_e}{D}\right)$$

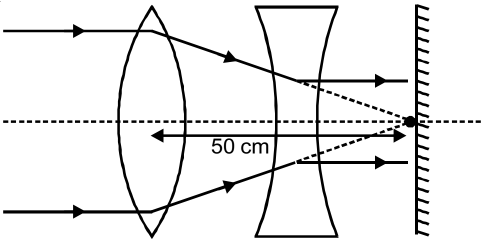
$$m = -\frac{200}{5}\left(1+\frac{5}{25}\right) = -\frac{200}{5}\times\frac{6}{5}$$

$m = -48$

42. A convex lens forms a real image of a point object at a distance of 50 cm from the convex lens. A concave lens is placed 10 cm behind the convex lens on the image side. On placing a plane mirror on the image side and facing the concave lens, it is observed that the final image now coincides with the object itself. The focal length of the concave lens is

(1) 50 cm (2) 20 cm (3) 40 cm (4) 25 cm

Sol. Answer (3)



Final image coincides with the object when rays fall normal to the mirror or parallel to principal axis. For this virtual object must be at the focus of concave lens.

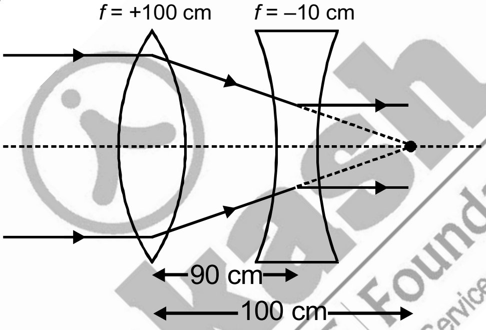
Distance of virtual object from concave lens = 50 – 10 = 40

Focal length of concave lens = 40 cm.

43. A convex lens of focal length 100 cm and a concave lens of focal length 10 cm are placed coaxially at a separation of 90 cm. If a parallel beam of light is incident on convex lens, then after passing through the two lenses the beam

(1) Converges (2) Diverges (3) Remains parallel (4) Disappears

Sol. Answer (3)

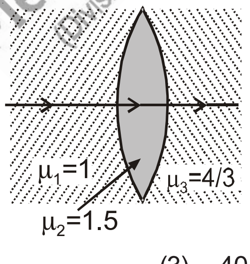


Virtual object for concave lens is at its focus.

SECTION - B

Objective Type Questions

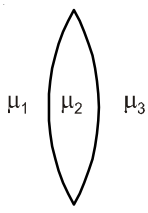
1. If radii of curvature of both convex surfaces is 20 cm, then focal length of the lens for an object placed in air in the given arrangement is



(1) 10 cm (2) 20 cm (3) 40 cm (4) 80 cm

Sol. Answer (3)

$$\frac{\mu_3}{f} = \frac{\mu_2 - \mu_1}{R_1} + \frac{\mu_3 - \mu_2}{R_2}$$



$\mu_1 = 1,\ \mu_2 = 1.5,\ \mu_1 = \frac{4}{3}$

$R_1 = +20$ cm, $R_2 = -20$ cm

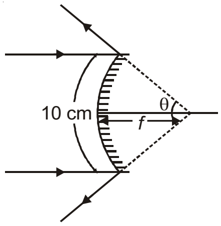
2. A driving mirror consists of a cylindrical mirror of radius of curvature 10 cm and the length over the curved surface is 10 cm. If the eye of the driver be assumed to be at a great distance from the mirror, then field of view in radian is

(1) 2.0 (2) 4.0 (3) 3.0 (4) 5.0

Sol. Answer (1)

$$f = \frac{R}{2} = 5 \text{ cm}$$

$$\theta = \frac{10}{5} = 2 \text{ rad}$$



3. Which of the following statements is correct?

(1) During hot summer days, the trees and other tall objects seem to be quivering because the density of air changes in an irregular way

(2) When the moon is near the horizon it appears bigger. This is due to optical illusion

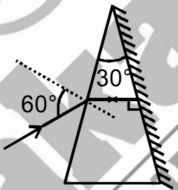
(3) If the critical angle for the medium of a prism is θ_C and the angle of prism is A, there will be no emergent ray when $A > 2\theta_C$

(4) All of these

Sol. Answer (4)

All the statements are true.

4. An isosceles prism of angle $A = 30°$ has one of its surfaces silvered. Light rays falling at an angle of incidence 60° on the other surface retrace their path after reflection from the silvered surface. The refractive index of prism material is



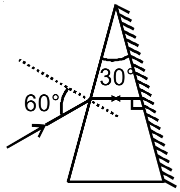
(1) 1.414 (2) 1.5 (3) 1.732 (4) 1.866

Sol. Answer (3)

For light to retrace its path it must reflect normally in the mirror.

When it does so, by geometry $r = 30°$

$$\mu = \frac{\sin i}{\sin r} = \frac{\sin 60^\circ}{\sin 30^\circ} = \sqrt{3} = 1.732$$



5. A short linear object of length l lies along the axis of a concave mirror at a distance u from it. If v is the distance of image from the mirror then size of the image is

(1) $l \times \frac{v}{u}$ (2) $l \times \frac{u}{v}$ (3) $l \times \left(\frac{v}{u}\right)^2$ (4) $l \times \left(\frac{u}{v}\right)^2$

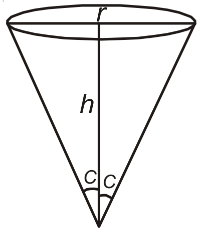
Sol. Answer (3)

Axial magnification of a short object is given by

$$m = \frac{l_1}{l} = \left(\frac{v}{u}\right)^2$$

$$l_1 = \left(\frac{v}{u}\right)^2 l$$

6. A fish looking up through the water sees the outside world contained in a circular horizon. If the refractive index of water is $\frac{4}{3}$ and the fish is 12 cm, below the surface. The radius of the circle is



(1) $\frac{16}{\sqrt{7}}$cm (2) $\frac{26}{\sqrt{7}}$cm (3) $\frac{36}{\sqrt{7}}$cm (4) $\frac{46}{\sqrt{7}}$cm

Sol. Answer (3)

$h = 12$

$\theta = i_C$

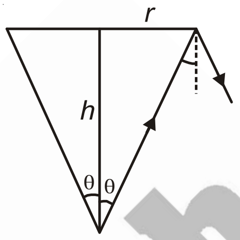
$\sin i_c = \frac{1}{\mu_w}$

$\sin i_c = \frac{3}{4}$

$r = h \tan i_C$

$r = h\frac{3}{\sqrt{16-9}}$

$r = \frac{36}{\sqrt{7}}$



7. In optical fibre, refractive index of inner part is 1.68 and refractive index of outer part is 1.44. The numerical aperture of the fibre is

(1) 0.5653 (2) 0.6653 (3) 0.7653 (4) 0.8653

Sol. Answer (4)

$\mu_0 \sin\theta = \sqrt{\mu_1^2 - \mu_2^2}$

(Numerical aperture)

$\mu_1 = 1.68$, $\mu_2 = 1.44$

8. Compare the dispersive powers of two prisms if one of them deviates the blue and red rays through 10° and 6° respectively and the second prism through 8° and 4.5°

(1) 0.69 (2) 0.79 (3) 0.89 (4) 0.99

Sol. Answer (3)

Dispersive power = $\frac{\delta_v - \delta_r}{\delta_y}$

$\delta_y = \frac{\delta_v + \delta_r}{2}$

$$w_1 = \frac{10-6}{8} = \frac{1}{2}$$

$$w_2 = \frac{8-4.5}{6.25} = \frac{3.5}{6.25}$$

$$\frac{w_1}{w_2} \approx 0.89$$

9. A thin prism of angle 6° made of glass of refractive index 1.5 is combined with another prism made of glass of refractive index 1.75 to produce dispersion without deviation. Then the angle of the second prism is

(1) 7° (2) 4° (3) 9° (4) 5°

Sol. Answer (2)

For dispersion without deviation :

$A_1(\mu_1 - 1) + A_2(\mu_2 - 1) = 0$

$6(0.5) + A_2(0.75) = 0$

$A_2 = 4^\circ$

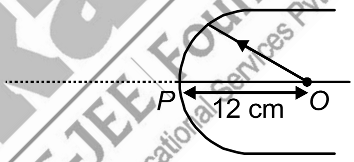
10. In a medium of refractive index 1.6 and having a convex surface has a point object in it at a distance of 12 cm from the pole. The radius of curvature is 6 cm. Locate the image as seen from air

(1) A real image at 30 cm (2) A virtual image at 30 cm

(3) A real image at 4.28 cm (4) A virtual image at 4.28 cm

Sol. Answer (2)

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$



$\mu_1 = 1.6$, $\mu_2 = 1$, $u = 12$ cm, $R = -6$ cm

$$\frac{1}{v} - \frac{1.6}{-12} = \frac{1-1.6}{-6}$$

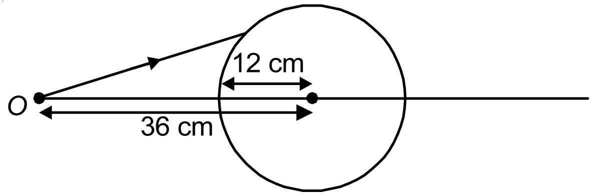
$v = -30$ cm. (Virtual image)

11. A point object is situated at a distance of 36 cm from the centre of the sphere of radius 12 cm and refractive index 1.5. Locate the position of the image due to refraction through sphere.

(1) 24 cm from the surface (2) 36 cm from the centre

(3) 24 cm from the centre (4) Both (1) & (2)

Sol. Answer (4)



$\mu_1 = 1$,

$\mu_2 = 1.5$

$u = -24$ cm,

$R = +12$ cm

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

$$\frac{1.5}{v} - \frac{1}{-24} = \frac{1.5-1}{+12}$$

$v \to \infty$ becomes parallel to the principal axis.

On second face, $\mu_1 = 1.5$, $\mu_2 = 1$, $u \to \infty$, $R = -12$ cm

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

$$\frac{1}{v} - \frac{1.5}{\infty} = \frac{1 - 1.5}{-12}$$

$v = 24$ cm

Final image μ at 24 cm from the surface and from centre of sphere.

12. A denser medium of refractive index 1.5 has a concave surface of radius of curvature 12 cm. An object is situated in the denser medium at a distance of 9 cm from the pole. Locate the image due to refraction in air.

(1) A real image at 8 cm (2) A virtual image at 8 cm

(3) A real image at 4.8 cm (4) A virtual image at 4.8 cm

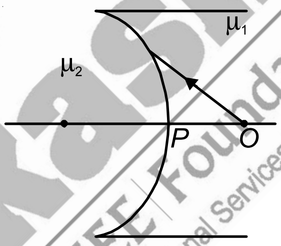
Sol. Answer (4)

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

$$\frac{1}{v} + \frac{1.5}{9} = \frac{0.5}{-12}$$

$$\frac{1}{v} = \frac{-1}{6} - \frac{1}{24}$$

$v = -4.8$



13. A light ray is travelling from air to glass. The reflected and refracted rays are perpendicular to each other. If the angle of incidence in air is *i* the refractive index of glass is

(1) sin *i* (2) cos *i* (3) tan *i* (4) cot *i*

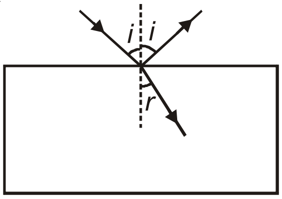
Sol. Answer (3)

180º = $i + 90 + r$

$r = 90 - i$

$$\mu = \frac{\sin i}{\sin r}$$

$\therefore \quad \mu = \tan i$



14. A ray is incident on boundary separating glass and water. Refractive index for glass is $\frac{3}{2}$ and refractive index for water is $\frac{4}{3}$ critical angle for glass-air boundary is

(1) $\sin^{-1}\left(\frac{3}{4}\right)$ (2) $\sin^{-1}\left(\frac{2}{3}\right)$ (3) $\sin^{-1}\left(\frac{8}{9}\right)$ (4) $\sin^{-1}\left(\frac{1}{9}\right)$

Sol. Answer (3)

$$\sin i_C = \frac{\mu_r}{\mu_d}$$

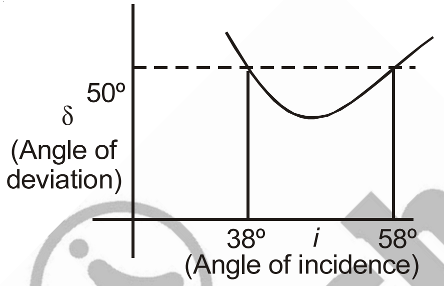
Where μ_r = R.I. of rarer medium

μ_d = R.I. of denser medium

$$\therefore \quad \sin i_C = \frac{4}{3} \times \frac{2}{3}$$

$$i_C = \sin^{-1}\left(\frac{8}{9}\right)$$

15. A plot between the angle of deviation and angle of incidence is shown in figure. From the graph one can say that the prism angle is



(1) 47° (2) 46° (3) 45° (4) 60°

Sol. Answer (2)

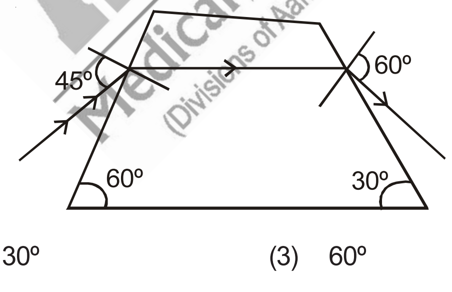
$i + e = A + \delta$

38° and 58° can be i or e in the equation as δ will be same for both values of incidence ray.

$38° + 58° = A + 50°$

$\therefore \quad A = 46°$

16. In the diagram, a ray is passing through a broken prism, find angular deviation for the ray



(1) 105° (2) 30° (3) 60° (4) 15°

Sol. Answer (4)

From triangle interior angles

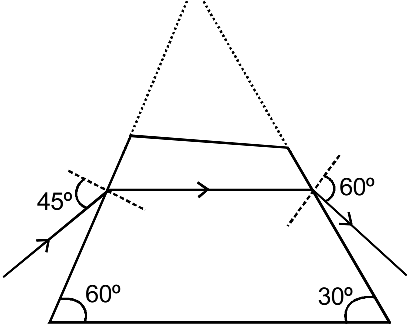
$A = 180° - 60° - 30°$

$= 90°$

$i + e = A + \delta$

$45° + 60° = 90 + \delta$

$\therefore \quad \delta = 15°$



17. A glass slab (μ = 1.5) of thickness 2 cm is placed on a spot. The shift of spot if it is viewed from top

(1) $\frac{2}{3}$ cm (2) $\frac{4}{3}$ cm (3) $\frac{1}{3}$ cm (4) $\frac{5}{3}$ cm

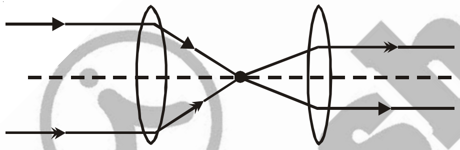
Sol. Answer (1)

$$\text{Shift} = t\left(1-\frac{1}{\mu}\right)$$

$$= 2\left(1-\frac{1}{1.5}\right)$$

$$= \frac{2}{3}\text{ cm}$$

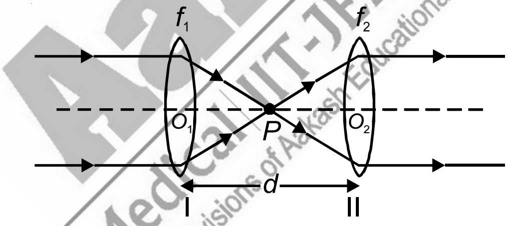
18. Ray diagram for two lenses kept at some distance given in the diagram, which of the following option is correct (f_1, f_2 = focal length, d = distance between lenses)



(1) $f_1+f_2 > d$ (2) $f_1+f_2 < d$

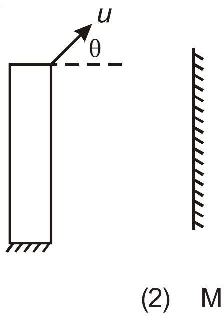
(3) $f_1+f_2 = d$ (4) Combination behaves like converging lens

Sol. Answer (3)



For parallel incidence image is at f_1 distance from O_1. For final emergence to be parallel object for II is at distance f_2 from O_2. The distance between I and II would be f_1 + f_2.

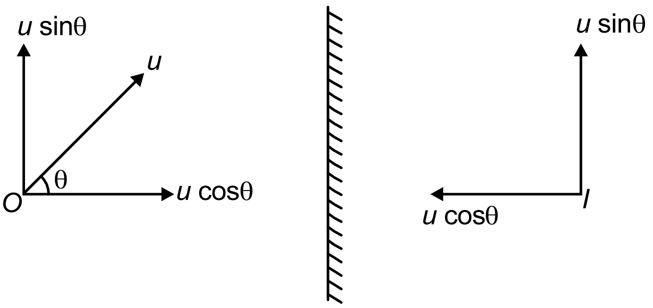
19. A ball is projected from top of the table with initial speed u at an angle of inclination q, motion of image of ball w.r.t ball



(1) Must be projectile (2) Must be straight line and vertical

(3) Must be straight line and horizontal (4) May be straight line, depends upon value of θ

Sol. Answer (3)



$$\vec{V}_{I_0} = \vec{V}_I - \vec{V}_0$$

$$\vec{V}_{I_0} = -u\cos\theta\,\hat{i} + u\sin\hat{j} - (u\cos\theta\,\hat{i} + u\sin\theta\hat{j})$$

$$\vec{V}_{I_0} = -2u\cos\theta\hat{i}$$

Straight line and horizontal

20. In displacement method, convex lens forms a real image of an object for its two different positions. If heights of the images in two cases be 24 cm and 6 cm, then the height of the object is

(1) 3 cm (2) 36 cm (3) 6 cm (4) 12 cm

Sol. Answer (4)

In displacement method

$$m_1 m_2 = 1$$

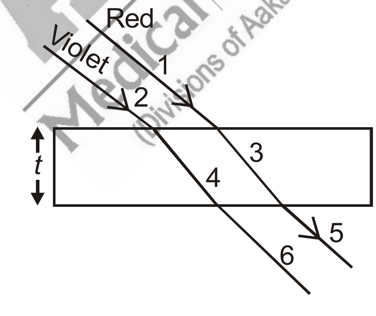
$$\frac{h_1}{h} \times \frac{h_2}{h} = 1$$

$$h = \sqrt{h_1 h_2}$$

$$h = \sqrt{24 \times 6}$$

$$h = 12 \text{ cm}$$

21. Two parallel rays of red and violet colour passed through a glass slab, which of the following is correct?



(1) 3 and 4 are parallel (2) 4 and 5 are parallel (3) 6 and 3 are parallel (4) 2 and 5 are parallel

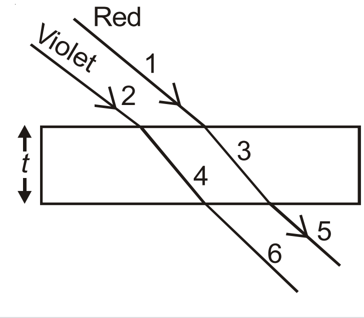
Sol. Answer (4)

When refraction occurs through parallel glass slab, the emergent ray is parallel to incident ray.

6 || 2, 5 || 1

because 1 || 2

⇒ 2 || 5



22. A plane glass is kept over a coloured word 'VIBGYOR', where colour of letters as same as the colours in white light start by letter, the letter which appears least raised is

(1) R (2) Y (3) O (4) V

Sol. Answer (1)

$$\mu = \frac{\text{Real depth}}{\text{Apparent depth}}$$

When an image is least raised its apparent depth is highest.

$\therefore$ R.I. is lowest which happens to be for red light.

23. The near point of a person is 75 cm. In order that he may be able to read book at a distance 30 cm. The power of spectacles lenses should be

(1) –2 D (2) +3.75 D (3) +2 D (4) +3 D

Sol. Answer (3)

$$\Rightarrow \frac{1}{-75} - \frac{1}{-30} = \frac{1}{f}$$

$$\Rightarrow \frac{1}{f} = \frac{1}{50}$$

$P = +2D$

24. If a lens is moved towards the object from a distance of 40 cm to 30 cm, the magnification of the image remains the same (numarically). The focal length of the lens is

(1) 20 cm (2) 15 cm (3) 35 cm (4) 18 cm

Sol. Answer (3)

$$\frac{f}{f+u_1} = \frac{-f}{f+u_2}$$

$u_1 = -40$ cm, $u_2 = -30$ cm

$f \neq 0$

$-(f - 40) = f - 30$

$-f + 40 = f - 30$

$f = +35$ cm

25. A convex lens of power +2.5 D is in contact with a concave lens of focal length 25 cm. The power of combination is

(1) –1.5 D (2) 0 D (3) +1.5 D (4) +6.5 D

Sol. Answer (1)

Power of concave lens = $-\frac{1}{0.25} = -4$ D

Adding combination = –4 D + 2.5 D = –1.5 D

26. For a telescope in normal adjustment, the length of telescope is found to be 27 cm. If the magnifying power of telescope, at normal adjustment is 8, the focal lengths of objective and eye piece are respectively

(1) 24 cm, 3 cm (2) 27 cm, 8 cm (3) 12 cm, 6 cm (4) 27 cm, 9 cm

Sol. Answer (1)

For normal adjustment $m = \dfrac{f_0}{f_e}$ and $L = f_0 + f_e$

$8 = \dfrac{f_0}{f_e}$

$f_0 = 8f_e$

From $27 = f_0 + f_e$

$27 = 8f_e + f_e$

$f_e = 3$ cm

$f_0 = 24$ cm

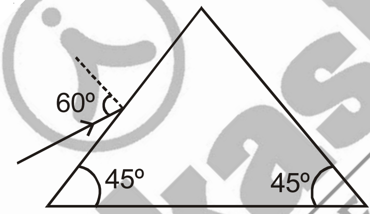
27. A converging lens of focal length 30 cm is placed in contact with another converging lens of unknown focal length, then possible value for focal length of combination is

(1) 15 cm (2) 60 cm (3) 36 cm (4) –12 cm

Sol. Answer (1)

Total power of combination will be more than power of given lens and focal length will be less.

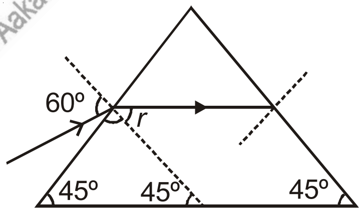
28. In the diagram the ray passing through prism is parallel to the base. Refractive index of material of prism is



(1) $\dfrac{\sqrt{3}}{2}$ (2) $\sqrt{3}$ (3) $\sqrt{2}$ (4) $\sqrt{\dfrac{3}{2}}$

Sol. Answer (4)

By geometry $r = 45º$ [Alternate angles]



$$\mu = \frac{\sin 60º}{\sin 45º} = \frac{\sqrt{3}}{2} \times \sqrt{2}$$

$$\mu = \sqrt{\frac{3}{2}}$$

29. In displacement method we use a lens of focal length f and distance between object and screen is 60 cm. Possible value for focal length is

(1) –15 cm (2) 30 cm (3) 12 cm (4) 20 cm

Sol. Answer (3)

$f \le \dfrac{D}{4}$

$f \le \dfrac{60}{4}$

$f \le 15$ cm

30. A red colour in air has wavelength 760 nm when light passes through water of refractive index $\left(n = \frac{4}{3}\right)$, wavelength becomes 570 nm. (wavelength of yellow colour in air is 570 nm). Then colour of red light in water is

(1) Red (2) Green (3) Yellow (4) Blue

Sol. Answer (1)

Colour of a wave depends more on frequency than wavelength as it depicts the amount of energy is carries. Since frequency and energy doesnot change it will simply remain red.

31. $\hat{n}_1$ is the unit vector along incident ray, $\hat{n}_2$ along normal and $\hat{n}_3$ is the unit vector along reflected ray, then which of the following must be true?

(1) $\hat{n}_1 \cdot \hat{n}_2 = 0$ (2) $\hat{n}_1 \cdot \hat{n}_3 = 0$ (3) $(\hat{n}_1 \times \hat{n}_2) \cdot \hat{n}_3 = 0$ (4) $(\hat{n}_1 \times \hat{n}_2) \times \hat{n}_3 = 0$

Sol. Answer (3)

The reflected ray, refracted ray a incident ray and normal all lie on the same plane. Hence (3) is true.

32. A double convex lens has two surfaces of equal radii 15 cm and refractive index $\mu = 1.5$, its focal length is equal to

(1) –15 cm (2) –30 cm (3) +15 cm (4) +30 cm

Sol. Answer (3)

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R} - \frac{1}{-R}\right)$$

$$\frac{1}{f} = 0.5\left(\frac{2}{15}\right)$$

$$\therefore \quad f = 15 \text{ cm}$$

33. The distance between a real object and its real image is 56 cm formed by converging lens, focal length of lens is

(1) $f \leq 14$ (2) $f > 14$ (3) $f = 14$ (4) $f = 28$

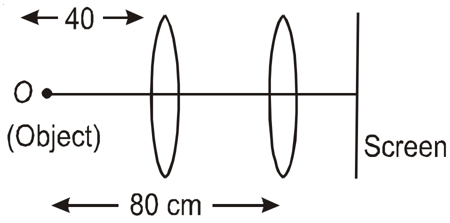
Sol. Answer (1)

$$f \leq \frac{D}{4}$$

$$f \leq \frac{56}{4}$$

$$f \leq 14 \text{ cm}$$

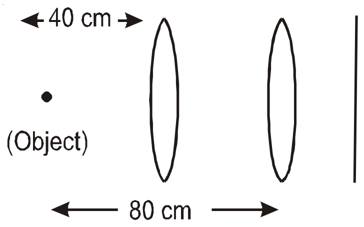
34. In displacement method, there are two position of a lens for which we get clear image. First position of the lens is at 40 cm from object and second is at 80 cm, the focal length of lens is



(1) 40 cm (2) $\frac{40}{3}$ cm (3) 80 cm (4) $\frac{80}{3}$ cm

Sol. Answer (4)

Displacement method is based on principle of reversibility. The image distance for 1st position of lens will be same as object position with IInd position of lens.



$u = -40$ cm

$V = +80$ cm

$$\frac{1}{f} = \frac{1}{80} - \frac{1}{-40}$$

$$f = \frac{80}{3} \text{ cm}$$

35. Maximum magnification produced by simple micro-scope of focal length $f = 5$ cm is

(1) 5 (2) 7 (3) 6 (4) 8

Sol. Answer (3)

Maximum magnification is when final image is at near point D.

$$m = 1 + \frac{D}{f} = 1 + \frac{25}{5} \quad [D = 25 \text{ cm}]$$

$= 6$

SECTION - C

Previous Years Questions

1. A rod of length 10 cm lies along the principal axis of a concave mirror of focal length 10 cm in such a way that its end closer to the pole is 20 cm away from the mirror. The length of the image is

(1) 10 cm (2) 15 cm (3) 2.5 cm (4) 5 cm

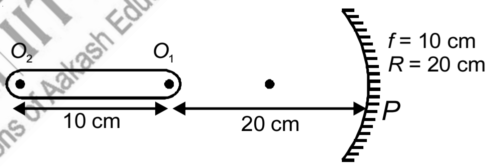
Sol. Answer (4)

O_1 is at C, image of O_1 will form at same postion.

For image of O_2

$u = -30$ cm

$f = -10$ cm



$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

$$\frac{1}{v} + \frac{1}{-30} = \frac{1}{-10}$$

$v = -15$ cm

Length of image

$I_1I_2 = |PI_2 - PI_1|$

$= |15 - 20|$

$= 5$ cm

2. A tall man of height 6 feet, want to see his full image. Then required minimum length of the mirror will be

(1) 12 feet (2) 3 feet (3) 6 feet (4) Any length

Sol. Answer (2)

Height - 6 ft

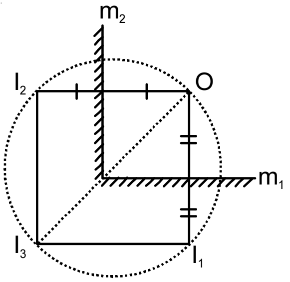
To see any object in a plane mirror complete, a mirror must be half the height of object.

So minimum height of mirror $= \dfrac{h}{2} = 3$ ft

3. Images formed by an object placed between two plane mirrors whose reflecting surfaces make an angle of 90° with one another lie on a

(1) Straight line (2) Parabola (3) Circle (4) Ellipse

Sol. Answer (3)



4. An object is placed between two plane mirrors inclined at an angle 'θ' to each other. If the number of images formed is 7, then the angle of inclination 'θ' is

(1) 15° (2) 30° (3) 45° (4) 60°

Sol. Answer (3)

$$7 = \frac{360}{\theta} - 1$$

$$\theta = 45^\circ$$

5. Which of the following is not due to total internal reflection?

(1) Brilliance of diamond

(2) Working of optical fibre

(3) Difference between apparent and real depth of a pond

(4) Mirage on hot summer days

Sol. Answer (3)

6. In optical fibres, the refractive index of the core is

(1) Greater than that of the cladding (2) Equal to that of the cladding

(3) Smaller than that of the cladding (4) Independent of that of the cladding

Sol. Answer (1)

7. Light travels through a glass plate of thickness t and having a refractive index μ. If c is the velocity of light in vacuum, the time taken by light to travel this thickness of glass is

(1) $\frac{t}{\mu c}$ (2) $\frac{\mu t}{c}$ (3) $t\mu c$ (4) $\frac{tc}{\mu}$

Sol. Answer (2)

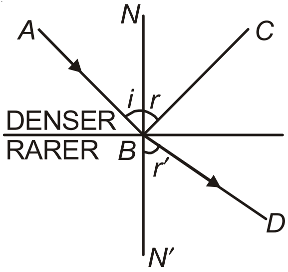
$$\text{Time} = \frac{t}{v\ (\text{Speed in glass})}$$

$$\mu = \frac{c}{V}$$

$$V = \frac{c}{\mu}$$

$$\text{Time} = \frac{\mu t}{c}$$

8. A ray of light from a denser medium strikes a rare medium as shown in figure. The reflected and refracted rays make an angle of 90° with each other. The angles of reflection and refraction are r and r'. The critical angle would be



(1) $\sin^{-1}(\tan r)$ (2) $\tan^{-1}(\sin r)$ (3) $\sin^{-1}(\cot r)$ (4) $\tan^{-1}(\sin r')$

Sol. Answer (1)

$i = r$

$r + r' = 90^\circ$

$i + r' = 90^\circ$

$r' = 90^\circ - i$

$$\sin c = \frac{1}{\mu\,(\text{R.I. of denser w.r.t. rarer})}$$

$\sin c = \mu$ (R.I. of rarer w.r.t. denser)

$$\sin c = \frac{\sin i}{\sin r'}$$

$$\sin c = \frac{\sin i}{\sin(90^\circ - i)}$$

$\sin c = \tan i$ $(i = r)$

$c = \sin^{-1}(\tan r)$

9. The refractive index of water is 1.33. What will be the speed of light in water?

(1) 4×10^8 m/s (2) 1.33×10^8 m/s (3) 3×10^8 m/s (4) 2.25×10^8 m/s

Sol. Answer (4)

$$1.33 = \frac{c}{V\,(\text{Speed of light in water})}$$

10. An electromagnetic radiation of frequency n, wavelength l, travelling with velocity v in air, enters a glass slab of refractive index μ. The frequency, wavelength and velocity of light in the glass slab will be respectively

(1) $n, 2\lambda$ and $\frac{v}{\mu}$ (2) $\frac{2n}{\mu}, \frac{\lambda}{\mu}$ and v (3) $\frac{n}{\mu}, \frac{\lambda}{\mu}$ and $\frac{v}{\mu}$ (4) $n, \frac{\lambda}{\mu}$ and $\frac{v}{\mu}$

Sol. Answer (4)

By definition of refractive index

Velocity of light becomes $\frac{v}{\mu}$

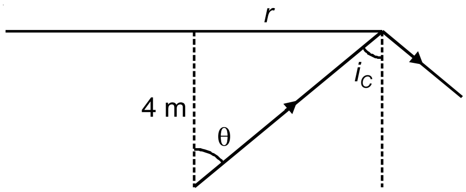
λ becomes $\frac{\lambda}{\mu}$

But frequency is constant.

11. A disc is placed on a surface of pond which has refractive index 5/3. A source of light is placed 4 m below the surface of liquid. The minimum radius of disc needed so that light is not coming out is

(1) ∞ (2) 3 m (3) 6 m (4) 4 m

Sol. Answer (2)



$i_c = \theta$

$\sin i_C = \frac{1}{\mu_d}$

$\sin i_C = \frac{3}{5}$

$\therefore \quad \tan i_c = \frac{3}{\sqrt{25-3^2}} = \frac{3}{4}$

$r = 4 \tan\theta$

$\therefore \quad r = 3$ m

12. A ray of light travelling in air have wavelength λ, frequency n, velocity v and intensity I. If this ray enters into water then these parameters are λ', n', v' and I' respectively. Which relation is correct from following?

(1) $\lambda = \lambda'$ (2) $n = n'$ (3) $v = v'$ (4) $I = I'$

Sol. Answer (2)

When ray enters water

λ becomes $\frac{\lambda}{\mu}$ and velocity becomes $\frac{v}{\mu}$

Intensity also changes

Only frequency n remains same so answer is (2).

13. Optical fibre are based on

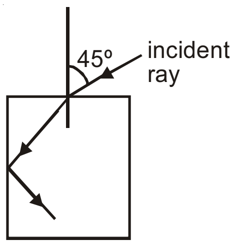
(1) Total internal reflection (2) Less scattering

(3) Refraction (4) Less absorption coefficient

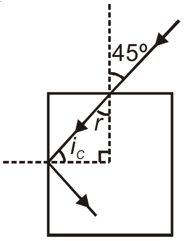
Sol. Answer (1)

Optical fibres depend on total internal reflection.

14. For the given incident ray as shown in figure, the condition of total internal reflection of this ray the required refractive index of prism will be



(1) $\frac{\sqrt{3}+1}{2}$ (2) $\frac{\sqrt{2}+1}{2}$ (3) $\sqrt{\frac{3}{2}}$ (4) $\sqrt{\frac{7}{6}}$



Sol. Answer (3)

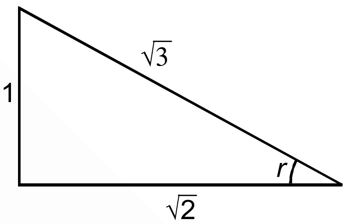
$i_C = 90 - r$

$$\sin(90 - r) = \left(\frac{1}{\mu_g}\right) \qquad \text{....(i)}$$

Also $\mu_g = \dfrac{\sin 45^\circ}{\sin r}$ ....(ii)

$$\therefore \quad \cos r = \frac{\sin r}{\sin 45^\circ}$$

$$\tan r = \sin 45^\circ = \frac{1}{\sqrt{2}}$$



$$\sin r = \frac{1}{\sqrt{3}}$$

$$\therefore \quad \mu = \frac{\sin i}{\sin r} = \sqrt{\frac{3}{2}}$$

15. The frequency of a light wave in a material is 2 × 10^{14} Hz and wavelength is 5000 Å. The refractive index of material will be

(1) 1.50 (2) 3.00 (3) 1.33 (4) 1.40

Sol. Answer (2)

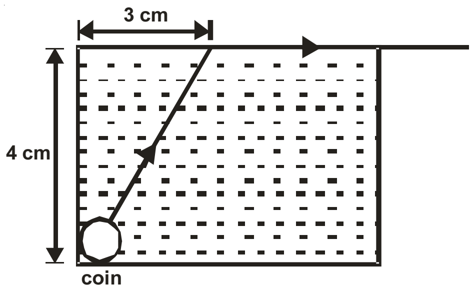
$$\mu = \frac{C}{v_m}$$

$$= \frac{C}{f_m \lambda_m} \text{ (Medium) } f_m = f_a \text{(air)}$$

$$= \frac{C}{f_a \, \lambda_m}$$

$$= \frac{3 \times 10^8}{2 \times 10^{14}} \times 5000 \times 10^{-10} = 3$$

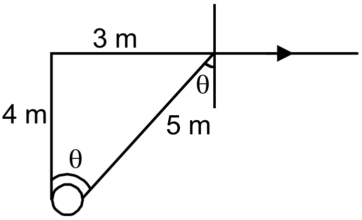
16. A small coin is resting on the bottom of a beaker filled with liquid. A ray of light from the coin travels upto the surface of the liquid and moves along its surface. How fast is the light travelling in the liquid?



(1) 2.4 × 10^8 m/s (2) 3.0 × 10^8 m/s (3) 1.2 × 10^8 m/s (4) 1.8 × 10^8 m/s

Sol. Answer (4)

θ is critical angle $\sin\theta = \frac{3}{5} = \frac{1}{\mu_l}$



$\therefore \quad \mu_l = \frac{5}{3}$

$\mu_l = \frac{v \text{ in air } (C)}{v \text{ in medium}}$

$\therefore \quad v \text{ in medium} = \frac{3}{5} \times 3 \times 10^8$

$= \frac{9}{5} \times 10^8$

$v = 1.8 \times 10^8$

17. A ray of light travelling in a transparent medium of refractive index μ, falls on a surface separating the medium from air at an angle of incidence of 45º. For which of the following value of μ the ray can undergo total internal reflection?

(1) $\mu = 1.25$ (2) $\mu = 1.33$ (3) $\mu = 1.40$ (4) $\mu = 1.50$

Sol. Answer (4)

$C < 45^\circ$

$\sin C < \sin 45^\circ$

$\frac{1}{\mu} < \sin 45^\circ$

$\mu > \sqrt{2}$

Only possible with $\mu = 1.5$

18. The speed of light in media M_1 and M_2 is 1.5×10^8 m/s and 2.0×10^8 m/s respectively. A ray of light enters from medium M_1 to M_2 at an incidence angle i. If the ray suffers total internal reflection, the value of i is

(1) Equal to $\sin^{-1}\left(\frac{2}{3}\right)$

(2) Equal to or less than $\sin^{-1}\left(\frac{3}{5}\right)$

(3) Equal to or greater than $\sin^{-1}\left(\frac{3}{4}\right)$

(4) Less than $\sin^{-1}\left(\frac{2}{3}\right)$

Sol. Answer (3)

$i > C$

$\sin i > \sin C$

$\sin i > \frac{\mu_2}{\mu_1}$

$\sin i > \frac{v_1}{v_2}$

$\sin i > \frac{1.5 \times 10^8}{2 \times 10^8}$

$\sin i > \frac{3}{4}$

$i > \sin^{-1}\left(\frac{3}{4}\right)$

19. A ray of light is incident on a 60º prism at the minimum deviation position. The angle of refraction at the first face (*i.e.*, incident face) of the prism is

(1) Zero (2) 30º (3) 45º (4) 60º

Sol. Answer (2)

At minimum deviation

$r = r'$

According to geometry of prism

$r + r' = A$

$2r = A$

$r = \frac{60}{2}$

$r = 30^\circ$

20. A layer of benzene ($\mu = 1.5$) 12 cm thick floats on water layer (m = 4/3) 8 cm thick in a vessel. When viewed from the top, the apparent depth of bottom of vessel below the surface of benzene will be

(1) 20 cm (2) 14 cm (3) 7 cm (4) 21 cm

Sol. Answer (2)

In case of multiple medium of different R.I.

Apparent depth $d = \frac{t_1}{\mu_1} + \frac{t_2}{\mu_2}$

$d = \frac{12}{1.5} + \frac{8}{4/3}$

$d = 8 + 6$

$= 14$ cm

21. The critical angle for a light travelling from medium *A* into medium *B* is θ. The speed of light in medium *A* is *v*, the speed of light in medium *B* is

(1) $\frac{v}{\cos\theta}$ (2) $v \sin\theta$ (3) $\frac{v}{\sin\theta}$ (4) $v \cos\theta$

Sol. Answer (3)

$\sin\theta = \frac{\mu_B}{\mu_A}$

$\mu_A \sin\theta = \mu_B$

$\mu_A = \frac{C}{v}$ $\mu_B = \frac{C}{v_B}$

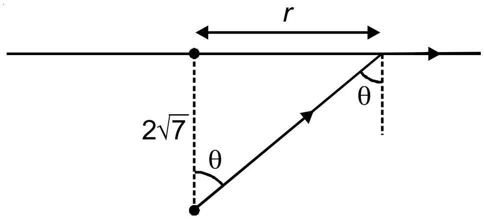
$\frac{C}{v}\sin\theta = \frac{C}{v_B}$

$\therefore \quad v_B = \frac{v}{\sin\theta}$

22. A small bulb is placed at a depth of $2\sqrt{7}$ m in water and floating opaque disc is placed over the bulb so that the bulb is not visible from the surface. The minimum diameter of the disc is ($\mu_{\text{water}} = 4/3$)

(1) 42 m (2) 6 m (3) $2\sqrt{7}$ m (4) 12 m

Sol. Answer (4)



$$\theta_{\max} = \sin^{-1}\frac{1}{\mu} = \sin^{-1}\frac{3}{4}$$

$$\sin\theta = \frac{3}{4}$$

$$\Rightarrow \tan\theta = \frac{3}{\sqrt{7}}$$

$$\frac{r}{2\sqrt{7}} = \frac{3}{\sqrt{7}}$$

$r = 6$ m

23. Two optical media of refractive indices μ_1 and μ_2 contain x and y number of waves in the same thickness. Their relative refractive index $\frac{\mu_2}{\mu_1}$ is equal to

(1) xy (2) $\frac{y}{x}$ (3) $\frac{x}{y}$ (4) $\frac{y-x}{x}$

Sol. Answer (2)

let wavelength of light in air is λ

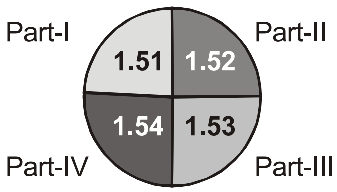
$\therefore$ Wavelength in medium $= \frac{\lambda}{\mu}$

$$t = \frac{x\lambda}{\mu_1} \text{ and } t = \frac{y\lambda}{\mu_2}$$

$$\frac{x}{y} = \frac{\mu_1}{\mu_2}$$

$$\Rightarrow \frac{\mu_2}{\mu_1} = \frac{y}{x}$$

24. A light ray is travelling through a ring of an optical fibre which is made of four different glasses (shown below) but each part has the same geometrical thickness. Their respective refractive indices are shown. The light ray will take the maximum time in crossing the part



(1) I (2) II (3) IV (4) Same in all

Sol. Answer (3)

R.I. of part IV is highest. So velocity will be lowest. Hence, maximum time is taken in part IV.

25. A ray of light is incident at an angle of incidence, *i*, on one face of a prism of angle *A* (assumed to be small) and emerges normally from the opposite face. If the refractive index of the prism is μ, the angle of incidence *i*, is nearly equal to

(1) $\frac{A}{\mu}$ (2) $\frac{A}{2\mu}$ (3) μA (4) $\frac{\mu A}{2}$

Sol. Answer (3)

$r_1 + r_2 = A$

For ray to pass normally $r_2 = 0$

$\therefore \quad r_1 = A$

$$\mu = \frac{\sin i}{\sin A}$$

$\mu \sin A = \sin i$

If both *A* and *i* are small

$i = A\mu$

26. For the angle of minimum deviation of a prism to be equal to its refracting angle, the prism must be made of a material whose refractive index

(1) Lies between $\sqrt{2}$ and 1

(2) Lies between 2 and $\sqrt{2}$

(3) Is less than 1

(4) Is greater than 2

Sol. Answer (2)

$\delta = i + e - A$

δ_{min}, $i = e$

$\delta_{min} = A$

$2A = 2i$

$A = i$

At δ_{min},

$$\mu = \frac{\frac{\sin A + \delta_m}{2}}{\sin\frac{A}{2}} = \frac{\sin A}{\sin\frac{A}{2}} = \frac{2\sin\frac{A}{2}.\cos\frac{A}{2}}{\sin\frac{A}{2}}$$

$$\mu = 2\cos\frac{A}{2}$$

$\mu = 2\cos\frac{i}{2}$ $(A = i)$

$i_{max} = 90°$

$\mu = 2\cos 45°$

$\mu = \sqrt{2}$

$i_{min} = 0°$

$\mu = 2\cos 0°$

$\mu = 2$

As R.I. lies between 2 and $\sqrt{2}$.

27. A thin prism of angle 15° made of glass of refractive index $\mu_1 = 1.5$ is combined with another prism of glass of refractive index $\mu_2 = 1.75$. The combination of the prisms produces dispersion without deviation. The angle of the second prism should be

(1) 12° (2) 5° (3) 7° (4) 10°

Sol. Answer (4)

Angle = 15º

$\mu_1 = 1.5$

$\mu_2 = 1.75$

$15(\mu_1 - 1) + A(\mu_2 - 1) = 0$

$7.5 + 0.75A = 0$

$0.75\,A = -7.5$

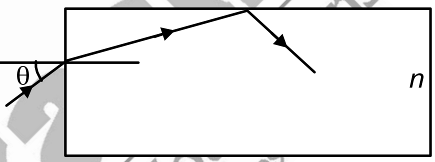
$$A = -\frac{7.5}{0.75}$$

$\therefore\ A = 10º$

28. Light enters at an angle of incidence in a transparent rod of refractive index *n.* For what value of the refractive index of the material of the rod the light once entered into it will not leave it through its lateral face whatsoever be the value of angle of incidence?

(1) $n = 1.1$ (2) $n = 1$ (3) $n > \sqrt{2}$ (4) $n = 1.3$

Sol. Answer (3)



$\sin\theta < \sqrt{n^2 - 1}$

$n > \sqrt{\sin^2\theta + 1}$

Maximum value of θ = 90º.

$n > \sqrt{2}$

29. If the refractive index of a material of equilateral prism is $\sqrt{3}$, then angle of minimum deviation of the prism is

(1) 60° (2) 45° (3) 30° (4) 75°

Sol. Answer (1)

R.I. = $\sqrt{3}$; $A = 60º$; $\delta_m = ?$

$$\mu = \frac{\sin\dfrac{(A+\delta_m)}{2}}{\sin\left(\dfrac{A}{2}\right)}$$

$$\sqrt{3} = \frac{\sin\dfrac{(60º+\delta_m)}{2}}{\sin 30º}$$

$$\sin^{-1}\frac{\sqrt{3}}{2} = \frac{60+\delta_m}{2}$$

$$60º = 30º + \frac{\delta_m}{2}$$

$$30º = \frac{\delta_m}{2}$$

$\delta_m = 60º$

30. A beam of light composed of red and green ray is incident obliquely at a point on the face of rectangular glass slab. When coming out on the opposite parallel face, the red and green ray emerge from

(1) Two points propagating in two different non parallel directions

(2) Two points propagating in two parallel directions

(3) One point propagating in two different directions

(4) One point propagating in the same directions

Sol. Answer (2)

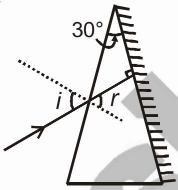
Since parallel beams of light will regain their original direction. They will again become parallel after emergence.

31. The refractive index of the material of a prism is $\sqrt{2}$ and its refracting angle is 30°. One of the refracting surfaces of the prism is made a mirror inwards. A beam of monochromatic light entering the prism from the other face will retrace its path after reflection from the mirrored surface if its angle of incidence on the prism is

(1) 45° (2) 60° (3) Zero (4) 30°

Sol. Answer (1)

By geometry $r = 90^\circ - 60^\circ = 30^\circ$

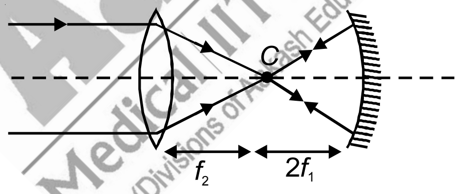


$$\sqrt{3} = \frac{\sin i}{\sin 30^\circ}$$

$$\therefore \quad \sin i = \frac{1}{\sqrt{2}}$$

$i = 45^\circ$

32. A concave mirror of focal length 'f_1' is placed at a distance of 'd' from a convex lens of focal length 'f_2'. A beam of light coming from infinity and falling on this convex lens - concave mirror combination returns to infinity. The distance d must equal



(1) $2f_1 + f_2$ (2) $-2f_1 + f_2$ (3) $f_1 + f_2$ (4) $-f_1 + f_2$

Sol. Answer (1)

33. When a biconvex lens of glass having refractive index 1.47 is dipped in a liquid, it acts as a plane sheet of glass. This implies that the liquid must have refractive index.

(1) Greater than that of glass (2) Less than that of glass

(3) Equal to that of glass (4) Less than one

Sol. Answer (3)

Power of lens is euqal to zero.

$$\frac{1}{f} = \left(\frac{\mu_g}{\mu_e} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = 0$$

$\Rightarrow \quad \mu_g = \mu_l$

34. A biconvex lens has a radius of curvature of magnitude 20 cm. Which one of the following options describe best the image formed of an object of height 2 cm placed 30 cm from the lens?

(1) Real, inverted, height = 1 cm
(2) Virtual, upright, height = 1 cm
(3) Virtual, upright, height = 0.5 cm
(4) Real, inverted, height = 4 cm

Sol. Answer (4)

$$\frac{1}{f} = (1.5-1)\left(\frac{1}{20}+\frac{1}{20}\right)$$

f = 20 cm

$$m = \frac{f}{f+u}$$

$$m = \frac{20}{20-30} = -2 \text{ (Real and inversed)}$$

$$\frac{h_i}{h_0} = -2\,,\ h_0 = 2\text{ cm}$$

μ_i = –4 cm

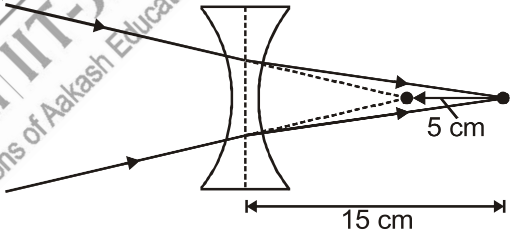
35. A converging beam of rays is incident on a diverging lens. Having passed through the lens the rays intersect at a point 15 cm from the lens on the opposite side. If the lens is removed the point where the rays meet will move 5 cm closer to the lens. The focal length of the lens is

(1) –30 cm (2) 5 cm (3) –10 cm (4) 20 cm

Sol. Answer (1)

For virtual object u = +10 cm, v = +15 cm

The ray diagram is as shown.



$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$$

$$\frac{1}{15}-\frac{1}{10}=\frac{1}{f}$$

$$\frac{2-3}{30}=\frac{1}{f}$$

f = –30 cm

36. Two thin lenses of focal lengths f_1 and f_2 are in contact and coaxial. The power of the combination is

(1) $\frac{f_1+f_2}{f_1f_2}$ (2) $\sqrt{\frac{f_1}{f_2}}$ (3) $\sqrt{\frac{f_2}{f_1}}$ (4) $\frac{f_1+f_2}{2}$

Sol. Answer (1)

$$\frac{1}{f}=\frac{1}{f_1}+\frac{1}{f_2}$$

$$P = \frac{f_1+f_2}{f_1f_2} \qquad \left[\frac{1}{f}=P\right]$$

37. A boy is trying to start a fire by focusing Sunlight on a piece of paper using an equiconvex lens of focal length 10 cm. The diameter of the Sun is 1.39×10^9 m and its mean distance from the earth is 1.5×10^{11} m. What is the diameter of the Sun's image on the paper?

(1) 12.4×10^{-4} m (2) 9.2×10^{-4} m (3) 6.5×10^{-4} m (4) 6.5×10^{-5} m

Sol. Answer (2)

$v = 10$ cm

$u = 1.5 \times 10^{11}$ m

$$\text{Magnification} = \frac{v}{u} = \frac{\text{Image diameter}}{\text{Sun's diameter}}$$

$$\frac{0.1}{1.5\times10^{11}} = \frac{\text{Image}}{1.39\times10^{9}}$$

$$\frac{1}{1.5\times10^{12}}\times1.39\times10^{9} = \text{Image}$$

or $\dfrac{1.39}{1.5}\times10^{-3} = \text{Image}$

or $9.2 \times 10^{-4} = \text{Image}$

$\therefore$ Image diameter = 9.2×10^{-4} m

38. Four lenses of focal length ±15 cm and ±150 cm are available for making a telescope. To produce the largest magnification, the focal length of the eyepiece should be

(1) +15 cm (2) +50 cm (3) –150 cm (4) –15 cm

Sol. Answer (1)

39. A lens is placed between a source of light and a wall. It forms images of area A_1 and A_2 on the wall, for its two different positions. The area of the source of light is

(1) $\dfrac{A_1 - A_2}{2}$ (2) $\dfrac{1}{A_1}+\dfrac{1}{A_2}$ (3) $\sqrt{A_1 A_2}$ (4) $\dfrac{A_1 + A_2}{2}$

Sol. Answer (3)

This is application of the displacement method for finding focal length.

Here $m_1m_2 = 1$

Let A_0 be area of object

$$\frac{A_1}{A_0}\times\frac{A_2}{A_0} = 1$$

$$A_0 = \sqrt{A_1A_2}$$

40. If f_V and f_R are the focal lengths of a convex lens for violet and red light respectively and F_V and F_R are the focal lengths of a concave lens for violet and red light respectively, then we must have

(1) $f_V > f_R$ and $F_V > F_R$ (2) $f_V < f_R$ and $F_V > F_R$ (3) $f_V > f_R$ and $F_V < F_R$ (4) $f_V < f_R$ and $F_V < F_R$

Sol. Answer (2)

$\mu_v > \mu_r$

A converging lens with higher refractive index will converge rays more hence value of $f_v < f_r$

Same is true for concave lenses but since values for focal length are taken as negative $F_v > F_r$

41. If a convex lens of focal length 80 cm and a concave lens of focal length 50 cm are combined together, what will be their resulting power?

(1) + 7.5 D (2) – 0.75 D (3) + 6.5 D (4) – 6.5 D

Sol. Answer (2)

$P = P_1 + P_2$

$$= \frac{1}{0.8} - \frac{1}{0.5}$$

$$= \frac{5}{4} - 2$$

$= -0.75$ D

42. The focal length of a converging lens is measured for violet, green and red colours. It is respectively f_v, f_g, f_r. We will get

(1) $f_v < f_r$ (2) $f_g > f_r$ (3) $f_v = f_g$ (4) $f_g = f_r$

Sol. Answer (1)

$\mu_v > \mu_g > \mu_r$

A converging lens with greater refractive index will bend rays more converging them closer.

$\therefore \quad f_v < f_g < f_r$

43. A luminous object is placed at a distance of 30 cm from the convex lens of focal length 20 cm. On the other side of the lens, at what distance from the lens a convex mirror of radius of curvature 10 cm be placed in order to have an upright image of the object coincident with it?

(1) 50 cm (2) 30 cm (3) 12 cm (4) 60 cm

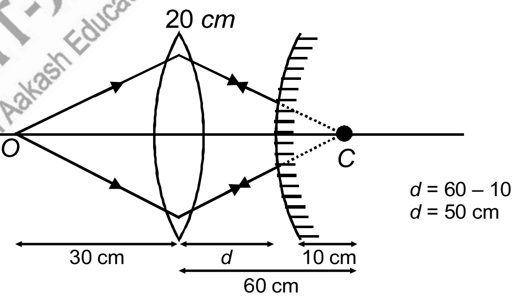
Sol. Answer (1)

For convex lens

$$\frac{1}{+20} = \frac{1}{v} - \frac{1}{-30}$$

$v = 60$ cm

Virtual object for convex mirror should be at its C.



44. A plano-convex lens is made of refractive index 1.6. The radius of curvature of the curved surface is 60 cm. The focal length of the lens is

(1) 200 cm (2) 100 cm (3) 50 cm (4) 400 cm

Sol. Answer (2)

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R} - \frac{1}{\infty}\right)$$

$$\frac{1}{f} = \frac{0.6}{60}$$

$f = 100$ cm

45. A planoconvex lens (m = 1.5) has radius of curvature 10 cm. It is silvered on its plane surface. Find focal length after silvering

(1) 10 cm (2) 20 cm (3) 15 cm (4) 25 cm

Sol. Answer (1)

$\mu = 1.5$

$R = 10$ cm

$P = 2P_L + P_m$

P_m = Power of mirror = 0

$\therefore \quad P = 2P_L$

$$P_L = (1.5-1)\left(\frac{1}{10}+\frac{1}{\infty}\right)$$

$$= \frac{0.5}{10}$$

$$P_L = \frac{1}{20} \text{ cm}$$

$P_L = 5$ D

$\therefore \quad P = 2P_L = 10$ D

$$f = \frac{1}{10} \text{ m } = 10 \text{ cm}$$

46. A bubble in glass slab (m = 1.5) when viewed from one side appears at 5 cm and 2 cm from other side, then thickness of slab is

(1) 3.75 cm (2) 3 cm (3) 10.5 cm (4) 2.5 cm

Sol. Answer (3)

$\mu = 1.5$

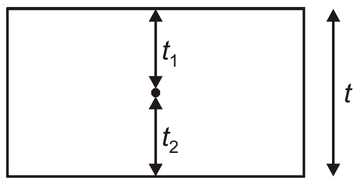
$$\mu = \frac{\text{Real depth}}{\text{Apparent depth}}$$

Real depth = Apparent depth μ_1

$t = t_1 + t_2$

$t = 5 \times 1.5 + 2 \times 1.5$

$= 10.5$ cm



47. A bulb is located on a wall. Its image is to be obtained on a parallel wall with the help of a convex lens. If the distance between the two walls is d, then required focal length will be

(1) Only $\frac{d}{4}$

(2) Only $\frac{d}{2}$

(3) More than $\frac{d}{4}$ but less than $\frac{d}{2}$

(4) Less than or equal to $\frac{d}{4}$

Sol. Answer (4)

$$f \le \frac{d}{4}$$

48. A convex lens is dipped in a liquid whose refractive index is equal to the refractive index of the lens. Then its focal length will

(1) Become zero (2) Become infinite

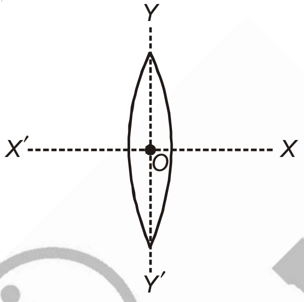
(3) Become small, but non-zero (4) Remain unchanged

Sol. Answer (2)

When this happens the lens will behave as a glass slab and parallel rays will converge at infinity.

$\therefore \quad f = \infty$

49. An equiconvex lens is cut into two halves along (i) XOX' and (ii) YOY' as shown in the figure. Let f, f', f'' be the focal lengths of the complete lens of each half in case (i), and of each half in case (ii), respectively. Choose the correct statement from the following



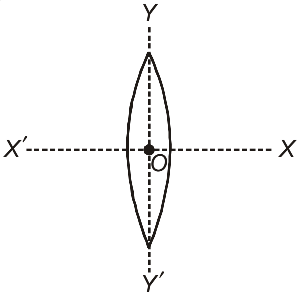
(1) $f' = f$, $f'' = 2f$ (2) $f' = 2f$, $f'' = f$ (3) $f' = f$, $f'' = f$ (4) $f' = 2f$, $f'' = 2f$

Sol. Answer (1)

$f = f'$ as radius of curvature of both surfaces is same.

$f'' = 2f$

by lens maker's formula :



$$\frac{1}{f''} = (\mu - 1)\left(\frac{1}{R} - \frac{1}{\infty}\right) \quad \text{....(i)}$$

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R} + \frac{1}{R}\right) \quad \text{....(ii)}$$

$$\frac{f}{f''} = \frac{1}{2} \quad \text{[Dividing (i) and (ii)]}$$

$\therefore \quad f'' = 2f$

50. A convex lens and a concave lens, each having same focal length of 25 cm, are put in contact to form a combination of lenses. The power in diopters of the combination is

(1) Zero (2) 25 (3) 50 (4) Infinite

Sol. Answer (1)

Each lens of same power but different is sign.

When added $P = P_1 + P_2$

$P = P_1 - P_2$

$P = 0$

51. A lens having focal length f and aperture of diameter d forms an image of intensity I. Aperture of diameter $\frac{d}{2}$ in central region of lens is covered by a black paper. Focal length of lens and intensity of image now will be respectively

(1) $\frac{f}{2}$ and $\frac{I}{2}$ (2) f and $\frac{I}{4}$ (3) $\frac{3f}{4}$ and $\frac{I}{2}$ (4) f and $\frac{3I}{4}$

Sol. Answer (4)

Focal length will not change as long as curvature of lens does not change.

$I \propto d^2$

d = Diameter of aperture

I = Intensity of image

$\frac{d}{2}$ = Aperture is covered by black paper

$I' \propto \frac{d^2}{4}$

$I' = \frac{I}{4}$ obstructed by paper

Intensity of image = $I - \frac{I}{4} = \frac{3I}{4}$

52. Which of the following is incorrect?

(1) A thin convex lens of focal length f_1 is placed in contact with a thin concave lens of focal length f_2. The combination will act as convex lens if $f_1 < f_2$

(2) Light on reflection at water-glass boundary will undergo a phase change of π

(3) Spherical aberration is minimized by achromatic lens

(4) If the image of distant object is formed in front of the retina then defect of vision may be myopia

Sol. Answer (3)

Achromatic lenses minimize chromatic aberration.

53. A double concave thin lens made out of glass ($\mu = 1.5$) have radii of curvature 500 cm. This lens is used to rectify the defect in vision of a person. The far point of the person will be at

(1) 5 m (2) 2.5 m (3) 1.25 m (4) 1 m

Sol. Answer (1)

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{\infty}$$

$$(1.5-1)\left(-\frac{2}{500}\right) = \frac{1}{v}$$

v = – 500 cm

v = – 5 m

54. A convex lens forms a real image 16 mm long on a screen. If the lens is shifted to a new position without disturbing the object or the screen then again a real image of length 81 mm is formed. The length of the object must be

(1) 48.5 mm (2) 36 mm (3) 6 mm (4) 72 mm

Sol. Answer (2)

This is the application of the displacement method.

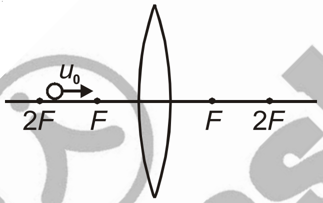
Size of object (m_0) = $\sqrt{m_1 m_2}$

$$\therefore \quad m_0 = \sqrt{16 \times 81}$$

$$= 4 \times 9$$

$$= 36 \text{ cm}$$

55. A point object is moving with speed u_0 at a position somewhere between 2*F* and *F* in front of a convex lens. The speed of its image is



(1) > u_0 (2) < u_0 (3) = u_0 (4) May be (1) or (2)

Sol. Answer (1)

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

Differentiating w.r.t. *t*

$$-\frac{1}{v^2}\frac{dv}{dt} - \left(-\frac{1}{u^2}\right)\frac{du}{dt} = 0$$

$$-\frac{1}{v^2}v_i + \frac{1}{u^2}v_0 = 0$$

$$\mathrm{v_i} = \frac{v^2}{u^2}\,\mathrm{v_0}$$

When $f < u < 2f$, *v* lies beyond 2*f*.

$\Rightarrow \quad v > 2f$

$$\frac{v^2}{u^2} > 1$$

$v_i > v_0$.

56. The minimum magnifying power of a telescope is M. If focal length of its eye lens is halved, the magnifying power will become

(1) $\frac{M}{2}$ (2) $2M$ (3) $3M$ (4) $4M$

Sol. Answer (2)

$M = \frac{f_0}{f_e}$

$M \propto \frac{1}{f_e}$

$f_e' = \frac{f_e}{2}$

$M' = 2M$

57. An object is placed in front of two convex lenses one by one at a distance u from the lens. The focal lengths of the lenses are 30 cm and 15 cm respectively. If the size of image formed in the two cases is same, then u is

(1) 15 cm (2) 20 cm (3) 25 cm (4) 30 cm

Sol. Answer (2)

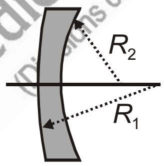
Magnification are same

$m_1 = -m_2$ $\left(m = \frac{f}{f+u}\right)$

$\frac{30}{30-u} = -\frac{15}{15-u}$

$\Rightarrow$ $u = 20$ cm

58. If R_1 and R_2 are the radii of curvature of the spherical surfaces of a thin lens and $R_1 > R_2$, then this lens can



(1) Correct myopia (2) Correct hypermetropia

(3) Correct presbiopia (4) Correct astigmatism

Sol. Answer (1)

$f < 0$ (Diverging)

59. The focal length of a thin lens in vacuum is f. If the material of the lens has $\mu = \frac{3}{2}$, its focal length when immersed in water of refractive index $\frac{4}{3}$ will be

(1) f (2) $\frac{4}{3}f$ (3) $2f$ (4) $4f$

Sol. Answer (4)

$$\frac{1}{f_v} = \left(\frac{3}{2}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

$$\frac{1}{f} = \frac{1}{2}\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

$$\frac{1}{f_w} = \left(\frac{\mu_g}{\mu_w}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

$$\frac{1}{f_w} = \left(\frac{9}{8}-1\right)\left(\frac{2}{f}\right)$$

$\Rightarrow$ $f_w = 4f$

60. The magnifying power of a telescope is 9. When it is adjusted for parallel rays the distance between the objective and eyepiece is 20 cm. The focal length of lenses are

(1) 18 cm, 2 cm (2) 11 cm, 9 cm (3) 10 cm, 10 cm (4) 15 cm, 5 cm

Sol. Answer (1)

$f_o + f_e = 20$ ....(i)

$\frac{f_o}{f_e} = 9$ ....(ii)

Solving (i) and (ii)

$f_o = 18$ cm $f_e = 2$ cm

61. For a telescope having f_o as the focal length of the objective and f_e as the focal length of the eyepiece, the length of the telescope tube is

(1) f_e (2) $f_o - f_e$ (3) f_o (4) $f_o + f_e$

Sol. Answer (4)

By the construction of the telescope $f_0 + f_e = L$

62. An astronomical telescope of tenfold angular magnification has a length of 44 cm. The focal length of the objective is

(1) 44 cm (2) 440 cm (3) 4 cm (4) 40 cm

Sol. Answer (4)

$m = 10$

$\frac{f_0}{f_e} = 10$ ....(i)

$f_0 + f_e = 44$ cm ....(ii)

Solving (i) and (ii)

$f_0 = 40$ cm

63. A microscope is focused on a mark on a piece of paper and then a slab of glass of thickness 3 cm and refractive index 1.5 is placed over the mark. How should the microscope be moved to get the mark in focus again?

(1) 2 cm upward (2) 1 cm upward (3) 4.5 cm downward (4) 1 cm downward

Sol. Answer (2)

$$\text{Shift} = t\left(1-\frac{1}{\mu}\right)$$

$$= 3\left(1-\frac{1}{1.5}\right)$$

$$= 1 \text{ cm}$$

So the microscope must be moved by 1 mm upwards

$$\mu = \frac{\text{Real depth}}{\text{Apparent depth}}$$

$$\text{Apparent depth} = \frac{\text{Real depth}}{\mu} = \frac{2}{3}\times 3\text{ mm} = 2\text{ mm}$$

$\therefore$ Shift = 3 – 2 = 1 mm

So the microscope must be moved 1 mm upwards.

64. Ray optics is valid, when characteristic dimensions are

(1) Much smaller than the wavelength of light (2) Of the same order as the wavelength of light

(3) Of the order of one millimeter (4) Much larger than the wavelength of light

Sol. Answer (4)

Ray optics is valid on a more macro scale compared to wavelength of light. On micro scale wave optics and wave-particle duality is more prominent.

65. The blue colour of the sky is due to the phenomenon of

(1) Scattering (2) Dispersion (3) Reflection (4) Refraction

Sol. Answer (1)

Blue colour of the sky is due to scattering of light also called the Rayleigh scattering.

66. Rainbow is formed due to

(1) Scattering and refraction (2) Total internal reflection and dispersion

(3) Reflection only (4) Refraction and dispersion

Sol. Answer (4)

Rainbow's colours appear due to dispersion, which occurs after refraction.

67. If the focal length of objective lens is increased then magnifying power of

(1) Microscope will increase but that of telescope decrease

(2) Microscope and telescope both will increase

(3) Microscope and telescope both will decrease

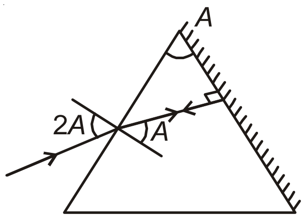
(4) Microscope will decrease but that of telescope will increase

Sol. Answer (4)

68. The angle of a prism is A. One of its refracting surfaces is silvered. Light rays falling at an angle of incidence $2A$ on the first surface returns back through the same path after suffering reflection at the silvered surface. The refractive index μ, of the prism is

(1) $2\sin A$ (2) $2\cos A$ (3) $\frac{1}{2}\cos A$ (4) $\tan A$

Sol. Answer (2)



$i = 2A,\ r = A$

$$\frac{\sin i}{\sin r} = \mu$$

$$\frac{\sin 2A}{\sin A} = \mu \ \Rightarrow\ \mu = 2\cos A$$

69. The refracting angle of a prism is A, and refractive index of the material of the prism is $\cot(A/2)$. The angle of minimum deviation is

(1) 180° + 2A (2) 180° – 3A (3) 180° – 2A (4) 90° – A

Sol. Answer (3)

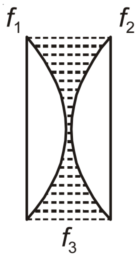
$$\mu = \frac{\sin\left(\frac{A}{2}+\delta_m\right)}{\sin\frac{A}{2}},\ \cot\frac{A}{2} = \frac{\sin\left(\frac{A}{2}+\delta_m\right)}{\sin\frac{A}{2}} \Rightarrow \frac{\cos\frac{A}{2}}{\sin\frac{A}{2}} = \frac{\sin\left(\frac{A}{2}+\delta_m\right)}{\sin\frac{A}{2}}$$

$$90-\frac{A}{2} = \frac{A}{2}+\frac{\delta_m}{2} \ \Rightarrow\ \delta_m = (180-2A)$$

70. Two identical thin plano-convex glass lenses (refractive index 1.5) each having radius of curvature of 20 cm are placed with their convex surfaces in contact at the centre. The intervening space is filled with oil of refractive index 1.7. The focal length of the combination is

(1) 50 cm (2) – 20 cm (3) – 25 cm (4) – 50 cm

Sol. Answer (4)



$$\frac{1}{f} = \frac{1}{f_1}+\frac{1}{f_2}+\frac{1}{f_3}$$

$$\frac{1}{f_1} = \frac{1}{f_2} = (1.5-1)\left(\frac{1}{20}+\frac{1}{\infty}\right)$$

$$\frac{1}{f_1} = \frac{1}{f_2} = \frac{1}{40}$$

$$\frac{1}{f_3} = (1.7-1)\left(-\frac{1}{20}-\frac{1}{20}\right) = -\frac{0.7}{10} = -\frac{7}{100}$$

$$\frac{1}{f} = \frac{1}{40}+\frac{1}{40}-\frac{7}{100}$$

$$\frac{1}{f} = -\frac{2}{100}$$

$$f = -50 \text{ cm}$$

SECTION - D

Assertion - Reason Type Questions

1. A : Plane and convex mirrors can produce real images of objects.

R : A plane or convex mirror can produce a real image if the object is virtual.

Sol. Answer (1)

Real images are formed from real intersection of light rays, which occur in convex mirror when the object is virtual.

2. A : A virtual image cannot be caught on a screen but it can be photographed.

R : The virtual image here serves as an object for the lens of the camera to produce a real image.

Sol. Answer (1)

Virtual image can be observed but real intersection of light rays needs to occur to take objects to screen.

3. A : When a diver under water looks obliquely at a fisherman standing on the bank of a lake then fisherman looks taller.

R : When a ray of light travelling in air enters water, it bends towards the normal.

Sol. Answer (1)

The ray of light bending towards normal makes it appear that light comes from further away.

4. A : The apparent depth of a tank of water decreases if viewed obliquely.

R : Real depth decreases if viewed obliquely.

Sol. Answer (3)

Apparent depth of tank decreases because the light ray, travels further through the water bending more in the process. Real depth remains the same are it was.

5. A : Proper cutting of diamond makes it sparkle.

R : Diamond has very large refractive index.

Sol. Answer (1)

Proper cutting of diamond makes it sprakle due to total internal refraction. A high reflective index makes total internal reflection easier.

6. A : The angle subtended at the eye by an object is equal to the angle subtended at the eye by the virtual image produced by a magnifying glass so the magnification produced is one.

R : During image formation through magnifying glass, the object as well as its image are at the same position.

Sol. Answer (4)

A magnifying glass magnifies the virtual image and magnification is greater than one. The reason is also false.

7. A : In viewing through a magnifying glass, angular magnification decreases if the eye is moved back.

R : Angle subtended at the eye becomes slightly less than the angle subtended at the lens.

Sol. Answer (1)

8. A : Magnifying power of a simple microscope cannot be increased beyond a limit.

R : Magnifying power is inversely proportional to focal length and there are some practical difficulty of grinding, aberrations etc. because of which focal length cannot be decreased below a limit.

Sol. Answer (1)

There is a limit to how curved a glass piece can be made practically.

9. A : The objective and the eye-piece of a compound microscope should have short focal lengths.

R : Magnifying power of a compound microscope is inversely proportional to the focal lengths of both the lenses.

Sol. Answer (1)

For normal adjustment : $M = \dfrac{LD}{f_o \cdot f_e}$.

10. A : When viewing through a compound microscope, our eyes should be positioned not on the eye piece but a short distance away from it for best viewing.

R : The image of the objective in the eye-piece is known as 'eye-ring' and if we position our eyes on the eye-ring and the area of the pupil of our eye is greater or equal to the area of the eye-ring, our eyes will collect all the light refracted by the objective.

Sol. Answer (1)

11. A : The peculiar fish Anableps anableps swims with its eyes partially extending above the water surface so that it can see simultaneously above and below water.

R : This fish has egg shaped eye lens and two retina.

Sol. Answer (1)

12. A : A virtual image cannot be produced on a screen.

R : The light energy does not meet at the point(s) where virtual image is formed.

Sol. Answer (1)

To take a sharp image on a screen light rays must intersect really. This does not happen in virtual images.

13. A : Lenses of large aperture suffer from spherical aberration.

R : The curvature of the lens at central and peripheral regions is different.

Sol. Answer (3)

14. A : The image formed by a concave lens is always virtual.

R : The rays emerging from a concave lens never meet on the principal axis.

Sol. Answer (4)

Assertion is false as real image is formed by concave lens in care of virtual object. Reason is also false as real images are formed by real intersection of rays.

15. A : When two lenses in contact form an achromatic doublet, then the materials of the two lenses are always different.

R : The dispersive powers of the materials of the two lenses are of opposite sign.

Sol. Answer (3)

To achieve achromatic condition in two lenses in contact, refractive indices must be different, dispersive power cannot be negative.

16. A : A reflecting type of telescope is preferred over refracting type in astronomy.

R : A reflecting type of telescope is free from chromatic aberration and spherical aberration.

Sol. Answer (1)

❑ ❑ ❑

Chapter 10

Wave Optics

Solutions

SECTION - A

Objective Type Questions

1. Huygens' concepts of secondary wavelets

(1) Allow us to find the focal length of a thin lens (2) Give the magnifying power of a microscope

(3) Are a geometrical method to find a wavefront (4) Are used to determine the velocity of light

Sol. Answer (3)

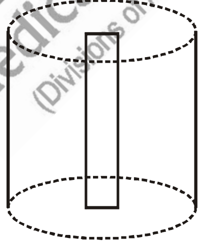
Huygens' concepts of secondary wavelets are a geometrical method to find a wavefront.

2. The intensity at a point at a distance r from a source which produces cylindrical wavefronts varies as

(1) $I \propto \frac{1}{r^2}$ (2) $I \propto \frac{1}{r}$ (3) $I \propto r^0$ (4) $I \propto \frac{1}{r^3}$

Sol. Answer (2)

The intensity at a point at a distance r from a source varies as $I \propto \frac{1}{r}$



This is because intensity is $\frac{\text{Power}}{\text{Area}}$ and the surface area of wavefronts changes by $2\pi rl$.

3. Four waves are expressed as

(i) $y_1 = a_1 \sin \omega t$, (ii) $y_2 = a_2 \sin 2\omega t$, (iii) $y_3 = a_3 \cos \omega t$ (iv) $y_4 = a_4 \sin (\omega t + \phi)$.

The interference is possible between

(1) (i) and (iii) (2) (i) and (ii) (3) (ii) and (iv) (4) Not possible at all

Sol. Answer (1)

Four waves are expressed as y_1 and y_3 can interfere with each other among the options as they have same frequency.

4. Two waves having intensities in the ratio of 9 : 1 produce interference. The ratio of maximum to minimum intensity is equal to

(1) 10 : 8 (2) 9 : 1 (3) 4 : 1 (4) 2 : 1

Sol. Answer (3)

$I_1 \propto A_1{}^2$ $\frac{I_1}{I_2} = \frac{1}{9} = \frac{A_1^2}{A_2^2}$

$I_2 \propto A_2{}^2$ $\therefore \frac{A_1}{A_2} = \frac{1}{3}$

$I_{\max} \propto (A_1 + A_2)^2$

$I_{\min} \propto (A_2 - A_1)^2$

$$\frac{I_{\max}}{I_{\min}} = \frac{(3+1)^2}{2^2} = \frac{16}{4} = \frac{4}{1}$$

$\therefore$ $I_{\max} : I_{\min} = 4 : 1$

5. If the light is polarised by reflection, then the angle between reflected and refracted light is

(1) π (2) $\pi/2$ (3) 2π (4) $\pi/4$

Sol. Answer (2)

According to Brewster's law

6. In an interference pattern produced by two identical slits, the intensity at the site of the central maximum is I. The intensity at the same spot when either of the two slits is closed is I_o, then

(1) $I = I_o$ (2) $I = 2\ I_o$

(3) $I = 4\ I_o$ (4) I and I_o are not related to each other

Sol. Answer (3)

Let amplitude of light from a slit be A.

$I_0 \propto A^2$

or $I \propto (A + A)^2$

$\therefore$ $\frac{I_0}{I} = \frac{1}{4}$

or $I = 4I_0$

7. The fringe width in Young's double-slit experiment can be increased if we decrease

(1) Separation of the slits (2) Distance between the source and the screen

(3) Wavelength of the source (4) All of these

Sol. Answer (1)

Fringe width (β) = $\frac{\lambda D}{d}$

Hence if we decrease d $\left(\beta \propto \frac{1}{d}\right)$

β is increased.

8. In case of Young’s experiment

(1) There are two virtual sources of light from same monochromatic source of light

(2) Both the slits get light from a single monochromatic source of light

(3) Two separate monochromatic sources of light of same wavelength are used

(4) None of these

Sol. Answer (2)

In case of Young's double slit. Experiment the waves from the slit should be coherent. Since true coherence is from the same source always answer will be (2).

9. If light from a galaxy observed on the earth's surface has a red shift, then

(1) Galaxy is stationary w.r.t. the earth (2) Galaxy is approaching the earth

(3) Galaxy is receding from the earth (4) Temperature of galaxy in increasing

Sol. Answer (3)

When there is Red shift. The wavelength is increased and frequency is decreased.

10. In Young’s double slit experiment, the separation between the slits is halved and the distance between the slits and screen is doubled. The new fringe width is

(1) Unchanged (2) Halved (3) Doubled (4) Quadrupled

Sol. Answer (4)

$$\beta = \frac{D\lambda}{d}$$

If d is halved and D is doubled

$$\beta_2 = \frac{\lambda \times 2D}{d/2}$$

$$\beta_2 = 4\beta$$

11. If one of the two slits of a Young’s double slit experiment is painted over so that it transmits half the light intensity of the other then

(1) The fringe system would disappear

(2) The bright fringes will be more bright and dark fringes will be more dark

(3) The dark fringes would be less dark and bright fringes would be less bright

(4) Bright as well as dark fringes would be more dark

Sol. Answer (3)

The net intensity or energy per unit area interfering to form fringer will decrease. Hence observed brightness will decrease.

12. Monochromatic light from a narrow slit illuminates two parallel slits producing an interference pattern on a screen. The separation between the screen and the slits is reduced to half. The fringe width

(1) Is doubled (2) Becomes four times

(3) Becomes one fourth (4) Becomes half

Sol. Answer (4)

Monochromatic light

$$\beta = \frac{\lambda D}{d}$$

If becomes $\frac{D}{2}$

$$\beta_2 = \frac{\lambda D}{2d} = \frac{\beta}{2}$$

13. Two slits separated by a distance of 1mm are illuminated with red light of wavelength 6.5×10^{-7} m. The interference fringes are observed on a screen placed 1m from the slits. The distance between the third dark fringe and the fifth bright fringe on the same side of central maxima is

(1) 0.65 mm (2) 1.62 mm (3) 3.25 mm (4) 4.88 mm

Sol. Answer (2)

$\lambda = 6.5 \times 10^{-7}$ mm

$d = 1$ mm

$D = 1$ m

$\left(\frac{nD\lambda}{d}\right)$ 5th bright fringe $= \frac{5D\lambda}{d}$

$\left((2n-1)\frac{D\lambda}{2d}\right)$ 3rd dark fringe $\frac{5D\lambda}{2d}$

$$\text{Distance }(d) = \frac{5D\lambda}{d} - \frac{5}{2}\frac{D\lambda}{d}$$

$$= \frac{5}{2}\frac{D\lambda}{d}$$

14. A double slit interference experiment is carried out in air and the entire arrangement is dipped in water. As a result

(1) The fringe width decreases (2) The fringe width increases

(3) The fringe width remains unchanged (4) Fringe pattern disappears

Sol. Answer (1)

In water or any other medium λ becomes $\frac{\lambda}{\mu}$ hence

$\beta = \frac{\lambda D}{d}$ becomes

$\beta_2 = \frac{\lambda D}{\mu d}$ or $\beta_2 > \frac{\beta}{\mu}$

So, fringe width decreases.

15. Double slit interference experiment is carried out with monochromatic light and interference fringes are observed. If now monochromatic light is replaced by white light; what change is expected in interference pattern?

(1) No change

(2) Pattern disappears

(3) White and dark fringes are observed throughout

(4) A few coloured fringes are observed on either side of central white fringe

Sol. Answer (4)

Central fringe is white because all the wave lengths are super-imposing at central position with maxima. On either sides all wavelengths make their maximas and minimas so they appeared coloured.

16. In a Young's double slit experiment the wavelength of red light is 7.8×10^{-5} cm and that of blue light is 5.2×10^{-5}cm. The value of n for which $(n + 1)$th blue bright band coincides with nth bright red band is

(1) 1 (2) 2 (3) 3 (4) 4

Sol. Answer (2)

Distance of n^{th} red band from central fringe = $\dfrac{n\lambda_R D}{d}$

Distance of $(n + 1)^{\text{th}}$ band (blue) from fringe = $\dfrac{(n+1)\,\lambda_B D}{d}$

$$\frac{n\lambda_R D}{d} = \frac{(n+1)\lambda_B D}{d}$$

17. In Young's double-slit experiment, a glass plate of refractive index 1.5 and thickness 5×10^{-4} cm is kept in the path of one of the light rays. Then

(1) There will be no shift in the interference pattern

(2) The fringe width will increase

(3) The fringe width will decrease

(4) The optical path of the ray will increase by 2.5×10^{-4} cm

Sol. Answer (4)

Optical path of the ray will become = $\mu \times \lambda$

Hence new path = 7.5×10^{-4}

$\therefore$ Increase in optical path length = $(7.5 - 5) \times 10^{-4}$

$= 2.5 \times 10^{-4}$

18. Which of the following is correct regarding microscope and telescope?

(1) Telescope provides magnification, whereas microscope provides resolution

(2) Telescope provides resolution whereas microscope provides magnification

(3) Both provide resolution

(4) Both provide magnification

Sol. Answer (2)

A telescope produces images of far object nearer to our eye. Therefore objects which are not resolved at far distance, can be resolved by looking at them through a telescope. A microscope on the other hand magnifies object and produced their large image.

19. If Young's experiment is performed using two separate identical sources of light instead of using two slits and one light source then the

(1) Interference fringes will be darker

(2) Interference fringes will be brighter

(3) Fringes will not be obtained

(4) Contrast between bright and dark fringes increases

Sol. Answer (3)

Two independent sources of light identical in nature are not coherent.

20. In a Young's double slit experiment, the intensity at the central maximum is I_0. The intensity at a distance $\beta/4$ from the central maximum is (β is fringe width)

(1) I_0 (2) $\frac{I_0}{2}$ (3) $\frac{I_0}{\sqrt{2}}$ (4) $\frac{I_0}{4}$

Sol. Answer (2)

Let the intensity of each source is I

$I_0 = 4I$

$y = \frac{\beta}{4}$

(Path difference at y distance from central maxima)

$\Delta x = \frac{yd}{D} = \frac{\lambda}{4}$

(phase difference) $\Delta\phi = \frac{\lambda}{4}\left(\frac{2\pi}{\lambda}\right) = \frac{\pi}{2}$

(Intensity at y distance)

$I' = 2I\,(1 + \cos\Delta\phi)$

$I' = 2\left(\frac{I_0}{4}\right)\left(1 + \cos\frac{\pi}{2}\right)$

$I' = \frac{I_0}{2}$

21. White light is used to illuminate the two slits in Young's experiment. The separation between the slits is b and the screen is at a distance d (>> b) from the slits. At a point directly in front of one of the slits, certain wavelengths are missing. The missing wavelength(s) is/are

(1) $\lambda = b^2/d$ (2) $\lambda = b^2/5d$ (3) $\lambda = b^2/3d$ (4) All of these

Sol. Answer (4)

Those wavelength will be missing for which the destructive interference occurs at the position, $y = \frac{b}{2}$

For destructive interference

$d' = b$

$D = d$

$$\frac{yd'}{D} = \frac{(2m-1)\lambda}{2}$$

$$\frac{b}{2}\left(\frac{b}{d}\right)=\frac{(2m-1)\lambda}{2}$$

$$\lambda = \frac{b^2}{(2m-1)\,d}$$

The possible wavelength are for m = 1, 2, 3

22. Oil floating on water looks coloured due to interference of light. What should be the order of magnitude of the thickness of oil layer in order that this effect may be observed?

(1) 10^{-6} m (2) 10^{-2} m (3) 10^{-10} m (4) 10^{-8} m

Sol. Answer (1)

The order of thickness must be in the order of the wavelength of visible light.

23. When white light is incident normally on an oil film of thickness 10^{-4} cm and refractive index 1.4 then the wavelength which will not be seen in the reflected system of light is

(1) 7000 Å (2) 5600 Å (3) 4000 Å (4) All of these

Sol. Answer (4)

For the wavelength which will not be seen

$$2\mu t \cos r = n\lambda$$

$r = 0$ (Normal incidence)

$$2(1.4)\, 10^{-4} \times 10^{-2} \cos 0^\circ = n\lambda$$

$$n\lambda = 2.8 \times 10^{-6}$$

$$n\lambda = 28000 \times 10^{-10}$$

$$\lambda = \frac{28000}{n}\,\text{Å}$$

For possible wavelength n = 1, 2, 3, ...

24. Imperfections in optical lenses can be observed with the help of

(1) Newton's Rings (2) Fresnel's Biprism

(3) Lloyd's single miror experiment (4) Young's double slit experiment

Sol. Answer (1)

25. Dark and colour patterns on thin soap films are due to

(1) Interference of light (2) Diffraction of light (3) Dispersion of light (4) Polarization of light

Sol. Answer (1)

The colours are seen due to this film interference.

26. Choose the correct statement

(1) While watching television by means of an antenna, a passing nearby aeroplane can produce wavering ghost images in the television picture

(2) Solar cells are often coated with a transparent thin film, such as silicon monoxide (SiO) to minimize reflective losses.

(3) Glass lenses used in cameras and other optical instruments are usually coated with a transparent thin film, such as magnesium fluoride (MgF_2) to reduce or eliminate unwanted reflection

(4) All of these

Sol. Answer (4)

27. The beautiful iridescent (like a rainbow) colors on the wings of a tropical or morpho butterfly are due to

(1) Thin film interference of light (2) Diffraction of light

(3) Polarization of light (4) Dispersion of light

Sol. Answer (1)

28. Some currency notes (to avoid counterfeits) change their colour as you tilt them. This is due to

(1) Diffraction (2) Polarization (3) Interference (4) Refraction

Sol. Answer (3)

Thin film interferance

29. Rainbows are classic example of the phenomenon of

(1) Interference (2) Diffraction (3) Polarization (4) Absorption

Sol. Answer (1)

30. The phenomenon of diffraction can be exhibited by

(1) Infrared waves (2) Microwaves (3) X-rays (4) All of these

Sol. Answer (4)

All electromagnetic waves can exhibit diffraction provided the size of aperture/obstacle is comparable to the wavelength of light.

31. Though quantum theory of light can explain a number of phenomenon observed with light, it is necessary to retain the wave nature of light to explain the phenomenon of

(1) Photoelectric effect (2) Diffraction (3) Compton effect (4) Black body radiation

Sol. Answer (2)

32. A diffraction pattern is obtained using a beam of red light. What happens, if the red light is replaced by blue light?

(1) No change

(2) Diffraction bands become narrower and get crowded together

(3) Bands become broader and farther apart

(4) Bands disappear

Sol. Answer (2)

Position of minima in diffraction pattern

$$\theta = \frac{n\lambda}{a}$$

Decrease of λ makes the diffraction bands narrower.

33. The main difference in the phenomenon of interference and diffraction in light waves is that

(1) Diffraction is due to interaction of light from the same wave-front whereas interference is the interaction of waves from two isolated sources

(2) Diffraction is due to interaction of light from same wavefront, whereas the interference is the interaction of two waves derived from the same source

(3) Diffraction is due to interaction of waves derived from the same source, whereas the interference is the bending of light from the same wavefront

(4) Diffraction is caused by reflected waves from a source whereas interference is caused due to refraction of waves from a surface

Sol. Answer (2)

34. The condition for observing Fraunhofer diffraction from a single slit is that the wave front incident on the slit should be

(1) Spherical (2) Cylindrical (3) Plane (4) Elliptical

Sol. Answer (3)

Source is at far position from slit.

35. A parallel beam of monochromatic light of wavelength 5000 Å is incident normally on a single narrow slit of width 0.001 mm. The light is focussed by a convex lens on a screen placed on focal plane. The first minimum will be formed for the angle of diffraction equal to

(1) 0° (2) 15° (3) 30° (4) 50°

Sol. Answer (3)

$d \sin\theta = \lambda$

$$\sin\theta = \frac{5000\times10^{-10}}{.001\times10^{-3}}$$

$$\sin\theta = \frac{1}{2}$$

$\theta = 30^{\circ}$

36. Monochromatic light of wavelength 580 nm is incident on a slit of width 0.30 mm. The screen is 2m from the slit. The width of the central maximum is

(1) 3.35×10^{-3} m (2) 2.25×10^{-3} m (3) 6.20×10^{-3} m (4) 7.7×10^{-3} m

Sol. Answer (4)

$$W = \frac{2D\lambda}{a}$$

$D = 2\text{m}$, $a = 0.3 \times 10^{-3}$ m

$\lambda = 580 \times 10^{-9}$ m

37. The resolving power of a compound microscope will be maximum when

(1) Red light is used to illuminate the object

(2) Violet light is used to illuminate the object instead of red light

(3) Infra red light is used to illuminate the object instead of visible light

(4) The microscope is in normal adjustment

Sol. Answer (2)

Resolving power $\propto \frac{1}{\lambda}$, $\lambda_{\text{red}} > \lambda_{\text{violet}}$

38. Why a DVD stores almost 30 times more information than a CD?

(1) DVD uses shorter - wavelength lasers of 6350Å but CD uses an infrared laser of 7800 Å

(2) CD uses shorter wavelength laser compared to a DVD

(3) CD works on the principle of diffraction

(4) DVD works on diffraction of light

Sol. Answer (1)

39. If a classroom door is open just a small amount, we can hear sounds coming from the room but we can't see what is going on inside the room because

(1) Diffraction of sound is easier as its wavelength is large

(2) Diffraction of light is easier as its wavelength is small

(3) Sound waves can be polarized

(4) Light waves can be polarized

Sol. Answer (1)

Audible frequency of sound is less and wavelength is large.

40. When you look at a clear blue sky you see tiny specks and hair like structures floating in your view, called "floaters". This is basically

(1) Interference pattern (2) Diffraction pattern (3) Emission spectra (4) Absorption spectra

Sol. Answer (2)

41. Unpolarised beam of light of intensity I is incident on two polarisers in contact. The angle between the axes of the two polarisers is θ. Intensity of the light finally emerging from the combination is

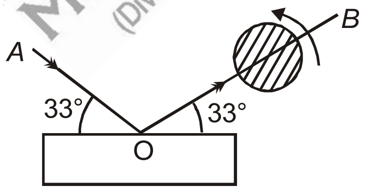
(1) $I\cos^2\theta$ (2) $\left(\frac{I}{2}\right)\cos^2\theta$ (3) $I\cos^4\theta$ (4) $\left(\frac{I}{2}\right)\cos\theta$

Sol. Answer (2)

After first polarisation intensity becomes $\frac{I}{2}$

After second polarisation it is $\frac{I}{2}\cos^2\theta$ by law of malus.

42. A beam of light AO is incident on a glass slab (m = 1.54) in a direction as shown in the diagram. The reflected ray OB is passed through a polariod. On viewing through the polariod, we find that on rotating the polariod (Given tan 57° = 1.54)



(1) The intensity is reduced down to zero and remains zero

(2) The intensity reduces down some what and rises again

(3) There is no change in intensity

(4) The intensity gradually reduces to zero and then again increases

Sol. Answer (4)

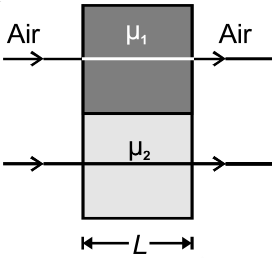
The ray is incident at Brewster's angle so it reflected ray will be plane polarised.

When passed through polarises the ray will display intensity according to the law of malus ($I_0\cos^2\theta$).

SECTION - B

Objective Type Questions

1. Two light rays initially in same phase travel through two media of equal length *L* having refractive index m_1 and m_2 ($m_1 > m_2$) as shown in figure. If the wave length of light rays in air is l, the phase difference of the emerging rays is given by



(1) $\frac{L\mu_1}{\lambda\mu_2}$ (2) $\frac{(\mu_1-\mu_2)L}{2\pi\lambda}$ (3) $\frac{2\pi(\mu_1-\mu_2)L}{\lambda}$ (4) Zero

Sol. Answer (3)

Path difference between the emerging rays = $\mu_1 L - \mu_2 L$

$$\frac{\phi}{2\pi} = \frac{(\mu_1-\mu_2)L}{\lambda}$$

$$\therefore \quad \phi = \frac{(\mu_1-\mu_2)L}{\lambda}$$

2. Light wave travel in vacuum along the *x*-axis, which of the following may represent the wave front

(1) $x = a$ (2) $y = a$ (3) $z = a$ (4) $x + y + z = a$

Sol. Answer (1)

Wave front is always perpendicular to direction of propagation of light.

3. In Young double slit experiment, 12 fringes are obtained in a certain fragment of the screen, when light of wavelength 600 nm is used. If the wavelength of light is changed to 400 nm, number of fringes observed in the same segment of the screen is

(1) 12 (2) 18 (3) 24 (4) 30

Sol. Answer (2)

Width of screen is = $\frac{12\lambda_1 D}{d}$

For new wavelength = $\frac{12\lambda_1 D}{d} = \frac{n\lambda_2 D}{d}$

$\therefore$ Number of fringes (n) = $\frac{12\lambda_1}{\lambda_2} = 12\times\frac{6000}{4000} = 18$

4. Two points separated by 0.05 mm can just be inspected in a microscope when light of wavelength 6000 Å is used. If light of wavelength 3000 Å is used then the limit of resolution becomes

(1) 0.05 mm (2) 0.025 mm (3) 0.1 mm (4) 0.15 mm

Sol. Answer (2)

Resolving power of a microscope is the shorter distance between two seperate point in a microscope's field of view that can be seen directly.

Resolving power $\propto \frac{\lambda}{2a}$ (a = aperture)

$$\frac{d_1}{d_2} = \frac{\lambda_1}{\lambda_2} \Rightarrow \frac{0.05}{d_2} = \frac{6000}{3000} \Rightarrow 0.025\text{ mm}$$

5. A thin film of water (μ = 4/3) is 3100 Å thick. If it is illuminated by white light at normal incidence. The colour of film in the reflected light will be

(1) Blue (2) Black (3) Yellow (4) Red

Sol. Answer (3)

Wave length for which maxima occurs

$$2\mu t \cos r = (2n - 1)\frac{\lambda}{2}$$

$$\lambda = \frac{4\mu t \cos r}{2n-1}$$

$$r = 0, \ \lambda = \frac{4\mu t}{2n-1}$$

for $n = 2$

$$\lambda = \frac{4(3100)}{3} \times \frac{4}{3}$$

$$= 5511.11\text{ Å}$$

(Wavelength of yellow)

6. The central fringe of the interference pattern produced by light of wavelength 6000 Å is found to shift to the position of 4th bright fringe after a glass plate of refractive index 1.5 is introduced in front of one slit in Young's experiment. The thickness of the glass plate will be

(1) 4.8 μm (2) 8.23 μm (3) 14.98 μm (4) 3.78 μm

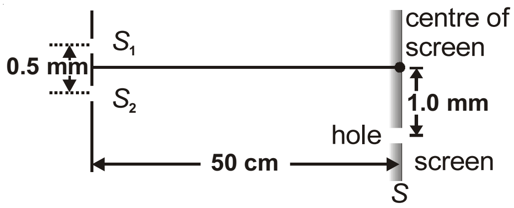
Sol. Answer (1)

Fringe shift = $\frac{(\mu - 1)tD}{d}$

4th bright fringe = $\frac{4\lambda D}{d}$

Equating both = $\frac{(\mu - 1)tD}{d} = \frac{4\lambda D}{d}$

7. In Young's double slit experiment shown in figure. S_1 and S_2 are coherent sources and S is the screen having a hole at a point 1.0 mm away from the central line. White light (400 to 700 nm) is sent through the slits. Which wavelength passing through the hole has strong intensity?



(1) 400 nm (2) 700 nm (3) 500 nm (4) 667 nm

Sol. Answer (3)

$$Y_n = \frac{nD\lambda}{d}$$

$Y_n = 10^{-3}$m, $D = 0.5$ m, $d = 0.5 \times 10^{-3}$ m

$$\lambda = \frac{500}{n}\text{nm}$$

8. In Young's double slit experiment, the intensity of light at a point on the screen where the path difference is λ is I_0. The intensity of light at a point where the path difference becomes $\frac{\lambda}{3}$ is

(1) I_0 (2) $\frac{I_0}{4}$ (3) $\frac{I_0}{3}$ (4) $\frac{I_0}{2}$

Sol. Answer (2)

Where the path difference is λ, the fringe intensity will be maximum.

$I_0 = 4I'$

(I' = intensity of each slit)

Where, $\Delta\ \times = \frac{\lambda}{3}$, $\Delta\phi = \frac{2\pi}{3}$

$$I = 4I'\ Cos^2\ \frac{\Delta\phi}{2}$$

$$I = I_0\ Cos^2\ \frac{\pi}{3}$$

$$I = \frac{I_0}{4}$$

9. Four different independent waves are represented by

(i) $y_1 = a_1\sin\omega t$ (ii) $y_2 = a_2\sin 2\omega t$ (iii) $y_3 = a_3\cos\omega t$ (iv) $y_4 = a_4\sin\left(\omega t + \frac{\pi}{3}\right)$

With which of two waves interference is possible?

(1) (i) & (ii) (2) (i) & (iv)

(3) (iii) & (iv) (4) Not possible with any combination

Sol. Answer (4)

(They are independent waves)

10. In YDSE, a thin film (μ = 1.6) of thickness 0.01 mm is introduced in the path of one of the two interfering beams. The central fringe moves to a position occupied by the 10**th** bright fringe earlier. The wave length of wave is

(1) 600 Å (2) 6000 Å (3) 60 Å (4) 660 Å

Sol. Answer (2)

Shift of fringes is given by $\frac{(\mu-1)tD}{d}$

This is equal to position of 10th bright fringe $\frac{10\lambda D}{d}$

$$\frac{0.6\times1\times10^{-5}D}{d}=\frac{10\lambda D}{d}$$

$\lambda = 0.6 \times 10^{-6}$

$\therefore$ $\lambda = 6 \times 10^{-7}$

or $\lambda = 6000$ Å

11. In Young's double slit experiment, the intensity at a point where path difference is $\frac{\lambda}{6}$ is I. If I_0 denotes the maximum intensity, $\frac{I}{I_0}$.

(1) $\frac{1}{\sqrt{2}}$ (2) $\frac{\sqrt{3}}{2}$ (3) $\frac{1}{2}$ (4) $\frac{3}{4}$

Sol. Answer (4)

Where, $\Delta x = \frac{\lambda}{6}$

$$\Delta\phi = \frac{2\pi}{\lambda}\Delta x$$

$$\therefore \quad \Delta\phi = \frac{\pi}{3}$$

$$I = I_0\cos^2\left(\frac{\Delta\phi}{2}\right)$$

$$I = I_0\cos^2\left(\frac{\pi}{6}\right)$$

or $I = I_0 \times \frac{3}{4}$

$$\therefore \quad \frac{I}{I_0}=\frac{3}{4}$$

12. The maximum intensity of fringes in Young's experiment is I. If one of the slits is closed, then intensity at that place becomes I_0. Then relation between I and I_0 is

(1) $I = I_0$ (2) $I = 2I_0$ (3) $I = 4I_0$ (4) There is no relation

Sol. Answer (3)

When the slits were open the waves interfered constructively

$I = 4I'$ (I' = Intensity of each slit)

If one of the slits is closed then intensity at that place is intensity of each slit $I' = I_0$

13. In Young's double slit interference experiment, the slit separation is made 3 folds. The fringe width becomes

(1) $\frac{1}{3}$ times (2) $\frac{1}{9}$ times (3) 3 times (4) 9 times

Sol. Answer (1)

Fringe width $\beta = \frac{\lambda D}{d}$

$$\beta' = \frac{\lambda D}{3d} = \frac{\beta}{3}$$

14. In Young's double slit experiment, the distance between the slits is reduced to half and the distance between the slit and the screen is doubled, then fringe width

(1) Will not change (2) Will become half (3) Will be doubled (4) Will become four times

Sol. Answer (4)

$$\beta = \frac{\lambda D}{d}$$

$$\beta' = \frac{\lambda \times 2D}{d/2} \qquad \therefore \quad \beta' = 4\beta$$

15. In Young's experiment, the separation between 5th maxima and 3rd minima is how many times as that of fringe width?

(1) 5 times (2) 3 times (3) 2.5 times (4) 2 times

Sol. Answer (3)

5th maximum $= \frac{5\lambda D}{d}$

3rd minimum $= \frac{(2n-1)\lambda D}{2d} = \frac{5\lambda D}{2d}$

$$\therefore \quad \text{Distance} = \frac{5\lambda D}{d} - \frac{5\lambda D}{2d}$$

$$= \frac{5\lambda D}{2d}$$

$\therefore$ Distance = 2.5 times

16. Refractive index of material is equal to the tangent of polarising angle. It is called

(1) Brewster's law (2) Lambert's law (3) Malus' law (4) Bragg's law

Sol. Answer (1)

$m = \tan i_p$

17. If the amplitude ratio of two sources producing interference is 3 : 5, the ratio of intensities of maxima and minima is

(1) 25 : 16 (2) 5 : 3 (3) 16 : 1 (4) 25 : 9

Sol. Answer (3)

$A_1 : A_2 = 3 : 5$ then $I_1 : I_2 = 9 : 25$

$$\frac{I_{\max}}{I_{\min}} = \frac{\left(\sqrt{I_1}+\sqrt{I_2}\right)^2}{\left(\sqrt{I_1}-\sqrt{I_2}\right)^2} = \left(\frac{3+5}{3-5}\right)^2$$

$$= \frac{16}{1}$$

18. In a Young's double slit experiment, the source illuminating the slits is changed from blue to violet. The width of the fringes

(1) Increases (2) Decreases (3) Becomes unequal (4) Remains same

Sol. Answer (2)

$$\beta = \frac{\lambda D}{d}$$

If λ decreases width of the fringes decreases.

19. In Young's double slit experiment, when two light waves form third minimum, they have

(1) Phase difference of 3π (2) Path difference of 3λ

(3) Phase difference of $\frac{5\pi}{2}$ (4) Path difference of $\frac{5\lambda}{2}$

Sol. Answer (4)

Path difference is given by $\Delta x = (2n-1)\frac{\lambda}{2} = \frac{5\lambda}{2}$

20. To observerve diffraction the size of an obstacle

(1) Should be of the same order as wavelength (2) Should be much smaller than the wavelength

(3) Has no relation to wavelength (4) Should be exactly $\frac{\lambda}{2}$

Sol. Answer (1)

21. If frequency of light wave propagating in water is halved, its speed

(1) Is halved (2) Is doubled (3) Remains same (4) Becomes four times

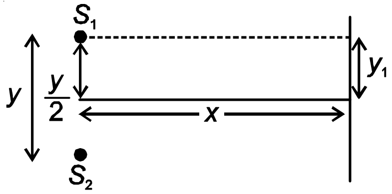
Sol. Answer (3)

Speed of light remains same in a medium.

22. White light is used in Young's double slit experiment. Separation between slits is *y* and the screen is at distance *x* from slits (x >> y). Which of these wavelengths is missing in front of one of the slits?

(1) $\frac{y^2}{x}$ (2) $\frac{y^2}{2x}$ (3) $\frac{y^2}{4x}$ (4) All of these

Sol. Answer (1)



Distance of minima from central maxima $y_1 = \frac{(2m-1)\lambda D}{2d}$

$y_1 = \frac{y}{2}$, $d = y$, $D = x$

$\lambda = \frac{y^2}{(2m-1)x}$ $m = 1, 2, 3, \ldots$

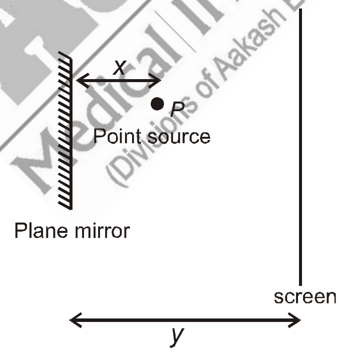
23. Corpuscular theory of light predicts speed of light to be

(1) Independent of medium (2) Greater in water than in vacuum

(3) Greater in vacuum than in water (4) Dependent on intensity of light

Sol. Answer (2)

24. Shape of interference fringes formed on the screen due to point source *P*, in the case shown here



(1) Parabolic (2) Elliptical (3) Circular (4) Hyperobic

Sol. Answer (3)

25. In Fraunhoffer diffraction from a single slit, wave front incident on the slit is

(1) Planar (2) Spherical

(3) Cylindrical (4) Either spherical or cylindrical

Sol. Answer (1)

Fraunhoffer diffraction is for the parallel incidence.

26. Young's double slit experiment is performed with monochromatic light. A thin film is introduced in front of one of the slits

(1) Intensity at the position of central maxima must decrease

(2) Intensity at the position of central maxima may increase

(3) Central maxima may remain unshifted

(4) Intensity at position of first maxima may decrease

Sol. Answer (4)

The entire fringe will experience a shifts and the only thing we can say for certain is the fourth option.

27. Apparent wavelength of light coming from a star moving away from earth is 0.02% more than its actual wavelength. Velocity of star is

(1) 30 km/s (2) 60 km/s (3) 90 km/s (4) 120 km/s

Sol. Answer (2)

$$\lambda_s\sqrt{\frac{C+V}{C-V}} = \lambda_0 \Rightarrow \lambda_s\sqrt{\frac{C+V}{C-V}} = \left(1+\frac{0.02}{100}\right)\lambda_s$$

$$\frac{C+V}{C-V} = \left(1+\frac{0.02}{100}\right)^2 \Rightarrow \frac{C+V}{C-V} - 1 = \frac{0.04}{100} \Rightarrow \frac{2V}{C-V} = \frac{1}{2500}$$

or $V = \dfrac{3\times10^5}{5001} \approx 60$ km/s

28. Diffraction is easily noticeable for sound waves than for light waves because sound waves

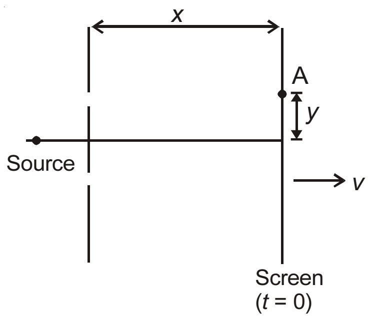
(1) Are high energy waves (2) Are low intensity waves

(3) Have longer wavelength (4) Are mechanical in nature

Sol. Answer (3)

For diffraction the obstacle and wavelengths must be of same order. Since they have longer wavelength they can easily cleaned around everyday absects more easily.

29. In the Young's arrangement, screen starts moving towards right with constant speed *v*. Initial distance between screen and plane of slits is x. At *t* = 0, 1st order maxima is lying at point A. After how much time first order minima lies at point A?



(1) $\dfrac{x}{2v}$ (2) $\dfrac{x}{v}$ (3) $\dfrac{x}{3v}$ (4) $\dfrac{2x}{3v}$

Sol. Answer (2)

Distance of 1st maxima from central fringe = $\frac{\lambda D}{d}$ $[D = x]$

Distance of 1st minima = $\frac{\lambda D}{2d}$

D at time $t = D_t = x + Vt$

$$\frac{\lambda x}{d} = \frac{\lambda(x + Vt)}{2d}$$

$$x = Vt$$

or $t = \frac{x}{V}$

30. Unpolarized light of intensity x is incident on a polarising sheet. Intensity of light which does not get transmitted is

(1) x (2) $\frac{x}{2}$ (3) $\frac{x}{4}$ (4) Zero

Sol. Answer (2)

Polariser transmits energy travelling along a single plane.

Energy transmitted is $\frac{x}{2}$

Hence energy left behind is $x - \frac{x}{2} = \frac{x}{2}$

31. Light of wavelength l is coming from a star. What is the limit of resolution of a telescope whose objective has diameter r ?

(1) $\frac{0.305\lambda}{r}$ (2) $\frac{0.61\lambda}{r}$ (3) $\frac{1.22\lambda}{r}$ (4) $\frac{2\lambda}{r}$

Sol. Answer (3)

32. Brewster angle for air to water transition is (refractive index of water is $\frac{4}{3}$)

(1) $\sin^{-1}\frac{3}{4}$ (2) $\cos^{-1}\frac{3}{4}$ (3) $\tan^{-1}\frac{3}{4}$ (4) $\cot^{-1}\frac{3}{4}$

Sol. Answer (4)

Brewster's angle is given by $\tan^{-1}\mu = \tan^{-1}\frac{4}{3}$ which is also written as $\cot^{-1}\frac{3}{4}$

33. Approximate thickness of oil film to observe interference of light (due to which it looks coloured) is

(1) 10 mm (2) 10^{-3} mm (3) 10 pm (4) 1 cm

Sol. Answer (2)

The thickness must be in the order of visible light.

34. Slit widths in a Young's double slit experiment are in the ratio 9 : 4. Ratio of intensity at minima to that at maxima is

(1) 4 : 9 (2) 16 : 81 (3) 1 : 25 (4) 1 : 16

Sol. Answer (3)

$W \propto I$

$\frac{I_1}{I_2} = \frac{9}{4} \quad \frac{I_{\min}}{I_{\max}} = \frac{\left(\sqrt{I_1} - \sqrt{I_2}\right)^2}{\left(\sqrt{I_1} + \sqrt{I_2}\right)^2}$

35. Width of slit in a single slit diffraction experiment such that 20 maxima of double slit interference pattern are obtained within central maxima of the diffraction pattern is (Slit separation for double slit arrangement = 2 mm)

(1) 0.05 mm (2) 0.1 mm (3) 0.2 mm (4) 0.4 mm

Sol. Answer (3)

$20 \frac{D\lambda}{d} = \frac{2D\lambda}{b} \quad , \quad d = 2\text{mm}$

36. In Fraunhoffer diffraction, at the angular position of first diffraction minimum, phase difference (in radian) between wavelets from opposite edges of the slit is

(1) $\frac{\pi}{2}$ (2) π (3) 2π (4) 4π

Sol. Answer (3)

For minima in diffraction $\Delta x = m\lambda$

For first minima $\Delta x = \lambda$

$\Delta\phi = 2\pi$

37. Choose the correct alternative

(1) When plane polarised light passes through polaroid, it changes its nature to linearly polarised

(2) Refracted light, when light is incident at Brewster angle, is linearly polarised

(3) Polarised light can be produced by scattering through $\frac{\pi}{2}$ in earth's atmosphere

(4) Natural light from sun is polarised

Sol. Answer (3)

SECTION - C

Previous Years Questions

1. A star, which is emitting radiation at a wavelength of 5000 Å, is approaching the earth with a velocity of 1.5×10^5 m/s. The change in wavelength of the radiation as received on the earth is

(1) 25 Å (2) 100 Å (3) Zero (4) 2.5 Å

Sol. Answer (4)

Emitting at a wavelength of 5000 Å

$\frac{\Delta\lambda}{\lambda} = \frac{V}{C}$

$\Delta\lambda = \frac{V}{C} \times \lambda = \frac{1.0 \times 10^4}{3 \times 10^8} \times 5000 \times 10^{-10} = 0.25$ Å

2. For a wavelength of light ‘l’ and scattering object of size ‘a’, all wavelengths are scattered nearly equally, if

(1) $a = \lambda$ (2) $a >> \lambda$ (3) $a << \lambda$ (4) $a \geq \lambda$

Sol. Answer (2)

For a >> λ Rayleigh and scattering not valid.

Here all wave lengths scattered nearly equally.

3. If two sources have a randomly varying phase difference $\phi(t)$, the resultant intensity will be given by

(1) I_0 (2) $\frac{I_0}{2}$ (3) $2I_0$ (4) $\frac{I_0}{\sqrt{2}}$

Sol. Answer (3)

If phase difference varies randomly with time, the wave are incoherent and the intensity of resultant waves is sum of individual intensities or $2I_0$.

4. In Young’s double-slit experiment, if the distance between the slits is halved and the distance between the slits and the screen is doubled, the fringe width becomes

(1) Half (2) Double (3) Four times (4) Eight times

Sol. Answer (3)

$$\beta = \frac{\lambda D}{d}$$

$$\beta' = \frac{2\lambda D}{d/2} = 4\beta$$

5. In a Fresnel biprism experiment, the two positions of lens give separation between the slits as 16 cm and 9 cm respectively. What is the actual distance of separation?

(1) 13 cm (2) 14 cm (3) 12.5 cm (4) 12 cm

Sol. Answer (4)

d_1 = 16 cm d_2 = 9 cm

Actual distance $2d = \sqrt{d_1 d_2}$

$2d = 4 \times 3$

or $2d = 12$ cm

6. Colours appear on a thin soap film and on soap bubbles due to the phenomenon of

(1) Interference (2) Dispersion (3) Refraction (4) Diffraction

Sol. Answer (1)

The phenomenon of thin film interferens is in effect.

7. On introducing a thin film in the path of one of the two interfering beam, the central fringe will shift by one fringe width. If $\mu = 1.5$, the thickness of the film is (wavelength of monochromatic light is l)

(1) 4λ (2) 3λ (3) 2λ (4) λ

Sol. Answer (3)

Shift shown = $\frac{\lambda D}{d}$

$$\frac{\lambda D}{d} = \frac{(\mu - 1)tD}{d}$$

or $\lambda = (1.5 - 1)t$

or $t = 2\lambda$

8. Two coherent monochromatic light beams of intensities I and $4I$ are superimposed; the maximum and minimum possible intensitites in the resulting beam are

(1) $5I$ and I (2) $5I$ and $3I$ (3) $9I$ and I (4) $9I$ and $3I$

Sol. Answer (3)

$I_1 = I$, $I_2 = 4I$

$$I_{\max} = \left(\sqrt{I_1} + \sqrt{I_2}\right)^2$$

$$I_{\min} = \left(\sqrt{I_1} + \sqrt{I_2}\right)^2$$

9. If two waves, each of intensity I_0, having the same frequency but differing by a constant phase angle of 60°, superimposing at a certain point in space, then the intensity of the resultant wave is

(1) $2I_0$ (2) $3I_0$ (3) $\sqrt{3}I_0$ (4) $4I_0$

Sol. Answer (2)

Resultant intensity is given by

$$I_r = I_0 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$$

$\therefore$ $I_r = I_0 + I_1 + 2I_0 \cos 60^\circ$

$\therefore$ $I_r = 3I_0$

10. In Young's double slit experiment, the fringe width is found to be 0.4 mm. If the whole apparatus is immersed in water of refractive index $\left(\frac{4}{3}\right)$, without disturbing the geometrical arrangement, the new fringe width will be

(1) 0.40 mm (2) 0.53 mm (3) 0.20 mm (4) 0.30 mm

Sol. Answer (4)

$\beta = 4 \times 10^{-3}$ m

In water λ becomes $\frac{\lambda}{\mu}$

or $\beta' = \frac{\beta}{\mu}$

$\therefore$ $\beta' = 0.30$ mm

11. In an interference experiment monochromatic light is replaced by white light, we will see

    (1) Uniform illumination on the screen

    (2) Uniform darkness on the screen

    (3) Equally spaced white and dark bands

    (4) A few coloured bands and then uniform illumination

Sol. Answer (4)

12. In Young's double slit experiment carried out with light of wavelength 5000 Å, the distance between the slit is 0.2 mm and the screen is at 200 cm from the plane of slits. The central maximum is at $x = 0$. The third maximum will be at x equal to

    (1) 1.5 cm (2) 1.67 cm (3) 0.5 cm (4) 5.0 cm

Sol. Answer (1)

$d = 0.2$ mm; $\lambda = 5000 \times 10^{-10}$ m; $D = 2$ m

$$3^{\text{rd}} \text{ maximum} = \frac{n\lambda D}{d}$$

or 3^{rd} maximum is at $= \dfrac{3\lambda D}{d}$

13. In Young's experiment when sodium light of wave length 5893 Å is used, then 62 fringes are seen in the field of view. Instead, if violet light of wavelength 4350 Å is used, then the number of fringes that will be seen in the field of view will be

    (1) 54 (2) 64 (3) 74 (4) 84

Sol. Answer (4)

Field of view of sodium light $= \dfrac{\lambda_s D \times n_s}{d}$

$$n_v \cdot \frac{\lambda_v D}{d} = n_s \frac{D}{d} \times \lambda_s$$

$$n_v = \lambda_v = n_s \lambda_s$$

$$n_v = \frac{5893 \times 62}{4350} = 83.99$$

14. In an interference pattern by two identical slits, the intensity of central maxima is I. What will be the intensity of the same spot, if one of the slits is closed?

    (1) $\dfrac{I}{2}$ (2) $\dfrac{I}{4}$ (3) I (4) $2I$

Sol. Answer (2)

$$I = I_0 + I_0 + 2\sqrt{I_0 I_0}$$

$$I_0 = \frac{I}{4}$$

15. If a thin mica sheet of thickness '*t*' and refractive index 'm' is placed in the path of one of the waves producing interference, then the whole interference pattern shifts towards the side of the sheet by a distance

(1) $\frac{d}{D}(\mu-1)t$ (2) $\frac{D}{d}(\mu-1)t$ (3) $Dd(\mu-1)t$ (4) $(\mu-1)t$

Sol. Answer (2)

16. In Young's experiment, the wavelength of red light is 7.8 × 10^{-5} cm and that of blue light 5.2 × 10^{-5} cm. The value of *n* for which $(n + 1)^{th}$ blue bright band coincides with n^{th} red bright band is

(1) 4 (2) 3 (3) 2 (4) 1

Sol. Answer (3)

$\lambda_r = 7.8 \times 10^{-5}$ cm

$\lambda_b = 5.2 \times 10^{-5}$ cm

$$\frac{n\lambda_r D}{d} = \frac{(n+1)\lambda_b D}{d}$$

17. A slit 5 cm wide is irradiated normally with micro waves of wavelength 1 cm. Then the angular spread of the central maximum on either side of the incident light is nearly

(1) $\frac{1}{5}$ radian (2) 4 radian (3) 5 radian (4) 6 radian

Sol. Answer (1)

b = 5 cm, λ = 1 cm

Angular spread of Central maxima $= \frac{\lambda}{b}$ on either side.

18. In Young's double slit experiment, the 10^{th} maximum of wavelength I_1 is at a distance of y_1 from the central maximum. When the wavelength of the source is changed to I_2, 5^{th} maximum is at a distance of y_2 from its central maximum. The ratio $\left(\frac{y_1}{y_2}\right)$ is

(1) $\frac{2\lambda_2}{\lambda_1}$ (2) $\frac{\lambda_1}{2\lambda_2}$ (3) $\frac{\lambda_2}{2\lambda_1}$ (4) $\frac{2\lambda_1}{\lambda_2}$

Sol. Answer (4)

$$y_1 = \frac{10\lambda_1 D}{d},\ y_2 = \frac{5\lambda_2 D}{d}$$

$$\frac{y_1}{y_2} = \frac{2\lambda_1}{\lambda_2}$$

19. A beam of light strickes a piece of glass at an angle of incidence of 60° and the reflected beam is completely plane polarised. The refractive index of the glass is

(1) 1.5 (2) $\sqrt{3}$ (3) $\sqrt{2}$ (4) $\frac{3}{2}$

Sol. Answer (2)

Brewster's angle = $\tan^{-1}\mu$

or $\tan 60^\circ = \mu$

$\therefore \quad \mu = \sqrt{3}$

20. Waves that cannot be polarised are

(1) Light waves (2) Electromagnetic waves

(3) Transverse waves (4) Longitudinal waves

Sol. Answer (4)

Since the vibrate along the direction of propagation.

21. Two polaroids are kept crossed to each other. Now one of them is rotated through an angle of 45°. The percentage of incident light now transmitted through the system is

(1) 15% (2) 25% (3) 50% (4) 75%

Sol. Answer (2)

Intensities after first polarises = $\frac{I_0}{2}$

After that applying law of malus

$I'' = I' \cos^2\phi \qquad \phi = 45^\circ$

$\therefore \quad I'' = \frac{I_0}{4}$

22. When the angle of incidence is 60° on the surface of a glass slab, it is found that the reflected ray is completely polarised. The velocity of light in glass is

(1) $\sqrt{2}\times10^8$ m/s (2) $\sqrt{3}\times10^8$ m/s (3) 2×10^8 m/s (4) $\frac{\sqrt{3}}{2}\times10^8$ m/s

Sol. Answer (2)

$\tan 60^\circ = \mu$ [Brewster's law]

Velocity of light in glass $= \frac{C}{\mu}$

$= \sqrt{3}\times10^8$ m/s

23. Light of wavelength l is incident on a slit of width '*d*'. The resulting diffraction pattern is observed on a screen at a distance *D*. The linear width of the principal maximum is then equal to the width of the slit if *D* equals

(1) $\frac{d}{\lambda}$ (2) $\frac{2\lambda}{d}$ (3) $\frac{d^2}{2\lambda}$ (4) $\frac{2\lambda^2}{d}$

Sol. Answer (3)

$\frac{2D\lambda}{d} = d, \qquad D = \frac{d^2}{2\lambda}$

24. In a Fraunhofer diffraction at a single slit of width *d* with incident light of wavelength 5500 Å, the first minimum is observed at angle of 30°. The first secondary maximum is observed at an angle q, equal to

(1) $\sin^{-1}\left(\frac{1}{\sqrt{2}}\right)$ (2) $\sin^{-1}\left(\frac{1}{4}\right)$ (3) $\sin^{-1}\left(\frac{3}{4}\right)$ (4) $\sin^{-1}\left(\frac{\sqrt{3}}{2}\right)$

Sol. Answer (3)

For first minima

$$\sin\theta = \frac{\lambda}{b}$$

$$\sin 30^\circ = \frac{\lambda}{b}$$

For first secondary maxima

$$\sin\theta = \frac{3\lambda}{2b}$$

$$\sin\theta = \frac{3}{4}$$

$$\Rightarrow \theta = \sin^{-1}\frac{3}{4}$$

25. Diameter of human eye lens is 2 mm. What will be the minimum distance between two points to resolve them, which are situated at a distance of 50 m from eye. The wavelength of light is 5000 Å?

(1) 2.32 m (2) 4.28 mm (3) 1.525 cm (4) 12.48 cm

Sol. Answer (3)

Minimum distance between two points = $\frac{1.22\lambda D}{d}$

d = 2 mm

D = 50 m

λ = 5000 Å

26. A beam of light of λ = 600 nm from a distant source falls on a single slit 1 mm wide and the resulting diffraction pattern is observed on a screen 2 m away. The distance between first dark fringes on either side of the central bright fringe is

(1) 1.2 cm (2) 1.2 mm (3) 2.4 cm (4) 2.4 mm

Sol. Answer (4)

Distance between first dark fringes on either side of the central bright fringe $\frac{2D\lambda}{b}$

D = 2 m

λ = 600 nm

b = 1 mm

27. In the Young's double-slit experiement, the intensity of light at a point on the screen where the path difference is λ is K, (λ being the wavelength of light used). The intensity at a point where the path difference is $\frac{\lambda}{4}$, will be

(1) K (2) $\frac{K}{4}$ (3) $\frac{K}{2}$ (4) Zero

Sol. Answer (3)

Where the path difference is λ the intensity is maximum

$I_{max} = 4I_0$, I_0 (intensity of each slit)

$K = 4I_0$

Path difference $= \frac{\lambda}{4}$

Phase difference $(\Delta\phi) = \frac{\lambda}{4}\left(\frac{2\pi}{\lambda}\right)$

$= \frac{\pi}{2}$

$$I = 4I_0\cos^2\left(\frac{\Delta\phi}{2}\right)$$

$$= 4I_0\cos^2\frac{\pi}{4}$$

$$= 2I_0$$

$$= 2\left(\frac{K}{4}\right)$$

$$= \frac{K}{2}$$

28. In a double slit experiment, the two slits are 1 mm apart and the screen is placed 1 m away. A monochromatic light of wavelength 500 nm is used. What will be the width of each slit for obtaining ten maxima of double slit within the central maxima of single slit pattern?

(1) 0.02 mm (2) 0.2 mm (3) 0.1 mm (4) 0.5 mm

Sol. Answer (2)

$$10\frac{D\lambda}{d} = \frac{2D\lambda}{b}$$

$D = 1$m. $d = 1$ mm

$l = 500$ nm

b = Width of each slit

$$b = \frac{d}{5}$$

$b = 0.2$ mm

29. For a parallel beam of monochromatic light of wavelength 'λ', diffraction is produced by a single slit whose width 'a' is of the order of the wavelength of the light. If 'D' is the distance of the screen from the slit, the width of the central maxima will be

(1) $\frac{2Da}{\lambda}$ (2) $\frac{2D\lambda}{a}$ (3) $\frac{D\lambda}{a}$ (4) $\frac{Da}{\lambda}$

Sol. Answer (2)

Width of central maxima = Distance between first dark fringes on either side of the central fringe $= \frac{2D\lambda}{a}$

SECTION - D

Assertion-Reason Type Questions

1. A : The speed of light in vacuum doesn't depend on nature of the source, direction of propagation, motion of the source or observer wavelength and intensity of the wave.

R : The speed of light in vacuum is a universal constant independent of all the factors listed and anything else.

Sol. Answer (1)

2. A : The speed of light, sound waves, water waves in a medium is independent of the nature of the source or intensity (so long it is low).

R : Speed of the waves in a medium depends on wavelength.

Sol. Answer (2)

3. A : Speed of light in a medium is independent of the motion of the source relative to the medium.

R : Speed of light in a medium depends on the motion of the observer relative to the medium.

Sol. Answer (2)

4. A : When monochromatic light is incident on a surface separating two media, the reflected and refracted light both have the same frequency as the incident frequency.

R : At any interface between the two media, the electric (and magnetic) fields must satisfy certain boundary conditions for all times and frequency determines the time dependence of fields.

Sol. Answer (1)

5. A : When light travels from a rarer to a denser medium, it loses some speed but it doesn't imply a reduction in the energy carried by the light wave.

R : Energy carried by a wave depends on the amplitude of the wave and not on the speed of wave propagation.

Sol. Answer (1)

6. A : When a narrow pulse of light is sent through a medium, it doesn't retain its shape as it travels through the medium.

R : Since the speed of propagation in a medium depends on wavelength, different wavelength components of the pulse travel with different speeds.

Sol. Answer (1)

7. A : In the wave picture of light, intensity of light is determined by the square of the amplitude of the wave.

R : In the photon picture of light, for a given frequency, intensity of light is determined by the number of photons per unit area.

Sol. Answer (2)

8. A : The speed of light in still water is not same as that in flowing water.

R : The speed of light in water is not independent of the relative motion between the observer and the medium.

Sol. Answer (1)

9. A : In a single-slit diffraction experiment, if the width of the slit is made double the original width the size of the central diffraction band reduces by half and intensity increase four fold.

R : The intensity of interference fringes in a double slit arrangement is modulated by the diffraction pattern of each slit.

Sol. Answer (2)

10. A : When a tiny circular obstacle is placed in the path of light from a distant source, a bright spot is seen at the centre of the shadow of the obstacle.

R : Waves diffracted from the edge of the circular obstacle interfere constructively at the centre of the shadow producing a bright spot.

Sol. Answer (1)

11. A : Ray optics assumes that light travels in a straight line which is disapproved by diffraction effects, yet the ray optics assumption is so commonly used in understanding location and several other properties of images in optical instruments.

R : Typical sizes of apertures involved in ordinary optical instruments are much larger than the wavelength of light.

Sol. Answer (1)

12. A : The phase difference between any two points on a wavefront is zero.

R : Corresponding to a beam of parallel rays of light, the wavefronts are planes parallel to one another.

Sol. Answer (2)

13. A : Light waves can be polarised.

R : Light waves are transverse in nature.

Sol. Answer (1)

14. A : The law of conservation of energy is violated during interference.

R : For sustained interference the phase difference between the two waves must change with time.

Sol. Answer (4)

15. A : When the apparatus of YDSE is brought in a liquid from air, the fringe width decreases.

R : The wavelength of light decreases in the liquid.

Sol. Answer (1)

16. A : The resolving power of a telescope decreases on decreasing the aperture of its objective lens.

R : The resolving power of a telescope is given as $\frac{D}{1.22\,\lambda}$, where D is aperture of the objective and λ is the wavelength of light.

Sol. Answer (1)

❑ ❑ ❑

Chapter 11

Dual Nature of Radiation and Matter

Solutions

SECTION - A

Objective Type Questions

1. When photon of energy 3.8 eV falls on metallic surface of work function 2.8 eV, then the kinetic energy of emitted electrons are

(1) 1 eV (2) 6.6 eV (3) 0 to 1 eV (4) 2.8 eV

Sol. Answer (3)

$h\nu = w_0 + \text{KE}_{\text{max}}$

$3.8 - 2.8 = \text{KE}_{\text{max}}$

$\therefore \quad \text{KE}_{\text{max}} = 1 \text{ eV}$

2. The photoelectric work function

(1) Is different for different materials (2) Is same for all metals

(3) Depends upon frequency of the incident light (4) Depends upon intensity of the incident light

Sol. Answer (1)

Work function is the property of material.

3. The phenomenon of photoelectric effect was first explained by

(1) Hallwach (2) Einstein (3) Planck (4) Bohr

Sol. Answer (2)

Einstein won the Nobel Prize for predicting photoelectric effect by proposing the dual nature of light.

4. The energy of the most energetic photoelectrons emitted from a metal target depends upon

(1) Threshold frequency of the metal (2) Photoelectric work function of the metal

(3) Wavelength of the incident radiation (4) All of these

Sol. Answer (4)

$h\nu - w_0 = \text{KE}_{\text{max}}$

Hence, all options are correct.

5. Threshold wavelength for sodium is 6 × 10^{-7}m. Then photoemission occurs for light of wavelength λ if

(1) $\lambda > 6 \times 10^{-7}$ metre (2) $\lambda < 6 \times 10^{-7}$ metre

(3) $\lambda = 5 \times 10^{14}$ metre (4) Frequency $\leq 5 \times 10^{14}$ hertz

Sol. Answer (2)

$\lambda \leq \lambda_{\text{threshold}}$

6. In photoelectric effect, the slope of stopping potential versus frequency of incident light for a given surface will be

(1) $h\,e^{-1}$ (2) $e\,h$ (3) e (4) h

Sol. Answer (1)

$$V_0 = \frac{h}{e}f - \frac{w_0}{e}$$

7. When a metallic surface is illuminated with light of wavelength λ, the stopping potential is x volt. When the same surface is illuminated by light of wavelength 2λ, the stopping potential is $\frac{x}{3}$. Threshold wavelength for the metallic surface is

(1) $\frac{4\lambda}{3}$ (2) 4λ (3) 6λ (4) $\frac{8\lambda}{3}$

Sol. Answer (2)

From Einstein photoelectric equation.

$h.v = \phi + K_{max}$

$\frac{hc}{\lambda} = \phi + ev_0$ (v_0 = stopping potential)

$\frac{hc}{\lambda} = \phi + ex$

$\frac{hc}{2\lambda} = \phi + e\frac{x}{3}$

On solving

(work function) $\phi = \frac{hc}{4\lambda}$

$\frac{hc}{\lambda_0} = \frac{hc}{4\lambda}$

$\lambda_0 = 4\lambda.$

8. A monochromatic point source of light is placed at a distance d from a metal surface. Photo electrons are ejected at a rate n per second, and with maximum kinetic energy E. If the source is brought nearer to distance $d/2$, the rate and the maximum kinetic energy per photoelectron become nearly

(1) $2n$ and $2E$ (2) $4n$ and $4E$ (3) $4n$ and E (4) n and $4E$

Sol. Answer (3)

Intensity $\propto \frac{1}{d^2}$

So when the source of light is brought closer

Intensity becomes 4 times.

Hence, rate $\propto$ Intensity the rate will become $4n$.

KE_{max} depends on incident frequency which does not change and will remain E.

9. Given that a photon of light of wavelength 10000 Å has energy 1.23 eV. Now when light of intensity I_0 and wavelength 5000 Å falls on a photo cell the saturation current and stopping potential are 0.40 μA and 1.36 V respectively. The work function is

(1) 0.43 eV (2) 1.10 eV (3) 1.36 eV (4) 2.47 eV

Sol. Answer (2)

λ = 10000 Å has E = 1.23 eV

$\because$ Energy of 5000 Å photon = 2.46 eV

$2.46 = \phi + 1.36$

$\phi = 1.1\ ev$

10. If the frequency of light incident on a metallic plate be doubled, how will the maximum kinetic energy of the photoelectrons change?

(1) It becomes more than double (2) It becomes less than double

(3) It becomes exactly double (4) It does not change

Sol. Answer (1)

$hf = w_0 + KE_{max}$

$KE_{max} = hf - w_0$

Since w_0 is constant.

KE_{max} will become more than double

11. Wave nature of light cannot explain photoelectric effect because in photoelectric effect, it is seen that

(1) For the frequency of light below a certain value, the photoelectric effect does not take place, irrespective of intensity

(2) Maximum kinetic energy of ejected electrons is independent of intensity of radiation

(3) There is no time lag between the incidence of radiation and emission of electrons

(4) All of these

Sol. Answer (4)

(Laws of photo electric emission)

12. The photoelectric threshold for a certain metal surface is 330 Å. What is the maximum kinetic energy of the photoelectrons emitted, if radiations of wavelength 1100 Å are used ?

(1) 1 eV (2) 2 eV (3) 7.5 eV (4) No electron is emitted

Sol. Answer (4)

Since λ incident is greater than threshold wavelength. No electron will be ejected.

13. When a point source of light is at a distance of 50 cm from a photoelectric cell, the cut-off voltage is found to be V_0. If the same source is placed at a distance of 1 m from the cell, then the cut-off voltage will be

(1) $V_0/4$ (2) $V_0/2$ (3) V_0 (4) $2\,V_0$

Sol. Answer (3)

Stopping potential depends on incident light and will not change.

14. In photoelectric effect when photons of energy $h\nu$ fall on a photosensitive surface (work function $h\nu_0$) electrons are emitted from the metallic surface. It is possible to say that

(1) All ejected electrons have same kinetic energy equal to $h\nu - h\nu_0$

(2) The ejected electrons have a distribution of kinetic energy from zero to $(h\nu - h\nu_0)$

(3) The most energetic electrons have kinetic energy equal to $h\nu$

(4) All ejected electrons have kinetic energy $h\nu_0$

Sol. Answer (2)

$KE_{max} = h\nu - h\nu_0$ and hence the energies of electrons can range anywhere between these values.

15. Light of frequency 1.5 times the threshold frequency is incident on photo-sensitive material. If the frequency is halved and intensity is doubled, the photo current becomes

(1) Quadrupled (2) Doubled (3) Halved (4) Zero

Sol. Answer (4)

If frequency is halved, the initial frequency will become less than incident frequency

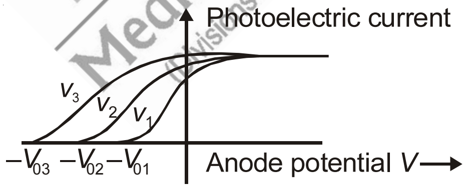
16. The work function of a substance is 4eV. The longest wavelength of light that can cause the emission of photoelectrons from this substance is approximately

(1) 540 nm (2) 400 nm (3) 310 nm (4) 220 nm

Sol. Answer (3)

$$\phi = \frac{hc}{\lambda_0}$$

17. In photoelectric effect, the curve between photoelectric current and anode potential V (for different frequencies) is shown in figure, then



(1) $v_1 > v_2 > v_3$ (2) $v_1 < v_2 < v_3$ (3) $v_1 = v_2 = v_3$ (4) $v_1 > v_2 < v_3$

Sol. Answer (2)

As is evident from the graph $v_1 < v_2 < v_3$, V_1, V_2, V_3 in this case are the stopping potential.

18. X-rays of wavelength 22 pm are scattered from a carbon target at an angle of 85° to the incident beam. The Compton shift for X-rays is

(1) 2.2 pm (2) 1.1 pm (3) 0.55 pm (4) 4.4 pm

Sol. Answer (1)

$$\lambda' - \lambda = \frac{h}{m_0 c}(1 - \cos\phi)$$

19. The cathode of a photocell is changed such that the work function changes from w_1 to w_2 ($w_2 > w_1$). If the saturation currents before and after the change are I_1 and I_2 and all other conditions are unchanged, then (assuming $h\nu > w_2$)

(1) $I_1 = I_2$ (2) $I_1 < I_2$ (3) $I_1 > I_2$ (4) $I_1 < I_2 < 2I_2$

Sol. Answer (1)

Saturation current depends on intensity which does not change. Hence, $I_1 = I_2$

20. If the energy of a photon is E, then its momentum is (c is velocity of light)

(1) E/c (2) $E/2c$ (3) $2E/c$ (4) It has no momentum

Sol. Answer (1)

$\frac{hc}{\lambda} = E$ and momentum is $\frac{h}{\lambda}$ for photon

$\therefore$ P of a photon = $\frac{E}{C}$

21. The de Broglie wavelength of an electron in the n^{th} Bohr orbit is related to the radius R of the orbit as

(1) $n\lambda = \pi R$ (2) $n\lambda = \frac{3}{2}\pi R$ (3) $n\lambda = 2\pi R$ (4) $n\lambda = 4\pi R$

Sol. Answer (3)

$n\lambda = 2\pi r$ (According to Bohr's theory)

22. A photon and an electron both have wavelength 1Å. The ratio of energy of photon to that of electron is

(1) 1 (2) 0.012 (3) 82.7 (4) 10^{-10}

Sol. Answer (3)

$$\text{E(Photon)} = \frac{hc}{\lambda}$$

$$\text{E(electron)} = \frac{P^2}{2\,m_e} = \left(\frac{h}{\lambda}\right)^2 \frac{1}{2\,m_e}$$

23. Wavelength of an electron accelerated through a potential difference of 1 volt is

(1) 12.27 Å (2) 1.234 Å (3) 1 micron (4) 1 fermi

Sol. Answer (1)

Energy gained by one electron = 1 eV

$P = \sqrt{2mE}$ and $\lambda = \frac{h}{P}$

Hence, $\lambda = \frac{h}{\sqrt{2mE}}$

$$\therefore \quad \lambda = \frac{h}{\sqrt{2m_e}}$$

24. For a proton accelerated through V volts, de Broglie wavelength is given as λ =

(1) $\frac{12.27}{\sqrt{V}}$ Å (2) $\frac{0.101}{\sqrt{V}}$ Å (3) $\frac{0.286}{\sqrt{V}}$ Å (4) $\frac{12400}{V}$ Å

Sol. Answer (3)

Energy gained by proton = 1 eV

$\lambda = \frac{h}{\sqrt{2mE}}$ or $\lambda = \frac{h}{\sqrt{2m_e}} \times \frac{1}{\sqrt{V}}$

25. The wavelength of matter waves is independent of

(1) Mass (2) Velocity (3) Momentum (4) Charge

Sol. Answer (4)

The wavelength of matter waves is given by $\lambda = \frac{h}{mv}$

Hence, it is independent of charge.

26. Which one of the following statements is not true about de-Broglie waves ?

(1) All atomic particles in motion have waves of a definite wavelength associated with them

(2) The higher the momentum, the longer is the wave-length

(3) The faster the particle, the shorter is the wave-length

(4) For the same velocity, a heavier particle has a shorter wavelength

Sol. Answer (2)

$\lambda = \frac{h}{P}$. Hence, higher the momentum shorter is the wavelength.

27. A proton and an alpha particle are accelerated through the same potential difference. The ratio of de Broglie wavelength of the proton to that of the alpha particle will be

(1) 2 : 1 (2) 1 : 1 (3) 1 : 2 (4) 2√2 : 1

Sol. Answer (4)

Energy gained by protons = 1 eV

Energy gained by alpha particle = 2 eV

$\lambda_P = \frac{h}{\sqrt{2mE}}$ $\lambda_\alpha = \frac{h}{\sqrt{2 \times 4m \times 2\text{ eV}}}$

$\frac{\lambda_P}{\lambda_\alpha} = \frac{2\sqrt{2}}{1}$

28. The ratio of specific charge e/m of a proton to that of an α-particle is

(1) 1 : 4 (2) 1 : 2 (3) 4 : 1 (4) 2 : 1

Sol. Answer (4)

Charge by mass ratio of proton = $\frac{e}{m_P}$

Charge by mass ratio of α particle = $\frac{2e}{4m_P}$

∴ Ratio of specific charge = 2 : 1

29. Choose the only correct statement out of the following

    (1) Only a charged particle in motion is accompanied by matter waves

    (2) Only subatomic particles in motion are accompanied by matter waves

    (3) Any particle in motion, whether charged or uncharged, is accompanied by matter waves

    (4) No particle, whether at rest or in motion, is ever accompanied by matter waves

Sol. Answer (3)

30. Neglecting variation of mass with velocity, the wavelength associated with an electron having a kinetic energy E is proportional to

    (1) $E^{\frac{1}{2}}$ (2) E (3) $E^{-\frac{1}{2}}$ (4) E^{-2}

Sol. Answer (3)

$$\lambda = \frac{h}{\sqrt{2mE}}$$

$$\therefore \quad \lambda \propto E^{-1/2}$$

31. Of the following having the same kinetic energy, the one which has the largest wavelength is

    (1) An alpha particle (2) A neutron (3) A proton (4) An electron

Sol. Answer (4)

$$\lambda = \frac{h}{\sqrt{2mE}}$$

$$\lambda \propto \frac{1}{\sqrt{2m}}$$

Hence, answer is electron.

32. The de Broglie wavelength λ associated with a proton increases by 25%, if its momentum is decreased by p_0. The initial momentum was

    (1) $4\,p_0$ (2) $\frac{p_0}{4}$ (3) $5\,p_0$ (4) $\frac{p_0}{5}$

Sol. Answer (3)

$$\frac{\lambda_2 - \lambda_1}{\lambda_1} = \frac{25}{100}$$

$$\frac{\lambda_2}{\lambda_1} = \frac{5}{4} \Rightarrow \frac{P_1}{P_2} = \frac{5}{4}$$

$$P_2 - P_1 = -P_0$$

$$\frac{4P_1}{5} - P_1 = -P_0$$

$$P_1 = 5P_0$$

SECTION - B

Objective Type Questions

1. If in a photoelectric cell, the wavelength of incident light is changed from 4000 Å to 3000 Å then change in stopping potential will be

(1) 0.66 V (2) 1.03 V (3) 0.33 V (4) 0.49 V

Sol. Answer (2)

Wavelength is changed from 4000 Å to 3000 Å

$$\frac{hc}{\lambda_1} = \text{KE}_{\text{max}} + w_0$$

$$\frac{hc}{\lambda_2} = \text{KE}_{\text{max}(2)} + w_0$$

$$\frac{hc}{\lambda_1} - \frac{hc}{\lambda_2} = \text{KE}_{\text{max}} - \text{KE}_{\text{max}(2)}$$

$$\frac{hc}{\lambda_1} - \frac{hc}{\lambda_2} = eV$$

$$\left(\frac{hc}{\lambda_1} - \frac{hc}{\lambda_2}\right) \times \frac{1}{e} = V$$

$V = 1.03$ V

2. Find the number of electrons emitted per second by a 24 W source of monochromatic light of wavelength 6600 Å, assuming 3% efficiency for photoelectric effect (take $h = 6.6 \times 10^{-34}$ Js)

(1) 48×10^{19} (2) 48×10^{17} (3) 8×10^{19} (4) 24×10^{17}

Sol. Answer (4)

Energy per photon = hf or $\frac{hc}{\lambda}$

Number of photon's per second = $\frac{24}{hf}$

Number of electrons emitted = $\frac{3}{100} \times \frac{24}{hc} \times \lambda$

3. In photoelectric effect, if a weak intensity radiation instead of strong intensity of suitable frequency is used then

(1) Photoelectric effect will get delayed (2) Photoelectric effect will not take place

(3) Maximum kinetic energy will decrease (4) Saturation current will decrease

Sol. Answer (4)

Saturation current which depends on intensities will decrease.

4. The work function of tungsten is 4.50 eV. The wavelength of fastest electron emitted when light whose photon energy is 5.50 eV falls on tungsten surface, is

(1) 12.27 Å (2) 0.286 Å (3) 12400 Å (4) 1.227 Å

Sol. Answer (3)

$$KE_{max} = \frac{hc}{\lambda} - w_0 = 5.5 - 4.5$$

$$\therefore \quad KE_{max} = 1 \text{ eV}$$

$$\lambda = \frac{h}{\sqrt{2mE}}$$

5. A proton is accelerated through 225 V. Its de Broglie wavelength is

(1) 0.1 nm (2) 0.2 nm (3) 0.3 nm (4) 0.4 nm

Sol. Answer (2)

Energy it gains = 225 eV

$$\lambda = \frac{h}{mv} = \frac{\lambda h}{\sqrt{2mE}}$$

6. For same energy, find the ratio of λ_{photon} and $\lambda_{electron}$ (Here *m* is mass of electron)

(1) $c\sqrt{\frac{2m}{E}}$ (2) $\frac{1}{c}\sqrt{\frac{2m}{E}}$ (3) $\frac{1}{c^2}\sqrt{\frac{2m}{E}}$ (4) $\frac{1}{c}\sqrt{\frac{2m}{E^2}}$

Sol. Answer (1)

Energy of photon = $\frac{hc}{\lambda_P}$

$$\lambda_P = \frac{hc}{E} \qquad \lambda_e = \frac{h}{\sqrt{2mE}}$$

$$\frac{\lambda_P}{\lambda_e} = c\sqrt{\frac{2m}{E}}$$

7. What should be the velocity of an electron so that its momentum becomes equal to that of a photon of wavelength 5200 Å?

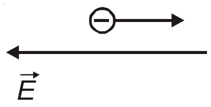
(1) 700 m/s (2) 1000 m/s (3) 1400 m/s (4) 2800 m/s

Sol. Answer (3)

Momentum of photon = $\frac{h}{\lambda}$

$$\frac{h}{\lambda} = m_e v \qquad \text{or} \qquad v = \frac{\lambda}{\lambda m_e}$$

8. Figure shows four situations in which an electron is moving in electric / magnetic field. In which case the de Broglie wavelength of electron is increasing?

(1)


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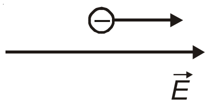

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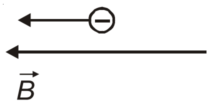

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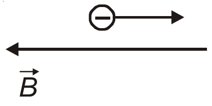


Sol. Answer (2)

$$\lambda \propto \frac{1}{v}$$

de Broglie wavelength of an electron depends on its velocities. Velocity of the electron is only decreasing in the IInd case.

9. A photosensitive metallic surface is illuminated alternately with lights of wavelength 3100 Å and 6200 Å. It is observed that maximum speeds of the photoelectrons in two cases are in ratio 2 : 1. The work function of the metal is (hc = 12400 eVÅ)

(1) 1 eV (2) 2 eV (3) $\frac{4}{3}$ eV (4) $\frac{2}{3}$ eV

Sol. Answer (3)

$$E_1 = \frac{hc}{\lambda_1} = -w_0 \quad \text{or} \quad \frac{1}{2}m_eV^2 = \frac{hc}{\lambda_1} - w_0$$

$$E_2 = \frac{hc}{\lambda_2} - w_0 \quad \text{or} \quad \frac{1}{2}m_e 4V^2 = \frac{hc}{\lambda_2} - w_0$$

$$\frac{1}{4} = \frac{\frac{hc}{\lambda_1} - w_0}{\frac{hc}{\lambda_2} - w_0}$$

$$\frac{hc}{\lambda_2} - w_0 = \frac{4hc}{\lambda_1} - 4w_0$$

$$3w_0 = \frac{4hc}{\lambda_1} - \frac{hc}{\lambda_2}$$

$$w_0 = \frac{12400}{3}\left(\frac{4}{\lambda_1} - \frac{1}{\lambda_2}\right)$$

w_0 = 2 eV

10. For an electron microscope, which of the following is false?

(1) It uses magnetic lens to converge electron beam

(2) Its resolving power is directly proportional to accelerating potential of electrons

(3) Its resolving power is inversely proportional to wavelength of electrons

(4) Magnification attained with the help of it is of the order of 10^6

Sol. Answer (2)

Fact.

11. The energy of a photon of wavelength λ is given by

(1) $h\lambda$ (2) $ch\lambda$ (3) $\frac{\lambda}{hc}$ (4) $\frac{hc}{\lambda}$

Sol. Answer (4)

Energy of a photon = $\frac{hc}{\lambda}$

12. The approximate wavelength of a photon of energy 2.48 eV is

(1) 500 Å (2) 5000 Å (3) 2000 Å (4) 1000 Å

Sol. Answer (2)

E = 2.48 eV

$$E = \frac{hc}{\lambda}$$

$$\lambda = \frac{hc}{E}$$

13. Wavelength of a 1 keV photon is 1.24×10^{-9} m. What is the frequency of 1 MeV photon?

(1) 1.24×10^{15} Hz (2) 2.4×10^{20} Hz (3) 1.24×10^{18} Hz (4) 2.4×10^{23} Hz

Sol. Answer (2)

Wavelength of 1 keV photon is 1.24×10^{-9} m

$$E \propto \frac{1}{\lambda}$$

$$\frac{E_1}{E_2} = \frac{\lambda_2}{\lambda_1}$$

$$f_2 = \frac{c}{\lambda_2}$$

14. Which of the following statements is not correct?

(1) Photographic plates are sensitive to infrared rays

(2) Photographic plates are sensitive to ultraviolet rays

(3) Infrared rays are invisible but can cast shadows like visible light

(4) Infrared photons have more energy than photons of visible light

Sol. Answer (4)

Infrared photons have less frequency than visible light. Hence, they have less energy.

15. Ultraviolet radiations of 6.2 eV fall on an aluminium surface (work function 4.2 eV). The kinetic energy (in joule) of the fastest electron emitted is approximately

(1) 3.2×10^{-21} (2) 3.2×10^{-19} (3) 3.2×10^{-17} (4) 3.2×10^{-15}

Sol. Answer (2)

Energy incident = 6.2 eV

Work function 4.2 eV

$$\begin{aligned}KE_{max} &= \text{Energy incident} - \text{Work function}\\ &= 2\text{ eV}\\ &= 3.2 \times 10^{-19}\text{ J}\end{aligned}$$

16. The work function of a metallic surface is 5.01 eV. The photo electrons are emitted when light of wavelength 2000 Å falls on it. The potential difference applied to stop the fastest photo electrons is [$h = 4.14 \times 10^{-15}$ eV s]

(1) 1.2 volt (2) 2.24 volt (3) 3.6 volt (4) 4.8 volt

Sol. Answer (1)

$w_0 = 5.01$ eV

$$KE_{max} = \frac{hc}{\lambda} - 5.01$$

$$\begin{aligned}KE_{max} &= \frac{4.14 \times 10^{-15}C}{2000 \times 10^{-10}} - 5.01\,\text{eV}\\ &= 2.07 \times 10^{-8}\,C - 5.01\text{ eV}\\ &= 6.21 - 5.01\\ &= 1.2\text{ eV}\end{aligned}$$

$$\text{Stopping potential} = \frac{KE_{max}}{e} = 1.2\text{ V}$$

17. A radio transmitter operates at a frequency of 880 kHz and a power of 10 kW. The number of photons emitted per second is

(1) 1.72×10^{31} (2) 1.327×10^{34} (3) 13.27×10^{34} (4) 0.075×10^{-34}

Sol. Answer (1)

Power = 10×10^3 watt

Frequency = 880×10^3 Hz

Energy per photon = hf

$\therefore$ Number of photons = $\frac{10 \times 10^3}{hf}$

18. Assuming photoemission to take place, the factor by which the maximum velocity of the emitted photo electrons changes when the wavelength of the incident radiation is increased four times, is (assuming work function to be negligible in comparison to hc/λ)

(1) 4 (2) $\frac{1}{4}$ (3) 2 (4) $\frac{1}{2}$

Sol. Answer (4)

$$\text{KE}_{\text{max}} = \frac{hc}{\lambda} - w_0$$

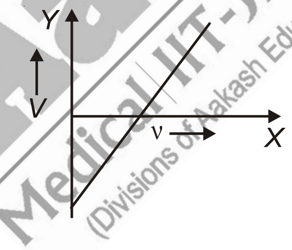
Work function is negligible

$$\frac{1}{2}mv^2 = \frac{hc}{\lambda}$$

$$\therefore \quad v^2 \propto \frac{1}{\lambda}$$

If λ is increased to 4 times velocities become half.

19. The stopping potential V for photoelectric emission from a metal surface is plotted along Y-axis and frequency ν of incident light along X-axis. A straight line is obtained as shown. Planck's constant is given by



(1) Slope of the line

(2) Product of slope on the line and charge on the electron

(3) Product of intercept along Y-axis and mass of the electron

(4) Product of slope and mass of electron

Sol. Answer (2)

$h\nu = \text{KE}_{\text{max}} + w_0$

$\text{KE}_{\text{max}} = \text{eV}$

$h\nu = eV + w_0$

$$v = \frac{h\nu}{e} - w_0$$

$$\text{Slope}(m) = \frac{h}{e}$$

$h = me$

20. If the work function of a metal is 'ϕ' and the frequency of the incident light is 'ν', there is no emission of photo electron for

(1) $\nu < \frac{\phi}{h}$ (2) $\nu = \frac{\phi}{h}$ (3) $\nu > \frac{\phi}{h}$ (4) $\nu >=< \frac{\phi}{h}$

Sol. Answer (1)

Frequency = ν, work function = ϕ

$h\nu = \phi + KE_{max}$

$KE_{max} = 0$

$\nu = \frac{\phi}{h}$, hence, no emission occurs when $\nu = \frac{\phi}{h}$

21. Specific heat of water is 4.2 J/g°C. If light of frequency 3×10^9 Hz is used to heat 400 gm of water from 20°C to 40°C, the number of photons needed will be

(1) 1.69×10^{29} (2) 1.69×10^{28} (3) 2.80×10^4 (4) 2.80×10^5

Sol. Answer (2)

$S = 4.231$ gºC

$\nu = 3 \times 10^9$ Hz

$m = 400$ g

Energy of one photon = $h\nu$

Heat needed for 20ºC temp. change = $ms\Delta T = 400 \times 4.2 \times 20$ J

$$\therefore \quad \text{Number of photons} = \frac{400 \times 4.2 \times 20}{h\nu} = \frac{400 \times 4.2 \times 20}{6.63 \times 10^{-34} \times 3 \times 10^9} = 1689 \times 10^{25} = 1.69 \times 10^{28}$$

22. The work function of a certain metal is 2.3 eV. If light of wave number 2×10^6 m^{-1} falls on it, the kinetic energies of fastest and slowest ejected electron will be respectively

(1) 2.48 eV, 0.18 eV (2) 0.18 eV, zero (3) 2.30 eV, 0.18 eV (4) 0.18 eV, 0.18 eV

Sol. Answer (2)

$w_0 = 2.3$ eV

$n = \frac{1}{\lambda} = 2 \times 10^6$ m^{-1} (wave number)

$hcn = KE_{max} + w_0$

$hcn = KE_{max} + 2.3$ eV

23. When the electromagnetic radiations of frequencies 4×10^{15} Hz and 6×10^{15} Hz fall on the same metal in different experiments, the ratio of maximum kinetic energy of electrons liberated is 1 : 3. The threshold frequency for the metal is

(1) 2×10^{15} Hz (2) 1×10^{15} Hz (3) 3×10^{15} Hz (4) 1.67×10^{15} Hz

Sol. Answer (2)

Frequencies given are 4 × 10^{15} and 6 × 10^{15} Hz

$hf_1 = E_1 + w_0$

$hf_2 = E_2 + w_2$

$E_1 : E_2 = 1 : 3$

$\therefore \quad E_2 = 3E_1$

$E_1 + w_0 = hf_1$ ....(i)

$3E_1 + w_0 = hf_2$ ....(ii)

Solve for w_0.

24. How many photons are emitted by a laser source of 5 × 10^{-3} W operating at 632.2 nm in 2 s? ($h = 6.63 \times 10^{-34}$ Js)

(1) 3.2 × 10^{16} (2) 1.6 × 10^{16} (3) 4 × 10^{16} (4) 0.4 × 10^{16}

Sol. Answer (1)

$$\text{Number of photons per second} = \frac{\text{Total energy emitted/sec}}{\text{Energy of one photon}}$$

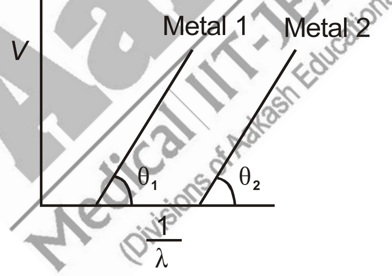
$$\text{Energy of one photon} = \frac{hc}{\lambda} = \frac{hc}{632.2 \times 10^{-9}}$$

Energy per second emitted = 5 × 10^{-3} w

Total number of photons = Photons emitted per second × Time

When time = 2 s

25. V (stopping potential) is plotted against $\frac{1}{\lambda}$, where λ is wavelength of incident radiations, for two metals



(1) Metal 1 may be gold and metal 2 may be cesium

(2) $\theta_1 > \theta_2$, if metal -1 is gold and metal-2 is cesium

(3) $\theta_1 = \theta_2$, for any two metals

(4) $\theta_1 > \theta_2$, if metal -1 and metal-2 are gold and copper respectively

Sol. Answer (3)

$$\frac{hc}{\lambda} = \frac{hc}{632.2 \times 10^{-9}}$$

$$\frac{hc}{\lambda} = eV + w_0$$

$$eV = \frac{hc}{\lambda} - w_0$$

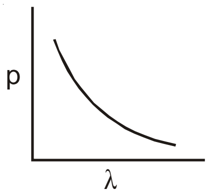
$$V = \frac{hc}{e} \times \frac{1}{\lambda} - \frac{w_0}{e}$$

$\tan\theta = \frac{hc}{e}$ = constant [Slope of V vs $\frac{1}{\lambda}$ graph]

$\therefore$ θ is same for all metals.

26. Variation of momentum of particle (p) with associated de-Broglie wavelength (λ) is shown correctly by

(1)



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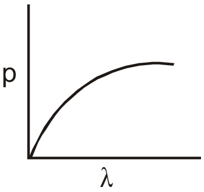

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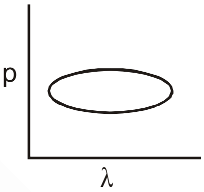

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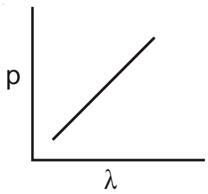


Sol. Answer (1)

$\lambda = \frac{h}{P}$ which is a hyperbolic graph like(1).

27. A photon and a proton have equal energy E. Ratio of wavelengths $\frac{\lambda_{\text{photon}}}{\lambda_{\text{proton}}}$ is proportional to

(1) E (2) $\sqrt{E}$ (3) $\frac{1}{\sqrt{E}}$ (4) E^0

Sol. Answer (3)

$\lambda_{\text{Photon}} = \frac{hc}{E}$ $\lambda_{\text{Proton}} = \frac{h}{\sqrt{2mE}}$

$$\frac{\lambda_{\text{Photon}}}{\lambda_{\text{Proton}}} = c\sqrt{\frac{2m}{E}} \propto \frac{1}{\sqrt{E}}$$

28. Violet light is falling on a photosensitive material causing ejection of photoelectrons with maximum kinetic energy of 1 eV. Red light falling on metal will cause emission of photoelectrons with maximum kinetic energy (approximately) equal to

(1) 1.2 eV (2) 0.9 eV

(3) 0.5 eV (4) Zero, that is no photoemission

Sol. Answer (4)

When violet light falls on photosensitive material

$$\frac{hc}{\lambda_v} = E_v + w_0$$

$$\therefore \quad \frac{hc}{\lambda_v} - 1 = w_0$$

$\frac{hc}{\lambda_v} - w_0 < 0$ as difference in energies of the violet and red light is greater than 1 eV.

29. For a proton accelerated through potential difference of one volt, kinetic energy gained in eV is

(1) 1 (2) 1840 (3) $\frac{1}{1840}$ (4) 931.5×10^{-6}

Sol. Answer (1)

Kinetic energy = qV

For one electron energy gained is therefore = eV

30. If frequency of light falling on a photosensitive material doubles

(1) Saturation photocurrent doubled

(2) Saturation photocurrent becomes more than double

(3) Cut-off voltage becomes more than double

(4) Stopping potential doubles

Sol. Answer (3)

$h\nu = E + w_0$

$h\nu - w_0 = E_1$

When frequency is doubled

$2h\nu - w_0 = E_2$

or $E_2 = 2E_1 + w_0$

E_2 is more than double of E_1

31. Photoelectrons from metal do not come out with same energy. Most appropriate explanation is

(1) Some electrons loose energy in form of heat

(2) Work function of a metal is average energy required to pull out electrons

(3) Electrons in metal occupy different energy levels and work function is the minimum energy required for electron in highest level of conduction band to get out of metal

(4) For some electrons, some part of energy gained during inelastic collision with photon is spent in over coming attractive force by nucleus

Sol. Answer (3)

32. For an alpha particle, accelerated through a potential difference V, wavelength (in Å) of the associated matter wave is

(1) $\frac{12.27}{\sqrt{V}}$ (2) $\frac{0.101}{\sqrt{V}}$ (3) $\frac{0.202}{\sqrt{V}}$ (4) $\frac{0.286}{\sqrt{V}}$

Sol. Answer (2)

Wavelength (λ) = $\frac{h}{P}$

or $\lambda = \frac{h}{\sqrt{2mE}}$

$E = 2e \times V$ for V potential difference

$$\lambda = \frac{h}{\sqrt{4m_eV}}$$

$$\lambda = \frac{0.101}{\sqrt{V}}$$

SECTION - C

Previous Years Questions

1. Which one among the following shows particle nature of light?

(1) Photoelectric effect (2) Interference (3) Refraction (4) Polarization

Sol. Answer (1)

2. Two radiations of photons energies 1 eV and 2.5 eV, successively illuminate a photosensitive metallic surface of work function 0.5 eV. The ratio of the maximum speeds of the emitted electrons is

(1) 1 : 4 (2) 1 : 2 (3) 1 : 1 (4) 1 : 5

Sol. Answer (2)

$E_{\text{Photon}} = \text{KE}_{\text{max}} + w_0$

$$\frac{\text{KE}_1}{\text{KE}_2} = \frac{0.5}{2} = \frac{1}{4}$$

3. In photoelectric emission process from a metal of work function 1.8 eV, the kinetic energy of most energetic electrons is 0.5 eV. The corresponding stopping potential is

(1) 2.3 V (2) 1.8 V (3) 1.3 V (4) 0.5 V

Sol. Answer (4)

$\text{KE}_{\text{max}} = 0.5$ eV

Stopping potential only depends on maximum KE of electron ejected.

4. The slope of V versus ν graph where ν and V are the frequency of incident light and stopping potential for a given surface will be

(1) h (2) $\frac{h}{e}$ (3) eh (4) e

Sol. Answer (2)

$h\nu = \text{KE}_{\text{max}} + w_0$

$$\frac{h\nu}{e} - \frac{w_0}{e} = V$$

Slope = $\frac{h}{e}$

5. Photoelectric emission occurs only when the incident light has more than a certain minimum

(1) Frequency (2) Power (3) Wavelength (4) Intensity

Sol. Answer (1)

6. The threshold frequency for a photosensitive metal is 3.3×10^{14} Hz. If light of frequency 8.5×10^{14} Hz is incident on this metal, the cut-off voltage for the photoelectric emission is nearly

(1) 5 V (2) 1 V (3) 2 V (4) 3 V

Sol. Answer (3)

$h\nu = h\nu_0 + \text{KE}_{\text{max}}$

$\text{KE}_{\text{max}} = h\nu - h\nu_0$

$$V = \frac{h}{e}(\nu - \nu_0)$$

7. An electron in the hydrogen atom jumps from excited state *n* to the ground state. The wavelength so emitted illuminates a photosensitive material having work function 2.75 eV. If the stopping potential of the photoelectron is 10 V, then the value of *n* is

(1) 5 (2) 2 (3) 3 (4) 4

Sol. Answer (4)

w_0 = 2.75 eV

KE_{max} = 10 eV

Energy incident = $KE_{max} + w_0$

$$\frac{hc}{\lambda} = 10 + 2.75 \text{ eV} \qquad \text{....(i)}$$

Also, $\frac{1}{\lambda} = R\left(\frac{1}{1^2} - \frac{1}{n^2}\right)$ ....(ii)

Solving (i) and (ii)

8. The maximum kinetic energy of the photoelectrons varies

(1) Inversely with the intensity and is independent of the frequency of the incident radiation

(2) Inversely with the frequency and is independent of the intensity of the incident radiation

(3) Linearly with the frequency and the intensity of the incident radiation

(4) Linearly with the frequency and is independent of the intensity of the incident radiation

Sol. Answer (4)

$h\nu = KE_{max} + w_0$

Hence, KE_{max} varies linearly with frequency

9. The work function for Al, K and Pt is 4.28 eV, 2.30 eV and 5.65 eV respectively. Their respective threshold frequencies would be

(1) Pt > Al > K (2) Al > Pt > K (3) K > Al > Pt (4) Al > K > Pt

Sol. Answer (1)

Higher work function means higher frequency as

$w_0 = h\nu_0$

$\therefore$ Pt > Al > K

10. The work function of a surface of a photosensitive material is 6.2 eV. The wavelength of the incident radiation for which the stopping potential is 5 V lies in the

(1) X-ray region (2) Ultraviolet region (3) Visible region (4) Infrared region

Sol. Answer (2)

w_0 = 6.2 eV KE_{max} = 5 eV

Net incident energy/photon = 5 + 6.2 = 11.2 eV

λ corrrspond to 11.2 eV energy belongs to ultraviolet region.

11. If a photon has velocity *c* and frequency ν, which of the following represents its wavelength?

(1) $\frac{h\nu}{c^2}$ (2) $h\nu$ (3) $\frac{hc}{\nu}$ (4) $\frac{c}{\nu}$

Sol. Answer (4)

12. The velocity of photons is proportional to (where ν = frequency)

(1) $\frac{1}{\sqrt{\nu}}$ (2) ν^2 (3) ν^0 (4) $\sqrt{\nu}$

Sol. Answer (3)

$$h\nu = \frac{1}{2}mv^2 + w_0$$

Hence, there is no direct relationship between v and ν.

13. Which of the following statement is correct?

(1) The photocurrent increases with intensity of light

(2) The stopping potential increases with increase in intensity of incident light

(3) The current in photocell increases with increasing frequency

(4) The photocurrent is proportional to the applied voltage

Sol. Answer (1)

Increase of intensity increases the number of photoelectron emiting from plate.

14. Light of wavelength 5000 Å falls on a sensitive plate with photoelectric work function of 1.9 eV. The kinetic energy of the photoelectron emitted will be

(1) 1.24 eV (2) 2.48 eV (3) 0.58 eV (4) 1.16 eV

Sol. Answer (3)

$$\frac{hc}{\lambda} = \text{KE}_{\text{max}} + w_0 \qquad [w_0 = 1.9 \text{ eV}]$$

$$\text{KE}_{\text{max}} = \frac{hc}{\lambda} - w_0$$

15. In a photo-emissive cell, with exciting wavelength λ, the fastest electron has speed v. If the exciting wavelength is changed to $\frac{3\lambda}{4}$, the speed of the fastest emitted electron will be

(1) Less than $v(4/3)^{1/2}$ (2) $v(4/3)^{1/2}$ (3) $v(3/4)^{1/2}$ (4) Greater than $v(4/3)^{1/2}$

Sol. Answer (4)

$$\frac{hc}{\lambda} = \frac{1}{2}mv^2 + w_0$$

If λ becomes $\frac{3\lambda}{4}$

$$\frac{4hc}{3\lambda} - w_0 = \frac{1}{2}mv'^2$$

$$\therefore \quad v' > v\left(\frac{4}{3}\right)^{1/2}$$

16. The photoelectric work function for a metal surface is 4.125 eV. The cut-off wavelength for this surface is about

(1) 3000 Å (2) 2062.5 Å (3) 4125 Å (4) 6000 Å

Sol. Answer (1)

w_0 = 4.125 eV

$$\frac{hc}{\lambda_0} = 4.125$$

$$\lambda_0 = \frac{hc}{4.125 \times 1.6 \times 10^{-19}}$$

17. As the intensity of incident light increases

(1) Kinetic energy of emitted photoelectrons increases

(2) Photoelectric current decreases

(3) Photoelectric current increases

(4) Kinetic energy of emitted photoelectrons decreases

Sol. Answer (3)

Photoelectric current $\propto$ Intensity

18. A 200 W sodium street lamp emits yellow light of wavelength 0.6 μm. Assuming it to be 25% efficient in converting electrical energy to light, the number of photons of yellow light it emits per second is

(1) 62×10^{20} (2) 3×10^{19} (3) 1.5×10^{20} (4) 6×10^{18}

Sol. Answer (3)

Wavelength = 0.6 μm

Power = 200 W

Light energy emitted = $\frac{25}{100} \times 200$ W = 50 W

Number of photons = $\frac{50}{hc} \times 0.6 \times 10^{-6} = \frac{50 \times 0.6 \times 10^{-6}}{6.63 \times 10^{-34} \times 3 \times 10^{8}} = 1.5 \times 10^{20}$

19. A photo-cell is illuminated by a source of light, which is placed at a distance *d* from the cell. If the distance becomes *d*/2. Then number of electrons emitted per second will be

(1) Remain same (2) Four times (3) Two times (4) One-fourth

Sol. Answer (2)

Intensity $\propto \frac{1}{(\text{Distance})^2}$

If distance is halved intensity becomes 4 times. Hence, photocurrent becomes 4 times.

20. The value of Planck's constant is

(1) 6.63×10^{-34} J/s (2) $6.63 \times \mathrm{I}0^{-34}$ kg m^2/s^2 (3) 6.63×10^{-34} kg m^2 (4) 6.63×10^{-34} J s

Sol. Answer (4)

21. The work functions for metals *A, B* and *C* are respectively 1.92 eV, 2.0 eV and 5 eV. According to Einstein's equation the metals which will emit photoelectrons for a radiation of wavelength 4100 Å is/are

(1) None of these (2) *A* only (3) *A* and *B* only (4) All the three metals

Sol. Answer (3)

$\frac{hc}{\lambda}$ where λ = 4100 Å is such that $\frac{hc}{4100\text{ Å}} = 3.01\,\text{eV}$

Hence, only *A* and *B* will show emission.

22. A photosensitive metallic surface has work function $h\nu_0$. If photons of energy $2h\nu_0$ fall on this surface, the electrons come out with a maximum velocity of 4 × 10^6 m/s. When the photon energy is increased to 5 $h\nu_0$, then maximum velocity of photoelectrons will be

(1) 2 × 10^7 m/s (2) 2 × 10^6 m/s (3) 8 × 10^6 m/s (4) 8 × 10^5 m/s

Sol. Answer (3)

When incident energy is 2 $h\nu_0$

$2h\nu = KE_{max} + w_0$

$$2h\nu_0 = \frac{1}{2}\times m\times(4\times10^6)^2 + h\nu_0$$

$$h\nu_0 = \frac{1}{2}m\times(2\times10^6)^2$$

When incident energy is $5h\nu_0$

$$5h\nu_0 - h\nu_0 = \frac{1}{2}mv_2^2$$

$$4h\nu_0 = \frac{1}{2}mv_2^2$$

23. A photocell employs photoelectric effect to convert

(1) Change in the frequency of light into a change in the electric current

(2) Change in the frequency of light into a change in electric voltage

(3) Change in the intensity of illumination into a change in photoelectric current

(4) Change in the intensity of illumination into a change in the work function of the photocathode

Sol. Answer (3)

24. When photons of energy hν fall on an aluminium plate (of work function E_0), photoelectrons of maximum kinetic energy *K* are ejected. If the frequency of radiation is doubled, the maximum kinetic energy of the ejected photoelectrons will be

(1) $K + h\nu$ (2) $K + E_0$ (3) $2K$ (4) K

Sol. Answer (1)

$h\nu = K + E_0$

$2h\nu = K_2 + E_0$

$K_2 = K + E_0$

25. Monochromatic light of frequency 6.0 × 10^{14} Hz is produced by a laser. The power emitted is 2 × 10^{-3} W. The number of photons emitted, on an average, by the source per second is

(1) 5 × 10^{16} (2) 5 × 10^{17} (3) 5 × 10^{14} (4) 5 × 10^{15}

Sol. Answer (4)

$\nu = 6 \times 10^{14}$ Hz

Power = 2×10^{-3} W

Number of photons = $\dfrac{2\times10^{-3}}{h\times6\times10^{14}}$

26. A 5 watt source emits monochromatic light of wavelength 5000 Å. When placed 0.5 m away, it liberates photoelectrons from a photosensitive metallic surface. When the source is moved to a distance of 1.0 m, the number of photoelectrons liberated will be reduced by a factor of

(1) 8 (2) 16 (3) 2 (4) 4

Sol. Answer (4)

Intensity $\propto \dfrac{1}{d^2}$

When distance is doubled intensity reduces by 4 times and does photocurrent.

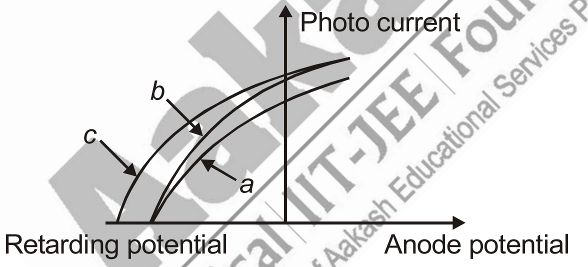
27. The number of photoelectrons emitted for light of a frequency ν (higher than the threshold frequency ν_0) is proportional to

(1) Frequency of light (ν) (2) $\nu - \nu_0$

(3) Threshold frequency (ν_0) (4) Intensity of light

Sol. Answer (4)

28. The figure shows a plot of photo current versus anode potential for a photosensitive surface for three different radiations. Which one of the following is a correct statement?



(1) Curves (*b*) and (*c*) represent incident radiations of same frequency having same intensity

(2) Curves (*a*) and (*b*) represent incident radiations of different frequencies and different intensities

(3) Curves (*a*) and (*b*) represent incident radiations of same frequency but of different intensities

(4) Curves (*b*) and (*c*) represent incident radiations of different frequencies and different intensities

Sol. Answer (3)

Same stopping potential means incident light is of same frequency.

29. A source S_1 is producing 10^{15} photons per second of wavelength 5000 Å. Another source S_2 is producing 1.02×10^{15} photons per second of wavelength 5100 Å. Then (power of S_2)/(power of S_1) is equal to

(1) 0.98 (2) 1.00 (3) 1.02 (4) 1.04

Sol. Answer (2)

Power of source – 1 = $10^{15}\times\dfrac{hc}{\lambda_1}$ [λ_1 = 5000 Å]

Power of source – 2 = $1.02 \times 10^{15} \times \dfrac{hc}{\lambda_2}$ [λ_2 = 5100 Å]

30. The potential difference that must be applied to stop the fastest photoelectrons emitted by a nickel surface, having work function 5.01 eV, when ultraviolet light of 200 nm falls on it, must be

(1) 1.2 V (2) 2.4 V (3) –1.2 V (4) –2.4 V

Sol. Answer (3)

Energy of incident light = $\frac{hc}{200\times10^{-9}}$

w_0 = 5.01 eV

Incident energy = $KE_{max} + w_0$

$(eV)\frac{hc}{\lambda_e}-5.01=eV$

31. When monochromatic radiation of intensity *I* falls on a metal surface, the number of photoelectron and their maximum kinetic energy are *N* and *T* respectively. If the intensity of radiation is 2*I*, the number of emitted electrons and their maximum kinetic energy are respectively

(1) *N* and 2*T* (2) 2*N* and *T* (3) 2*N* and 2*T* (4) *N* and *T*

Sol. Answer (2)

Number of photoelectrons = 2*N*

max. KE = *T*

Increase intensity of radiation increases number of photoelectrons emitted. Energy of photoelectron depends on frequency of radiation.

32. Monochromatic radiation emitted when electron on hydrogen atom jumps from first excited to the ground state irradiates a photosensitive material. The stopping potential is measured to be 3.57 V. The threshold frequency of the material is

(1) 1.6×10^{15} Hz (2) 2.5×10^{15} Hz (3) 4×10^{15} Hz (4) 5×10^{15} Hz

Sol. Answer (1)

Stopping potential = 3.57 V

KE_{max} = 3.57 eV

Energy incident = $13.6\left[\frac{1}{1^2}-\frac{1}{2^2}\right]$ = 3.4 × 3 = 10.2 eV

or w_0 = 10.2 eV – 3.57 eV or w_0 = 6.63 eV

or $\nu=\frac{6.63\times1.6\times10^{-19}}{h}$ or $\nu = 1.6\times10^{15}$

33. If in a photoelectric cell, the wavelength of incident light is changed from 4000 Å to 3000 Å then change in stopping potential will be

(1) 0.66 V (2) 1.03 V (3) 0.33 V (4) 0.49 V

Sol. Answer (2)

$$\frac{hc}{\lambda_1}-w_0=eV_1 \quad ....(i)$$

$$\frac{hc}{\lambda_2}-w_0=eV_2 \quad ....(ii)$$

$$\frac{hc}{\lambda_1}-\frac{hc}{\lambda_2}=e(V_1-V_2)$$

34. Find the number of electrons emitted per second by a 24 W source of monochromatic light of wavelength 6600Å, assuming 3% efficiency for photoelectric effect (take $h = 6.6 \times 10^{-34}$ Js)

(1) 48×10^{19} (2) 48×10^{17} (3) 8×10^{19} (4) 24×10^{17}

Sol. Answer (4)

Power = 24 W

Energy of one photon = $\dfrac{hc}{\lambda}$ [λ = 6600 Å] ....(i)

Energy incident on photographic plate = 0.03 × 24 watt = 0.072 watt ....(ii)

Dividing (ii) by (i)

$n = 24 \times 10^{17}$ photon

35. The photo-electrons emitted from a surface of sodium metal are such that they

(1) All are of the same frequency

(2) Have the same kinetic energy

(3) Have the same de-Broglie wavelength

(4) Have their speeds varying from zero to a certain maximum value

Sol. Answer (4)

Photo electrons they emit from different locations in metal plates.

36. In photoelectric effect, if a weak intensity radiation instead of strong intensity of suitable frequency is used then

(1) Photoelectric effect will get delayed (2) Photoelectric effect will not take place

(3) Maximum kinetic energy will decrease (4) Saturation current will decrease

Sol. Answer (4)

37. The work function of tungsten is 4.50 eV. The wavelength of fastest electron emitted when light whose photon energy is 5.50 eV falls on tungsten surface, is

(1) 12.27 Å (2) 0.286 Å (3) 12400 Å (4) 1.227 Å

Sol. Answer (1)

$w_0 = 4.5$ eV

Photon energy = 5.5 eV

$\text{KE}_{\max}$ = Photon energy – w_0

or $E = 1$ eV

$$\lambda = \frac{h}{\sqrt{2mE}}$$

Solving λ = 12.27 Å

38. An α-particle moves in a circular path of radius 0.83 cm in the presence of a magnetic field of 0.25 Wb/m^2. The de-Broglie wavelength associated with the particle will be

(1) 10 Å (2) 0.01 Å (3) 1 Å (4) 0.1 Å

Sol. Answer (2)

$$v = \frac{qBr}{m}$$

$$\lambda = \frac{h}{mv} = \frac{h}{qBr}$$

39. If the momentum of an electron is changed by P, then the de-Broglie wavelength associated with it changes by 0.5%. The initial momentum of electron will be

(1) $200\,P$ (2) $400\,P$ (3) $\frac{P}{200}$ (4) $100\,P$

Sol. Answer (1)

$$\lambda = \frac{h}{P_0}$$

$$\frac{d\lambda}{\lambda} = -\frac{dP_0}{P_0} \qquad \Rightarrow \frac{|d\lambda|}{\lambda} = \frac{|dP_0|}{P_0}$$

$$\frac{0.5}{100} = \frac{P}{P_0}$$

$P_0 = 200P$

40. Electrons used in an electron microscope are accelerated by a voltage of 25 kV. If the voltage is increased to 100 kV then the de-Broglie wavelength associated with the electrons would

(1) Increase by 4 times (2) Increase by 2 times

(3) Decrease by 2 times (4) Decrease by 4 times

Sol. Answer (3)

Electrons voltage = 25 kV

Voltage is increased to 100 kV

$$\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2m\,\text{KE}}}$$

Since KE becomes 4 KE

$$\lambda' = \frac{\lambda}{2}$$

41. In the Davisson and Germer experiment, the velocity of electrons emitted from the electron gun can be increased by

(1) Decreasing the potential difference between the anode and filament

(2) Increasing the potential difference between the anode and filament

(3) Increasing the filament current

(4) Decreasing the filament current

Sol. Answer (2)

42. A particle of mass 1 mg has the same wavelength as an electron moving with a velocity of 3×10^6 ms^{-1}. The velocity of the particle is (mass of electron = 9.1×10^{-31} kg)

(1) 2.7×10^{-21} ms^{-1} (2) 2.7×10^{-18} ms^{-1} (3) 9×10^{-2} ms^{-1} (4) 3×10^{-31} ms^{-1}

Sol. Answer (2)

$$\lambda_e = \frac{h}{m_e \times 3 \times 10^6}$$

$$\lambda_m = \frac{h}{1 \times 10^{-6} \times v}$$

$$\frac{\lambda_e}{\lambda_m} = \frac{10^{-6}\ v}{3\times10^{6}\times m_e}$$

or $\frac{\lambda_e}{\lambda_m} = \frac{3\times10^{6}\times9.1\times10^{-31}}{10^{-6}} = v$

or $3 \times 10^{12} \times 9.1 \times 10^{-31} = v$

or $v = 2.7 \times 10^{-18}$ m/s

43. An electron of mass *m,* when accelerated through a potential difference *V,* has de-Broglie wavelength *X.* The de-Broglie wavelength associated with a proton of mass *M* accelerated through the same potential difference, will be

(1) $\lambda\frac{M}{m}$ (2) $\lambda\frac{m}{M}$ (3) $\lambda\sqrt{\frac{M}{m}}$ (4) $\lambda\sqrt{\frac{m}{M}}$

Sol. Answer (4)

Path will gain some energy *E*

$$x = \frac{h}{\sqrt{2mE}}$$

$$\lambda_P = \frac{h}{\sqrt{2ME}}$$

$$\lambda_P = x\times\sqrt{\frac{m}{M}}$$

44. If we consider electrons and photons of same wavelength, then they will have same

(1) Momentum (2) Angular momentum (3) Energy (4) Velocity

Sol. Answer (1)

$\lambda = \frac{h}{P}$ always

So, if they have same wavelengths they have same momentum

45. An electron beam has a kinetic energy equal to 100 eV. Find its wavelength associated with a beam, if mass of electron = 9.1×10^{-31} kg and 1 eV = 1.6×10^{-19} J. (Planck's constant = 6.6×10^{-34} J-s)

(1) 24.6 Å (2) 0.12 Å (3) 1.2 Å (4) 6.3 Å

Sol. Answer (3)

KE = 100 eV

$m_e = 9.1 \times 10^{-31}$ kg

1 eV = 1.6×10^{-19} J

$$\lambda = \frac{6.6\times10^{-34}}{\sqrt{2mE}} = \frac{6.6\times10^{-34}}{\sqrt{2\times9.1\times10^{-31}\times100\times e}}$$

where $e = 1.6 \times 10^{-19}$

$\lambda = 1.2$ Å

46. If particles are moving with same velocity, then which has maximum de-Broglie wavelength?

(1) Proton (2) α-particle (3) Neutron (4) β-particle

Sol. Answer (4)

$$\lambda = \frac{h}{mv}$$

$$\therefore \quad \lambda \propto \frac{1}{m}$$

β particle which has least mass will have maximum wavelength.

47. When ultraviolet rays fall on a metal plate then photoelectric effect does not occur, it occurs by

(1) Infrared rays (2) X-rays (3) Radiowave (4) Light wave

Sol. Answer (2)

λ (x-rays) < λ (ultraviolet rays)

48. A metal surface is illuminated by the photons of energy 5 eV and 2.5 eV respectively. The ratio of their wavelengths is

(1) 1 : 3 (2) 1 : 4 (3) 2 : 5 (4) 1 : 2

Sol. Answer (4)

$$\text{Energy of photon} = \frac{hc}{\lambda}$$

$$\lambda = \frac{hc}{E}$$

$$\therefore \quad \frac{\lambda_1}{\lambda_2} = \frac{E_2}{E_1} = \frac{2.5}{5} = \frac{1}{2} = 4$$

49. If the energy of a photon is 10 eV, then its momentum is

(1) 3.33×10^{-23} kg-m/s (2) 3.33×10^{-25} kg-m/s (3) 3.33×10^{-29} kg-m/s (4) 3.33×10^{-27} kg-m/s

Sol. Answer (4)

$$\text{Momentum} = \frac{E}{c}$$

$$\text{Momentum} = \frac{10 \times 1.6 \times 10^{-19}}{3 \times 10^{8}} = \frac{16}{3} \times 10^{-27} = 3.33 \times 10^{-27}$$

50. An electron and a proton have same kinetic energy. Ratio of their respective de-Broglie wavelength is about

(1) $\frac{12.27}{0.286}$ (2) $\frac{0.101}{0.286}$ (3) $\frac{0.286}{12.27}$ (4) $\frac{0.101}{12.27}$

Sol. Answer (1)

$$\lambda = \frac{h}{\sqrt{2ME}} \qquad \therefore \quad \lambda \propto \frac{1}{\sqrt{m}}$$

$$\lambda_e = \sqrt{\frac{M}{m}} \times \lambda_P$$

51. Dynamic mass of the photon in usual notations is given by

(1) $\frac{hv}{c}$ (2) $\frac{h\lambda}{c}$ (3) $\frac{h}{c\lambda}$ (4) $\frac{h}{cv}$

Sol. Answer (3)

$$\frac{h}{c\lambda}$$

52. de-Broglie wavelength associated with an electron revolving in the n^{th} state of hydrogen atom is directly proportional to

(1) n (2) $\frac{1}{n}$ (3) n^2 (4) $\frac{1}{n^2}$

Sol. Answer (1)

$$n\lambda = 2\pi r$$

$$\lambda \propto \frac{r}{n},\ r \propto n^2.$$

53. A proton is accelerated through 225 V. Its de-Broglie wavelength is

(1) 0.1 nm (2) 0.2 nm (3) 0.3 nm (4) 0.4 nm

Sol. Answer (2)

Energy = 225 eV

$$\lambda = \frac{h}{\sqrt{2mE}}$$

$$\lambda = 0.2 \text{ nm}$$

54. When the energy of the incident radiation is increased by 20%, the kinetic energy of the photoelectrons emitted from a metal surface increased from 0.5 eV to 0.8 eV. The work function of the metal is

(1) 0.65 eV (2) 1.0 eV (3) 1.3 eV (4) 1.5 eV

Sol. Answer (2)

$$E = W_0 + 0.5 \quad \text{...(i)}$$

$$1.2E = W_0 + 0.8 \quad \text{...(ii)}$$

From (ii) – (i)

$$E = 1.5 \text{ eV}$$

$$W_0 = 1 \text{ eV}$$

55. If the kinetic energy of the particle is increased to 16 times its previous value, the percentage change in the de-Broglie wavelength of the particle is

(1) 25 (2) 75 (3) 60 (4) 50

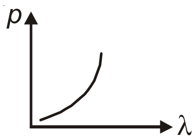
Sol. Answer (2)

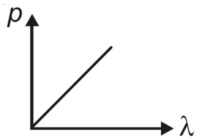
$$K = \frac{h^2}{2m\lambda^2} \Rightarrow \frac{K_1}{K_2} = \frac{\lambda_2^2}{\lambda_1^2} \Rightarrow \frac{1}{16} = \frac{\lambda_2^2}{\lambda_1^2} \Rightarrow \frac{\lambda_2}{\lambda_1} = \frac{1}{4}$$

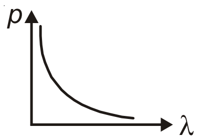
$$\lambda_2 = \frac{\lambda_1}{4}$$

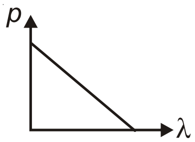
$$\Delta\lambda\% = \frac{\lambda_1 - \frac{\lambda_1}{4}}{\lambda_1} \times 100 = 75\%$$

56. Which of the following figures represent the variation of particle momentum and the associated de-Broglie wavelength?

(1) 

(2) 

(3) 

(4) 

Sol. Answer (3)

Linear momentum = p, wavelength = λ

$$\lambda = \frac{h}{p} \Rightarrow \lambda \propto \frac{1}{p}$$

57. A certain metallic surface is illuminated with monochromatic light of wavelength λ. The stopping potential for photo-electric current for this light is $3V_0$. If the same surface is illuminated with light of wavelength 2λ, the stopping potential is V_0. The threshold wavelength for this surface for photo-electric effect is

(1) $\frac{\lambda}{6}$ (2) 6λ (3) 4λ (4) $\frac{\lambda}{4}$

Sol. Answer (3)

$$\frac{hc}{\lambda} = W_0 + e3V_0 \qquad \text{...(i)}$$

$$\frac{hc}{2\lambda} = W_0 + eV_0 \qquad \text{(iii)}$$

From (i) & (ii)

$$eV_0 = \frac{hc}{4\lambda} \text{ and } W_0 = \frac{hc}{4\lambda}$$

Threshold wavelength = 4λ

SECTION - D

Assertion-Reason Type Questions

1. A : Every metal has a definite work function, still all photoelectrons do not come out with the same energy if incident radiation is monochromatic.

R : Work function is the minimum energy required for the electron in the highest level of the conduction band to get out of the metal. Not all electrons in the metal belong to this level rather they occupy a continuous band of levels.

Sol. Answer (1)

2. A : Work function of aluminium is 4.2 eV. Emission of electrons will be possible by two photons, each of 2.5 eV energy, striking the electron of aluminium.

R : Energy of a photon can be less than the work function of the metal, for photoelectron emission.

Sol. Answer (4)

Both the assertion and reason are incorrect. The quantised nature of light allows emission only when the photon striking the electron has enough energy to eject the electron. There will be no emission due to photons with energy less than work function.

3. A : On increasing the intensity of light, the number of photoelectrons emitted is more. Also the kinetic energy of each photon increases but the photoelectric current is constant.

   R : Photoelectric current is independent of intensity but increases with increasing frequency of incident radiation.

Sol. Answer (4)

On increasing the intensity of light only number of photoelectrons increase and not the KE of electrons or photons.

4. A : The process of photoelectron emission and thermionic emission of electrons is different.

   R : Photoelectric emission does not depend upon temperature, whereas thermionic emission is temperature dependent.

Sol. Answer (1)

The process of photoelectric emission depends of frequency of wave and thermionic emission occurs when metal is heated.

5. A : Wave nature of particles is not visible in daily life.

   R : In daily life, mass of particles is very high so their de Broglie wavelength is very small.

Sol. Answer (1)

The assertion is correct and reason is correct explanation $\lambda = \frac{h}{mv}$ and it is very low for masses in every day life as *h* is very small.

6. A : If a stationary nucleus emits an α-particle, the de Broglie wavelengths of the daughter nucleus and the α-particle are equal.

   R : The magnitudes of the linear momenta of the daughter nucleus and the α-particle are the same.

Sol. Answer (1)

7. A : When a photon of energy $h\nu$ is incident on an electron in a metal of work function $\phi(< h\nu)$, the electron will not necessarily come out of the metal.

   R : Work function is the minimum energy required to liberate an electron out of a metal. So some electrons may require more energy for their liberation.

Sol. Answer (1)

8. A : The photoelectric effect is a proof of the quantized nature of the light.

   R : Each photon in a light beam has same amount of energy.

Sol. Answer (3)

The assertion is correct but reason is completely false. It can only be true for completely monochromatic laser.

9. A : A photon cannot transfer all of its energy to an isolated electron.

   R : When energy of a photon is more than 1.02 MeV, it can materialize into two particles called electron and positron.

Sol. Answer (2)

10. A : There is almost no time-lag between the incidence of light and the emission of photoelectrons.

    R : A photon transfers almost all its energy to a single electron in a metal.

Sol. Answer (1)

❑ ❑ ❑

Chapter 12

Atoms

Solutions

SECTION - A

Objective Type Questions

1. An alpha particle colliding with one of the electrons in a gold atom loses

(1) Most of its momentum
(2) About $\frac{1}{3}$rd of its momentum
(3) Little of its energy
(4) Most of its energy

Sol. Answer (3)

The mass of an electron is hundred of times lesser than the mass of an alpha particle. Hence the alpha particles does not transfer much of its energy on collision with the electron.

2. According to classical theory, Rutherford atom was

(1) Electrostatically stable
(2) Electrodynamically unstable
(3) Semi stable
(4) Stable

Sol. Answer (1)

Rutherford designed his theory to be electrostatically stable.

3. The angular momentum of an electron in a hydrogen atom is proportional to (where r is radius of orbit)

(1) $\frac{1}{\sqrt{r}}$
(2) $\frac{1}{r}$
(3) $\sqrt{r}$
(4) r^2

Sol. Answer (3)

The angular momentum of an electron is quantised as

$$\Rightarrow \quad mvr = \frac{nh}{2\pi}$$

While radius of the n^th^ orbit is $r = n^2 r_0$ where, $r_0 = 0.53$ Å

4. When a hydrogen atom is raised from the ground state to third state

(1) Both kinetic energy and potential energy increase
(2) Both kinetic energy and potential energy decrease
(3) Potential energy increases and kinetic energy decreases
(4) Potential energy decreases and kinetic energy increases

Sol. Answer (3)

When hydrogen atom is raised from the ground state to third state

$$E = \frac{E_0}{3^2} \quad \text{or} \quad E = \frac{E_0}{9}$$

or PE is $\frac{-2E_0}{9}$ and KE is $\frac{E_0}{9}$ while initially, PE was $-2E_0$ and KE was E_0.

Hence, potential energy increases and kinetic energy decreases.

5. What is the angular momentum of an electron in Bohr's hydrogen atom whose energy is –3.4 eV?

(1) $\frac{h}{\pi}$ (2) $\frac{2h}{\pi}$ (3) $\frac{h}{2\pi}$ (4) $\frac{1}{4}$

Sol. Answer (1)

$$E = -\frac{E_0}{n^2}$$

$$3.4 = \frac{13.6eV}{n^2}$$

$$n^2 = \frac{13.6}{3.4}$$

$$n^2 = \frac{68}{17} = 4$$

or $n = 2$

Hence $mvr = \frac{nh}{2\pi}$ or $\frac{h}{\pi}$

6. The energy levels of a certain atom for first, second and third levels are E, $4\frac{E}{3}$ and $2E$ respectively. A photon of wavelength λ is emitted for a transition $3 \rightarrow 1$. What will be the wavelength of emission for transition $2 \rightarrow 1$?

(1) $\frac{\lambda}{3}$ (2) 3λ (3) $\frac{3\lambda}{4}$ (4) $\frac{4\lambda}{3}$

Sol. Answer (2)

$$\Delta E = 2E - E = \frac{hc}{\lambda_1}$$

$$\therefore\ E = \frac{hc}{\lambda_1}$$

Similarly $\frac{4E}{3} - E = \frac{hc}{\lambda_2}$

$\therefore \quad \frac{E}{3} = \frac{hc}{\lambda_2}$

$\therefore \quad \lambda_2 = 3\,\lambda_1$

7. The ground state energy of H - atom is –13.6 eV. The energy needed to ionise H - atom from its second excited state is

(1) 1.51 eV (2) 3.4 eV (3) 13.6 eV (4) 12.1 eV

Sol. Answer (1)

Energy for nth excited state $= \frac{E_0}{(n+1)^2}$

$\therefore$ To ionise H-atom from its second excited state $= \frac{13.6}{9} = 1.51\,eV$

8. If element with principal quantum number $n > 4$ were not allowed in nature, then the number of possible elements would be

(1) 60 (2) 32 (3) 4 (4) 64

Sol. Answer (1)

Number of electron possible in a shell is given by

$N = 2n^2$

where n is number of the shell

$N_1 = 2 \quad N_2 = 8 \quad N_3 = 18 \quad N_4 = 32$

Total $N = 2 + 8 + 18 + 32 = 60$ atoms

9. The angular speed of electron in the nth orbit of hydrogen atom is

(1) Directly proportional to n^2 (2) Directly proportional to n

(3) Inversely proportional to n^3 (4) Inversely proportional to n

Sol. Answer (3)

$mvr = \frac{nh}{2\pi}$

$\Rightarrow \quad m\omega r^2 = \frac{nh}{2\pi}$

$\Rightarrow \quad \omega \propto \frac{n}{r^2}$

As, $r \propto n^2$

$\therefore \quad \omega \propto \frac{1}{n^3}$

10. Of the various series of the hydrogen spectrum, the one which lies completely in the ultraviolet region is

(1) Lyman series (2) Balmer series (3) Paschen series (4) Brackett series

Sol. Answer (1)

The series will the highest frequencies is the Lyman series. Thus it is almost always in the electromagnetic.

11. As the *n* (number of orbit) increases, the difference of energy between the consecutive energy levels

(1) Remains the same (2) Increases

(3) Decreases (4) Sometimes increases and sometimes decreases

Sol. Answer (3)

The difference in energy, between consecutive energy levels keeps reducing as easily predicted by the equation of the line spectra, for hydrogen atom

$$\nu = \frac{R}{c}\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

12. The magnetic field induction produced at the centre of orbit due to an electron revolving in n^{th} orbit of hydrogen atom is proportional to

(1) n^{-3} (2) n^{-5} (3) n^5 (4) n^3

Sol. Answer (2)

$$mvr = \frac{nh}{2\pi} \rightarrow m\omega r^2 = \frac{nh}{2\pi} \rightarrow \omega \propto \frac{1}{n^3}$$

$$I = q_e \frac{I}{2\pi} \qquad \text{as } r \propto n^2$$

$$B = \mu_0 \frac{I}{2r}$$

$$B = \frac{\mu_0}{2\pi}\frac{\omega}{2r} \quad \text{again as } r \propto n^2$$

$$\therefore \quad B \propto \frac{1}{n^5}$$

13. The speed of an electron in the orbit of hydrogen atom in the ground state is

(1) *c* (2) *c*/10 (3) *c*/2 (4) *c*/137

Sol. Answer (4)

The speed of electron in ground state of an hydrogen atom is about 2.2×10^6 m/s. Which is approximately $\frac{c}{137}$, when *c* is the speed of light.

14. If the radius of the first orbit of hydrogen atom is 5.29×10^{-11} m, the radius of the second orbit will be

(1) 21.16×10^{-11} metre (2) 15.87×10^{-11} metre (3) 10.58×10^{-11} metre (4) 2.64×10^{-11} metre

Sol. Answer (1)

Radius of n^{th} orbit = $n^2 r_0$

Radius of 2^{nd} orbit = $4r_0$

$[r_0 \approx 5.3 \times 10^{-11}$ m$]$

$\therefore$ Hence radius needed ≈ 21.16×10^{-11} m

15. The ratio of minimum to maximum wavelength of radiation emitted by transition of an electron to ground state of Bohr's hydrogen atom is

(1) $\frac{3}{4}$ (2) $\frac{1}{4}$ (3) $\frac{1}{8}$ (4) $\frac{3}{8}$

Sol. Answer (1)

Minimum wavelength (λ_1)

$$\frac{1}{\lambda_1} = R\left(\frac{1}{1^2} - \frac{1}{\infty}\right) \qquad ....(i)$$

Maximum wavelength (λ_2)

$$\frac{1}{\lambda_2} = R\left(\frac{1}{1^2} - \frac{1}{2^2}\right) \qquad ....(ii)$$

$$\frac{\lambda_1}{\lambda_2} = \frac{3}{4}$$

16. In Bohr's model of the hydrogen atom, the ratio between the period of revolution of an electron in the orbit of n = 1 to the period of revolution of the electron in the orbit n = 2 is

(1) 1 : 2 (2) 2 : 1 (3) 1 : 4 (4) 1 : 8

Sol. Answer (4)

Period of electron in n^{th} orbit

$$T_n = \frac{2\pi r_n}{v_n}$$

$$T_n = \frac{2\pi r_0 n^3}{v_0}$$

$T_1 : T_2 = 1 : 8$

17. How many times does the electron go round the first Bohr orbit in a second?

(1) 6.57×10^5 (2) 6.57×10^{10} (3) 6.57×10^{13} (4) 6.57×10^{15}

Sol. Answer (4)

T_0 in ground state of hydrogen is $\approx 1.51 \times 10^{-16}$ s

Number of revolution = (f) = $\frac{1}{T_0} = \frac{1}{1.5 \times 10^{-16}} \approx 6.57 \times 10^{15}$

18. The ratio of the energies of the hydrogen atom in its first excited state to second excited state is

(1) 1/4 (2) 4/9 (3) 9/4 (4) 4

Sol. Answer (3)

Energy in its 1st excited = $\frac{E_0}{4}$

Energy in its 2nd excited state = $\frac{E_0}{9}$

$E_1 : E_2 = 9 : 4$

19. Which of the following transitions in a hydrogen atom emit photons of lowest frequency?

(1) $n = 2$ to $n = 1$ (2) $n = 4$ to $n = 2$ (3) $n = 4$ to $n = 3$ (4) $n = 3$ to $n = 1$

Sol. Answer (3)

The pair for which the value

$$f = cR\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

is lowest is 4 and 3

20. The energy of hydrogen-atom in its ground state is –13.6 eV. The energy of the level corresponding to $n = 5$ is

(1) –0.544 eV (2) –5.40 eV (3) –0.85 eV (4) –2.72 eV

Sol. Answer (1)

Energy in a hydrogen atom varies as $E = \frac{E_0}{n^2}$

$E_0 = -13.6$ eV $\quad n = 5$

$$E = \frac{-13.6}{5^2}$$

or $E = -0.544$ eV

21. If the electron in hydrogen atom jumps from third orbit to second orbit, the wavelength of the emitted radiation is given by

(1) $\lambda = \frac{36}{5R}$ (2) $\lambda = \frac{5R}{36}$ (3) $\lambda = \frac{5}{R}$ (4) $\lambda = \frac{R}{6}$

Sol. Answer (1)

$$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$\frac{1}{\lambda} = R\left(\frac{1}{4} - \frac{1}{9}\right)$$

$$\frac{1}{\lambda} = R\left(\frac{9-4}{36}\right)$$

$$\lambda = \frac{36}{5R}$$

22. When an electron is excited to nth energy state in hydrogen, the possible number of spectral lines emitted are

(1) n (2) $2n$ (3) $\frac{n^2 - n}{2}$ (4) $\frac{n^2 + n}{2}$

Sol. Answer (3)

$${}^nC_2 = \frac{n(n-1)}{2}$$

23. Which series of hydrogen atom lie in infra red region?

(1) Lyman (2) Balmer

(3) Brackett, Paschen and Pfund (4) All of these

Sol. Answer (3)

The Brackett, Paschen and Pfund series are series which lie in the infrared region.

24. Using Bohr's formula for energy quantization, the ionisation potential of the ground state of Li^{++} atoms is

(1) 122 V (2) 13.6 V (3) 3.4 V (4) 10.2 V

Sol. Answer (1)

Energy in a shell of an atom is given by

$$E = E_0 \frac{Z^2}{n^2}$$

E_{Li} = 13.6 × 9 or ≈ 122 V

25. The total energy of an electron in the hydrogen atom in the ground state is –13.6 eV. The kinetic energy of this electron is

(1) 13.6 eV (2) 0 (3) –13.6 eV (4) 6.8 eV

Sol. Answer (1)

Total energy = –PE + KE

where PE = –2KE

∴ KE = 13.6 eV

26. The wavelength of first member of Balmer series in hydrogen spectrum is λ. Calculate the wavelength of first member of Lyman series in the same spectrum

(1) $(5/27)\lambda$ (2) $(4/27)\lambda$ (3) $(27/5)\lambda$ (4) $(27/4)\lambda$

Sol. Answer (1)

$$\frac{1}{\lambda_1} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$$ [For 1st members of Balmer series]

$$\frac{1}{\lambda_2} = R\left(\frac{1}{1^2} - \frac{1}{2^2}\right)$$ [For 1st members of Lyman series]

$$\frac{\lambda_1}{\lambda_2} = \frac{36}{5} \times \frac{3}{4}$$

$$\lambda_2 = \lambda_1 \times \frac{5}{27}$$

27. Which state of triply ionised beryllium (Be^{3+}) has the same orbital radius as that of the ground state of hydrogen?

(1) 1 (2) 2 (3) 3 (4) 4

Sol. Answer (2)

Radius = $0.53\frac{n^2}{Z}$ Å

For radius of Beryllium to be same as hydrogen's ground state = $\frac{n^2}{Z}$ = 1

$n^2 = 4$

$n = 2$

28. Energy levels A, B, C of a certain atom correspond to increasing values of energy *i.e.* $E_A < E_B < E_C$. If λ_1, λ_2 and λ_3 be the wavelength corresponding to the transitions C to B, B to A and C to A respectively, then which of the following is correct?

(1) $\lambda_3 = \lambda_1 + \lambda_2$ (2) $\lambda_3 = \frac{\lambda_1\lambda_2}{(\lambda_1+\lambda_2)}$ (3) $\lambda_1 = \lambda_2\lambda_3/\lambda_2 + \lambda_3$ (4) $\lambda_3^2/\lambda_1^2 + \lambda_2^2$

Sol. Answer (2)

$E_C > E_B > E_A$

$$\frac{1}{\lambda_1} = R\left(\frac{1}{n_B^2} - \frac{1}{n_C^2}\right) \quad ....(i)$$

$$\frac{1}{\lambda_2} = R\left(\frac{1}{n_A^2} - \frac{1}{n_B^2}\right) \quad ....(ii)$$

$$\frac{1}{\lambda_3} = R\left(\frac{1}{n_A^2} - \frac{1}{n_C^2}\right)$$

(i) + (ii) → $\frac{1}{\lambda_1} + \frac{1}{\lambda_2} = R\left(\frac{1}{n_A^2} - \frac{1}{n_C^2}\right)$

$$\lambda_3 = \frac{\lambda_1\lambda_2}{\lambda_1+\lambda_2}$$

29. The minimum wavelength of the X-rays produced at accelerating potential V is λ. If the accelerating potential is changed to $2V$, then the minimum wavelength would become

(1) 4λ (2) 2λ (3) $\lambda/2$ (4) $\lambda/4$

Sol. Answer (3)

$$\lambda_{min} = \frac{12400}{V}$$

If potential is changed to $2V$

New $\lambda_{min} = \frac{\lambda}{2}$

30. X-rays of a particular wavelength are used to irradiate sodium and copper surfaces in two separate experiments and stopping potentials are determined. The stopping potentials are

(1) Equal in both cases (2) Greater for sodium (3) Greater for copper (4) Infinite in both cases

Sol. Answer (2)

The stopping potential is greater for sodium as it is easier to ionise sodium, than copper.

31. An X-ray tube has a short wavelength end at 0.45Å. The voltage of tube is

(1) 450000 V (2) 9600 V (3) 27500 V (4) 60600 V

Sol. Answer (3)

$$\lambda_{\min} = \frac{12400}{V}$$

32. The frequencies of X-rays, γ-rays and U.V. rays are respectively a, b and c. Then

(1) $a < b,\ b < c$ (2) $a < b,\ b > c$ (3) $a > b,\ b > c$ (4) $a > b,\ b < c$

Sol. Answer (2)

Frequency of the gamma rays as highest followed by X-rays and then UV rays.

33. The wavelength of the K_α line for an element of atomic number 43 is λ. The wavelength of the K_α line for an element of atomic number 29 is

(1) $\left(\frac{43}{29}\right)\lambda$ (2) $\left(\frac{42}{28}\right)\lambda$ (3) $\left(\frac{9}{4}\right)\lambda$ (4) $\left(\frac{4}{9}\right)\lambda$

Sol. Answer (3)

$$\sqrt{f} \propto (Z-1)$$

or $f \propto (Z-1)^2$

$$\therefore \quad \lambda \propto \frac{hc}{(Z-1)^2}$$

$$\frac{\lambda_1}{\lambda_2} = \frac{(Z_2-1)^2}{(Z_1-1)^2}$$

$$\frac{\lambda_1}{\lambda_2} = \left(\frac{28}{42}\right)^2$$

$$\frac{\lambda_1}{\lambda_2} = \left(\frac{2}{3}\right)^2$$

$$\frac{\lambda_1}{\lambda_2} = \frac{4}{9}$$

$$\lambda_2 = \frac{9}{4}\lambda_1$$

34. X-rays incident on a material

(1) Will exert a force on it (2) Will transfer energy to it

(3) May cause emission of electrons (4) All of these

Sol. Answer (4)

All the option are true phenomenon observed in the case of X-rays.

35. Penetrating power of X-rays increases with increase in

(1) Accelerating potential (2) Wavelength

(3) Mass number of the target material (4) Filament current

Sol. Answer (1)

Penetrating power depends on energy of the *x*-wave which depends on the accelerating potential of the X-ray tube.

36. If the potential difference *V* applied to the coolidge tube is doubled, then the cut off wavelength

(1) Is doubled (2) Is halved

(3) Remains unchanged (4) Is quadrupled

Sol. Answer (2)

$\lambda_{\min} = \frac{12400}{V}$ if V is doubled $\lambda_{\min}$ is halved.

37. Laser is/are

(1) Highly coherent (2) Highly monochromatic

(3) Highly directional (4) All of these

Sol. Answer (4)

All the above facts are true for a laser.

38. A situation of population inversion is related to

(1) Matter wave (2) γ-ray (3) X-ray (4) LASER

Sol. Answer (4)

A situation of population inversion means when more atoms in a group are in the excited state than lower energy states. This is used in LASER.

39. In He-Ne laser, metastable state exists in

(1) He (2) Ne (3) Both (1) & (2) (4) Neither He nor Ne

Sol. Answer (2)

Fact.

40. If the emitted radiation falls in the microwave region, the device is termed as

(1) LASER (2) MASER (3) Both (1) & (2) (4) None of these

Sol. Answer (2)

Stimulated emitted radiation in the microwave form is called MASER.

SECTION - B

Objective Type Questions

1. The wavelength of radiation emitted is λ_0 when an electron jumps from third to second orbit of hydrogen atom. For the electron to jump from the fourth to the second orbit of the hydrogen atom, the wavelength of radiation emitted will be

(1) $\frac{16}{25}\lambda_0$ (2) $\frac{20}{27}\lambda_0$ (3) $\frac{27}{20}\lambda_0$ (4) $\frac{25}{16}\lambda_0$

Sol. Answer (2)

$$\frac{1}{\lambda_0} = R\left(\frac{1}{2^2}-\frac{1}{3^2}\right)$$

$$\frac{1}{\lambda_0} = R\frac{5}{36}$$

$$\frac{1}{\lambda_1} = R\left(\frac{1}{2^2}-\frac{1}{4^2}\right)$$

$$\frac{1}{\lambda_1} = R\left(\frac{1}{4}-\frac{1}{16}\right)$$

$$\frac{1}{\lambda_1} = R\frac{3}{16}$$

$$\frac{\lambda_1}{\lambda_0} = \frac{5}{36}\times\frac{16}{3}$$

$$\lambda_1 = \frac{20}{27}\lambda_0$$

2. An electron in a hydrogen atom makes a transition from n_1 to n_2. If the time period of electron in the initial state is eight times that in the final state then

(1) $n_1 = 3n_2$ (2) $n_1 = 4n_2$ (3) $n_1 = 2n_2$ (4) $n_1 = 5n_2$

Sol. Answer (3)

Let $T_1 = n_1^3 T_0$

$T_2 = n_2^3 T_0$

$$\frac{T_1}{T_2} = \frac{n_1^3}{n_2^3}$$

$n_1 = 2n_2$

3. When a hydrogen atom emits a photon of energy 12.09 eV, its orbital angular momentum changes by (where h is Planck's constant)

(1) $\frac{3h}{\pi}$ (2) $\frac{2h}{\pi}$ (3) $\frac{h}{\pi}$ (4) $\frac{4h}{\pi}$

Sol. Answer (3)

This is the case of electron jumping from 3rd orbit to 1st orbit

$$\Delta L = \frac{n_1 h}{2\pi} - \frac{nh}{2\pi}$$

$$= \frac{3h}{2\pi} - \frac{h}{2\pi} = \frac{h}{\pi}$$

4. If the frequency of K_α X-rays emitted from the element with atomic number 31 is ν then the frequency of K_α X-rays emitted from the element with atomic number 51 would be

(1) $\frac{5}{3}\nu$ (2) $\frac{51}{31}\nu$ (3) $\frac{25}{9}\nu$ (4) $\frac{9}{25}\nu$

Sol. Answer (3)

$$\sqrt{\nu} = K_\alpha(31-1) \quad \text{....(i)}$$

$$\sqrt{\nu_x} = K_\alpha(51-1) \quad \text{....(ii)}$$

Dividing (ii) by (i)

$$\frac{\sqrt{\nu_x}}{\sqrt{\nu}} = \frac{50}{30}$$

$$\nu_x = \frac{25}{9}\nu$$

5. A hydrogen atom is in ground state. In order to get six lines in its emission spectrum, wavelength of incident radiation should be

(1) 800 Å (2) 825 Å (3) 970 Å (4) 1025 Å

Sol. Answer (3)

To get six possible emission lines the electron must be excite to the third level as

$$6 = \frac{n}{2}(n+1)$$

$\therefore$ $n = 3$

Frequency of incident radiation is such that $hf = 13.6\left(1 - \frac{1}{3^2}\right)$

or $\frac{hc}{\lambda} = 13.6 \times \frac{8}{9}$ or $\lambda = \frac{hc \times 9}{13.6 \times 8}$

or $\lambda = 970$ Å

6. The X-ray beam coming from the X-rays tube will be

(1) Monochromatic

(2) Dichromatic

(3) Having all wavelengths greater than a certain minimum wavelength

(4) Having all wavelengths between a minimum and maximum wavelengths

Sol. Answer (3)

Only the minimum wavelength is fixed in the case of an X-ray from X-ray tube. In this case X-rays are formed from emission by a substance and all possible transitions need to be accounted for. The only limit is the maximum energy supplied to material by incident light which depends on incident light.

7. If the energy in the first excited state in hydrogen atom is 23.8 eV then the potential energy of a hydrogen atom in the ground state can be assumed to be

(1) 10 eV (2) 23.3 eV (3) – 13.6 eV (4) Zero

Sol. Answer (4)

8. If energy required to remove one of the two electrons from He atom is 29.5 eV, then what is the value of energy required to convert a helium atom into α-particle?

(1) 54.4 eV (2) 83.9 eV (3) 29.5 eV (4) 24.9 eV

Sol. Answer (2)

Energy needed to convert He^+ ion to He^{2+} is = E_0Z^2

= 13.6 × 4

Hence total energy to create alpha particle of out of helium atom is

E_{total} = 13.6 × 4 + 29.5

= 83.9 eV

9. The maximum wavelength that a sample of hydrogen atoms can absorb is

(1) 912 Å (2) 1216 Å (3) 1028 Å (4) Infinite

Sol. Answer (2)

$$\frac{1}{\lambda_{max}} = R\left(\frac{1}{1^2} - \frac{1}{2^2}\right)$$

Solve for λ_{max}.

10. The lines in Balmer series have their wavelengths lying between

(1) 1266 Å to 3647 Å (2) 642 Å to 3000 Å (3) 3647 Å to 6563 Å (4) Zero to infinity

Sol. Answer (3)

$$\frac{1}{\lambda_{max}} = R\left(\frac{1}{2^2} - \frac{1}{\infty}\right)$$

$$\frac{1}{\lambda_{max}} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$$ solve for the range

11. If an electron in hydrogen atom jumps from third orbit to second orbit, the frequency of the emitted radiation is given by (c is speed of light)

(1) $\frac{3Rc}{29}$ (2) $\frac{5Rc}{36}$ (3) $\frac{7Rc}{36}$ (4) $\frac{8Rc}{31}$

Sol. Answer (2)

$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$$

$$f = R_e c\left(\frac{1}{4} - \frac{1}{9}\right)$$

$$f = \frac{Rc5}{36} = \frac{5Rc}{36}$$

12. Let F_1 be the frequency of second line of Lyman series and F_2 be the frequency of first line of Balmer series then frequency of first line of Lyman series is given by

(1) $F_1 - F_2$ (2) $F_1 + F_2$ (3) $F_2 - F_1$ (4) $\frac{F_1F_2}{F_1 + F_2}$

Sol. Answer (1)

$$F_1 = R_c\left[\frac{1}{n_1^2} - \frac{1}{n_3^2}\right] \quad ....(i)$$

$$F_2 = R_c\left[\frac{1}{n_2^2} - \frac{1}{n_3^2}\right] \quad ....(ii)$$

Subtracting (ii) from (i)

$$F = R_c\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$$F = F_1 - F_2$$

13. Identify the incorrect relationship

(1) Number of waves in an orbit, $n = \frac{2\pi r}{\lambda}$

(2) Number of revolutions of an electron per second in nth orbit = $\frac{v_n}{2\pi r_n}$

(3) Wavelength of an electron = $\frac{h}{p}$

(4) Speed of a (de-Broglie wavelength) particle accelerated by a potential difference V is $v = \frac{2eV}{m}$

Sol. Answer (4)

Kinetic energy gained by an electron accelerated by potential V is

$$KE = eV$$

or $\frac{1}{2}mv^2 = eV$

$$v = \sqrt{\frac{2eV}{m}}$$

Hence (4) is wrong.

14. If the difference between $(n + 1)^{th}$ Bohr radius and n^{th} Bohr radius is equal to the $(n - 1)^{th}$ Bohr radius then find the value of n

(1) 4 (2) 3 (3) 2 (4) 1

Sol. Answer (1)

Bohr radius is given by $r = r_0n^2$

Now $[(n + 1)^2 - n^2]r_0 = (n - 1)^2r_0$

$2n + 1 = (n - 1)^2$

$n^2 - 2n + 1 = 2n + 1$

$n^2 - 4n = 0$

$n(n - 4) = 0$

or $n = 4$

15. If radius of first orbit of hydrogen atom is 5.29×10^{-11} m, the radius of fourth orbit will be

(1) 8.46 Å (2) 10.23 Å (3) 9.22 Å (4) 9.48 Å

Sol. Answer (1)

5.3×10^{-11}

or 0.53 Å

Radius of n^{th} orbit $= 0.53 \times n^2$

Radius of 4^{th} orbit $= 0.53 \times 16$ Å

$= 8.46$ Å

16. Ratio of magnetic dipole moment to the angular momentum for hydrogen like atoms is (e and m are electronic charge and mass respectively)

(1) $\frac{e}{m}$ (2) $\frac{2e}{m}$ (3) $\frac{e}{2m}$ (4) $\frac{e}{4m}$

Sol. Answer (3)

Angular momentum of electron = mvr

Magnetic moment of electron.

17. The ratio of energies of hydrogen atom in its first excited state to third excited state is

(1) $\frac{1}{4}$ (2) $\frac{4}{1}$ (3) $\frac{3}{4}$ (4) $\frac{4}{3}$

Sol. Answer (2)

Energy in n^{th} excited state = $\dfrac{-13.6}{(n+1)^2}$

Energy in 1^{st} excited state = $\dfrac{-13.6}{4}$

Energy in 3^{rd} excited state = $\dfrac{-13.6}{16}$

Ratio $E_1 : E_3 = 4 : 1$

18. What should be the ratio of minimum to maximum wavelength of radiation emitted by transition of an electron to ground state of Bohr's hydrogen atom?

(1) $\dfrac{3}{4}$ (2) $\dfrac{1}{4}$ (3) $\dfrac{1}{8}$ (4) $\dfrac{3}{8}$

Sol. Answer (1)

In maximum wavelength electron falls from 1st excited state.

$$\frac{1}{\lambda_{\max}} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right]$$

In minimum wavelength the electron comes from infinity

$$\frac{1}{\lambda_{\min}} = R\left[\frac{1}{1^2} - \frac{1}{\infty^2}\right]$$

Hence $\dfrac{\lambda_{\max}}{\lambda_{\min}} = \dfrac{4}{3}$

19. The product of angular speed and tangential speed of electron in n^{th} orbit of hydrogen atom is

(1) Directly proportional to n^2
(2) Directly proportional to n^3
(3) Inversely proportional to n^4
(4) Independent of n

Sol. Answer (3)

Angular velocity = $\dfrac{v_n}{r_n}$

Product of angular velocity and tangential velocity = $\dfrac{v_n}{r_n} \times v_n$

or $\dfrac{v_n^2}{r_n}$

or $\dfrac{v_0}{r_0 n^4}$ $\left(\because v_n = \dfrac{v_0}{n} \text{ and } r_n = n^2 r_0\right)$

Hence product $\propto \dfrac{1}{n^4}$

20. Ground state energy of H-atom is –13.6 eV. The energy needed to ionise H-atom from its second excited state is

(1) 1.51 eV (2) 3.4 eV (3) 13.6 eV (4) 12.1 eV

Sol. Answer (1)

Total energy of n^{th} excited state is = $\dfrac{-13.6}{(n+1)^2}$

$\therefore$ Energy needed = $+\dfrac{13.6}{9} \approx 1.51\,\text{eV}$

21. The energy of hydrogen atom in its ground state is –13.6 eV, the energy of the level corresponding to $n = 7$ is

(1) –0.544 eV (2) –5.40 eV (3) –0.85 eV (4) –0.28 eV

Sol. Answer (4)

Energy of n^{th} shell is given by $E = \dfrac{E_0}{n^2}$

$$E = -\frac{13.6}{49}$$

$E \approx -0.28$ eV

22. Which series of hydrogen atom lie in infrared region?

(1) Lyman (2) Balmer

(3) Brackett, Paschen and Pfund (4) All of these

Sol. Answer (3)

In hydrogen atom. The Brackett, Paschen and Pfund series all lie in the infrared region.

23. Total energy of an electron in the hydrogen atom in the ground state is –13.6 eV. The potential energy of this electron is

(1) 13.6 eV (2) 0 (3) –27.2 eV (4) –13.6 eV

Sol. Answer (3)

Total energy = $\dfrac{\text{Potential energy}}{2} = -\text{KE}$

Hence potential energy = 2 × –13.6

= –27.2 eV

24. If potential energy of an electron in a hydrogen atom in first excited state is taken to be zero, kinetic energy (in eV) of an electron in ground state will be

(1) 13.6 eV (2) 10.2 eV (3) 3.4 eV (4) 5.1 eV

Sol. Answer (1)

If zero of potential energy is changed, KE does not change and continues to be + 13.6 eV.

When 2nd shell is taken as reference, ground state PE = –13.6 eV × 2 + 6.8 eV = –20.4 eV

KE = $\dfrac{-\text{PE}}{2}$ = 10.2 eV

25. Time period of revolution of an electron in n^{th} orbit in a hydrogen like atom is given by $T = \frac{T_0 n^a}{Z^b}$. Z = atomic number

(1) $T_0 = 1.5 \times 10^{-16}$ s, $a = 3$ (2) $T_0 = 6.6 \times 10^{15}$ s, $a = 3$

(3) $T_0 = 1.51 \times 10^{-16}$ s, $b = 3$ (4) $T_0 = 6.6 \times 10^{15}$ s, $b = 3$

Sol. Answer (1)

$$T = \frac{T_0 n^a}{Z^b} \qquad T_n = \frac{T_0 n^3}{Z}$$

$T_0 = 1.51 \times 10^{-16}$ s $\qquad a = 3$

Which is a fact.

26. Maximum wavelength in balmer series of hydrogen spectrum is

(1) 912 Å (2) 3645 Å (3) 6561 Å (4) 8201 Å

Sol. Answer (3)

27. In Rutherford's experiment, number of particles scattered at 90º angle are x per second. Number particles scattered per second at angle 60º is

(1) x (2) 4 x (3) 8 x (4) 16 x

Sol. Answer (2)

$$N(\theta) \propto \frac{Z^2}{\sin^4\left(\frac{\theta}{2}\right)E^2}$$

or $$N(\theta) \propto \frac{1}{\sin^4\left(\frac{\theta}{2}\right)}$$

θ = 60º and 90º

$$\therefore \quad \frac{N(90)}{N(60)} \propto \frac{\sin^4 30}{\sin^4 45}$$

$N(90º) = x$

$N(60º) = 4x$

28. Compton effect supports that

(1) X-rays are transverse waves

(2) X-rays have high frequency compared to visible light

(3) X-rays can easily penetrate matter

(4) Photons have momentum

Sol. Answer (4)

Compton effect is the scattering of particles due to radiation and prove that photons have momenta.

29. Which is the correct relation between de-Broglie wavelength of an electron in the n^{th} Bohr orbit and radius of the orbit R?

(1) $\lambda = n2\pi R$ (2) $\lambda = \dfrac{2\pi R}{n}$ (3) $\lambda = \dfrac{4\pi R}{n}$ (4) $\lambda = \dfrac{2\pi R}{nh}$

Sol. Answer (2)

$$\lambda = \frac{h}{mv} \text{ in } 2\pi r_n = \frac{nh}{mv_n}$$

30. Atomic number of anticathode material in an X-ray tube is 41. Wavelength of K_α X-ray produced in the tube is

(1) 0.66 Å (2) 0.76 Å (3) 0.82 Å (4) 0.88 Å

Sol. Answer (2)

$$\sqrt{f} = K_\alpha(Z-1)$$

$$\sqrt{f} = (40)$$

$$\sqrt{f} = \sqrt{2.48\times10^{15}}\times40$$

$$f = 2.48 \times 10^{15} \times 1600$$

$$\frac{c}{\lambda} = 2.48\times10^{15}\times1600$$

$\lambda = 0.76 \times 10^{-10}$ or $\lambda = 0.76$ Å

31. Hydrogen atoms are excited from ground state to the principal quantum number 5. Number of spectral lines observed will be

(1) 5 (2) 4 (3) 10 (4) 8

Sol. Answer (3)

Number of spectral lines are given by (N) = $\dfrac{n(n-1)}{2}$

or $N = \dfrac{5\times4}{2}$

or N = 10 lines

32. If in Bohr's atomic model, it is assumed that force between electron and proton varies inversely as r^4, energy of the system will be proportional to

(1) n^2 (2) n^4 (3) n^6 (4) n^8

Sol. Answer (3)

$$dE = Fdr$$

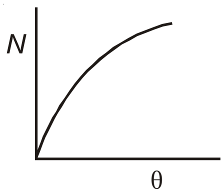
$$\int dE = \int \frac{k}{r^4}dr$$

$$E = \frac{k_1}{r^3}$$

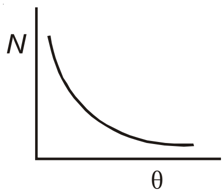
$E = \dfrac{k_2}{n^6}$ as $r \propto n^2$ (Where, k, k_1 and k_2 are constants)

33. Which of the following may be representing graph between number of scattered particles detected (N) and scattering angle (θ) in Rutherford's experiment?

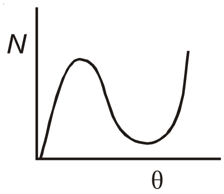
(1)



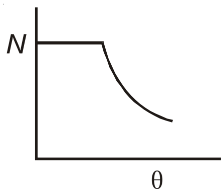
(2)



(3)



(4)



Sol. Answer (2)

$$N(\theta) = \frac{k}{\sin^4(\theta/2)}$$

Hence $N(\theta)$ decreases with increase in angle θ.

SECTION - C

Previous Years Questions

1. In a Rutherford scattering experiment when a projectile of charge z_1 and mass M_1 approaches a target nucleus of charge z_2 and mass M_2, the distance of closest approach is r_0. The energy of the projectile is

(1) Directly proportional of mass M_1

(2) Directly proportional of $M_1 \times M_2$

(3) Directly proportional of $z_1 z_2$

(4) Inversely proportional to z_1

Sol. Answer (3)

2. An electron makes a transition from orbit $n = 4$ to the orbit $n = 2$ of a hydrogen atom. What is the wavelength of the emitted radiations? (R = Rydberg's constant)

(1) $\frac{16}{4R}$ (2) $\frac{16}{5R}$ (3) $\frac{16}{2R}$ (4) $\frac{16}{3R}$

Sol. Answer (4)

Transition is from $n = 4$ to $n = 2$ of hydrogen atom

$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{4^2}\right)$$

$$\frac{1}{\lambda} = \frac{R}{16}$$

$$\lambda = \frac{16}{3R}$$

3. When a hydrogen atom is raised from the ground state to an excited state,

(1) Both K.E. and P.E. increase

(2) Both K.E. and P.E, decrease

(3) The P.E. decreases and K.E. increases

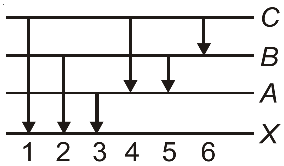
(4) The P.E. increases and K.E. decreases

Sol. Answer (4)

The potential energy increases when the electron is taken to a higher shell.

The kinetic energy or velocity of the electron decreases.

4. The figure indicates the energy level diagram of an atom and the origin of six spectral lines in emission (*e.g.* line number 5 arises from the transition from level *B* to *A*). Which of the following spectral lines will also occur in the absorption spectrum?



(1) 4, 5, 6 (2) 1, 2, 3, 4, 5, 6 (3) 1, 2, 3 (4) 1, 4, 6

Sol. Answer (3)

Only 1, 2, 3rd lines will be there in the absorption spectrum as those are the only line which include the ground state. In absorption a non-excited or ground-state atom absorbs energy and the electron goes into an excited state.

5. The energy of a hydrogen atom in its ground state is – 13.6 eV. The energy of the level corresponding to the quantum number *n* = 2 in the hydrogen atom is

(1) 0.54 eV (2) – 3.4 eV (3) – 2.72 eV (4) – 0.85 eV

Sol. Answer (2)

Energy in ground state hydrogen atom = –13.6 eV

In $n = 2$, $E = -\frac{13.6}{n^2} = -3.4$ eV

6. According to Bohr's principle, the relation between principal quantum number *(n)* and radius of orbit is

(1) $r \propto \frac{1}{n}$ (2) $r \propto \frac{1}{n^2}$ (3) $r \propto n$ (4) $r \propto n^2$

Sol. Answer (4)

$r = 0.53n^2$

Here $r \propto n^2$

7. When hydrogen atom is in its first excited level, its radius is …………… of the Bohr radius.

(1) Twice (2) 4 times (3) Same (4) Half

Sol. Answer (2)

$r = 0.53n^2$

At first excited level, $n = 2$

$r = 0.53 \times 4$

$r = 2.1$ Å

8. Atomic weight of Boron is 10.81 and it has two isotopes ${}_5B^{10}$ and ${}_5B^{11}$. Then the ratio of ${}_5B^{10} : {}_5B^{11}$ in nature would be

(1) 15 : 16 (2) 10 : 11 (3) 19 : 81 (4) 81 : 19

Sol. Answer (3)

Taking weighed mean

$10.81 = 10x + 11(1 - x)$

$10.81 = 10x + 11 - 11x$

$10.81 = 11 - x$

$x = 11 - 10.81$

$x = 0.19$

or 19%

$(x) : (1 - x) = 19 : 81$

9. In the Bohr model of a hydrogen atom, the centripetal force is furnished by the coulomb attraction between the proton and the electron. If a_0 is the radius of the ground state orbit, m is the mass and e is the charge on the electron and ε_0 is the vacuum permittivity, the speed of the electron is

(1) $\dfrac{e}{\sqrt{4\pi\varepsilon_0\, a_0 m}}$ (2) $\dfrac{e}{\sqrt{\varepsilon_0\, a_0 m}}$ (3) Zero (4) $\dfrac{\sqrt{4\pi\varepsilon_0\, a_0 m}}{e}$

Sol. Answer (1)

$$\frac{mv^2}{a_0} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{a_0^2}$$

$$v = \frac{e}{\sqrt{4\pi\varepsilon_0 a_0 \cdot m}}$$

10. Maximum frequency of emission is obtained for the transition

(1) $n = 2$ to $n = 1$ (2) $n = 6$ to $n = 2$ (3) $n = 1$ to $n = 2$ (4) $n = 2$ to $n = 6$

Sol. Answer (1)

Maximum frequency is obtained for maximum energy difference in levels

$$E = 13.6\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

The values of n_f and n_i for which this is maximum is $n_f = 1$ and $n_i = 2$.

11. When an electron do transition from $n = 4$ to $n = 2$, then emitted line in spectrum will be

(1) First line of Lyman series (2) Second line of Balmer series

(3) First line of Paschen series (4) Second line of Paschen series

Sol. Answer (2)

Fact.

12. The energy of hydrogen atom in nth orbit is E_n then the energy in nth orbit of singly ionised helium atom will be

(1) $4E_n$ (2) $E_n/4$ (3) $2E_n$ (4) $E_n/2$

Sol. Answer (1)

Energy in hydrogen like atom is given by $E_n \times Z^2$

Since $Z = 2$ in helium

$E = E_n \times 4$

13. In which of the following systems will the radius of the first orbit ($n = 1$) be minimum?

(1) Doubly ionized lithium (2) Singly Ionized helium

(3) Deuterium atom (4) Hydrogen atom

Sol. Answer (1)

$$r \propto \frac{1}{Z}$$

Since in lithium $Z = 3$

14. The Bohr model of atoms

(1) Assumes that the angular momentum of electrons is quantized

(2) Uses Einstein's photo-electric equation

(3) Predicts continuous emission spectra for atoms

(4) Predicts the same emission spectra for all types of atom

Sol. Answer (1)

Fact.

15. Energy E of a hydrogen atom with principal quantum number n is given by $E = \frac{-13.6}{n^2}$ eV . The energy of a photon ejected when the electron jumps from $n = 3$ state to $n = 2$ state of hydrogen is approximately

(1) 1.5 eV (2) 0.85 eV (3) 3.4 eV (4) 1.9 eV

Sol. Answer (4)

$$E = -13.6\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = 1.9 \text{ eV}$$

16. Energy levels are A, B and C of a certain atom corresponding to increasing values of energy *i.e.* $E_A < E_B < E_C$. If λ_1, λ_2 and λ_3 are wavelengths of radiations corresponding to transitions C to B, B to A and C *to* A respectively, which of the following relations is correct?

(1) $\lambda_3 = \lambda_1 + \lambda_2$ (2) $\lambda_3 = \frac{\lambda_1\lambda_2}{\lambda_1 + \lambda_2}$ (3) $\lambda_1 + \lambda_2 + \lambda_3 = 0$ (4) $\lambda_3^2 = \lambda_1^2 + \lambda_2^2$

Sol. Answer (2)

$$\frac{1}{\lambda_3} = R\left[\frac{1}{n_C^2} - \frac{1}{n_A^2}\right] \qquad \frac{1}{\lambda_1} = R\left[\frac{1}{n_C^2} - \frac{1}{n_B^2}\right]$$

$$\frac{1}{\lambda_2} = R\left[\frac{1}{n_B^2} - \frac{1}{n_A^2}\right]$$

$$\frac{1}{\lambda_3} = \frac{1}{\lambda_2} + \frac{1}{\lambda_1}$$

$$\frac{1}{\lambda_3} = \frac{\lambda_1\lambda_2}{\lambda_1 + \lambda_2}$$

17. Ionization potential of hydrogen atom is 13.6 eV. Hydrogen atoms in the ground state are excited by monochromatic radiation of photon energy 12.1 eV. According to Bohr's theory, the spectral lines emitted by hydrogen will be

(1) One (2) Two (3) Three (4) Four

Sol. Answer (3)

Electrons are excited by 12.1 eV radiation. New PE of electron = –(13.6 – 12.1) = –1.5 eV

This is the energy corresponding to $n = 3$

Hence number of spectral lines $\frac{n(n-1)}{2} = 3$

18. The total energy of electron in the ground state of hydrogen atom is –13.6 eV. The kinetic energy of an electron in the first excited state is

(1) 6.8 eV (2) 13.6 eV (3) 1.7 eV (4) 3.4 eV

Sol. Answer (4)

$$\text{KE} = \frac{-\text{PE}}{2}$$

$$\text{KE} = \frac{13.6}{2 \times n^2} \qquad n = 2$$

$$= 1.7 \text{ eV}$$

19. The ionization energy of the electron in the hydrogen atom in its ground state is 13.6 eV. The atoms are excited to higher energy levels to emit radiations of 6 wavelengths. Maximum wavelength of emitted radiation corresponds to the transition between

(1) $n = 4$ to $n = 3$ states (2) $n = 3$ to $n = 2$ states

(3) $n = 3$ to $n = 1$ state (4) $n = 2$ to $n = 1$ state

Sol. Answer (1)

The shell as state of an atom is $\frac{n \cdot (n-1)}{2} = 6$

$n = 4$

The lowest energy change will correspond the maximum wavelength.

20. The energy of a hydrogen atom in the ground state is –13.6 eV. The energy of a He^+ ion in the first excited state will be

(1) –6.8 eV (2) –13.6 eV (3) –27.2 eV (4) –54.4 eV

Sol. Answer (2)

$$E_{He^+} = \frac{E_0}{n^2} Z^2$$

$$= -13.6 \times \frac{4}{4}$$

$$= -13.6 \text{ eV}$$

21. A alpha nucleus of energy $\frac{1}{2}mv^2$ bombards a heavy nuclear target of charge *Ze*. Then the distance of closest approach for the alpha nucleus will be proportional to

(1) $\frac{1}{v^4}$ (2) $\frac{1}{Ze}$ (3) v^2 (4) $\frac{1}{m}$

Sol. Answer (4)

22. The electron in the hydrogen atom jumps from excited state (n = 3) to its ground state (n = 1) and the photons thus emitted irradiate a photosensitive material. If the work function of the material is 5.1 eV, the stopping potential is estimated to be (the energy of the electron in n^{th} state $E_n = -\frac{13.6}{n^2}\text{eV}$)

(1) 5.1 V (2) 12.1 V (3) 17.2 V (4) 7 V

Sol. Answer (4)

$$\text{Energy of radiation} = 13.6\left[\frac{1}{1^1} - \frac{1}{3^2}\right]$$

$$= 13.6\left[\frac{8}{9}\right]$$

$$= 12.08 \text{ eV}$$

$\text{KE}_{\text{max}} = E - w_0$

$= 12.08 - 5.1$

$= 6.98$ eV

23. Electron in hydrogen atom first jumps from third excited state to second excited state and then from second excited to the first excited state. The ratio of the wavelengths $\lambda_1 : \lambda_2$ emitted in the two cases is

(1) $\frac{27}{5}$ (2) $\frac{20}{7}$ (3) $\frac{7}{5}$ (4) $\frac{27}{20}$

Sol. Answer (2)

24. An electron of a stationary hydrogen atom passes from the fifth energy level to the ground level. The velocity that the atom acquired as a result of photon emission will be

(1) $\frac{25\text{ m}}{24\text{ hR}}$ (2) $\frac{24\text{ m}}{25\text{ hR}}$ (3) $\frac{24\text{ hR}}{25\text{ m}}$ (4) $\frac{25\text{ hR}}{24\text{ m}}$

Sol. Answer (3)

25. The transition from the state n = 3 to n = 1 in a hydrogen like atom results in ultraviolet radiation. Infrared radiation will be obtained in the transition from

(1) 2 → 1 (2) 3 → 2 (3) 4 → 2 (4) 4 → 3

Sol. Answer (4)

Energy released in this range is of infrared frequency range.

26. The wavelength of the first line of Lyman series for hydrogen atom is equal to that of the second line of Balmer series for a hydrogen like ion. The atomic number Z of hydrogen like ion is

(1) 2 (2) 3 (3) 4 (4) 1

Sol. Answer (1)

There are 2 equation and 2 unknown

$$\frac{1}{\lambda}=R\left[\frac{1}{1^2}-\frac{1}{2^2}\right] \quad ...(i)$$

also, $$\frac{1}{\lambda}=RZ^2\left[\frac{1}{2^2}-\frac{1}{4^2}\right] \quad ....(ii)$$

on comparing (i) and (ii), we get Z = 2.

27. Out of the following which one is not a possible energy for a photon to be emitted by hydrogen atom according to Bohr's atomic model?

(1) 13.6 eV (2) 0.65 eV (3) 1.9 eV (4) 11.1 eV

Sol. Answer (4)

Only the fourth is not available for any ionisation.

28. The ground state energy of hydrogen atom is –13.6 eV. When its electron is in the first excited state, its excitation energy is

(1) 0 (2) 3.4 eV (3) 6.8 eV (4) 10.2 eV

Sol. Answer (4)

Energy absorbed for electron to go to 2nd shell is $E=13.6\left(1-\frac{1}{2^2}\right)$

E = 10.2 eV

29. The ratio of radii of first shell of H atom and that of fourth shell of He^+ ion is

(1) 1 : 8 (2) 1 : 4 (3) $1:\sqrt{8}$ (4) 1 : 3

Sol. Answer (1)

$$r \propto \frac{n^2}{Z}$$

If r_H is 1 $r_{He} = \frac{4^2}{2} = 8$

$\therefore \quad r_H : r_{He} = 1 : 8$

30. The ionisation energy of 10 times ionised sodium atom is

(1) 13. 6 eV (2) 13.6 × 11 eV (3) $\frac{13.6}{(11)^2}$ eV (4) $13.6 \times (11)^2$ eV

Sol. Answer (4)

$E = E_0 \times Z^2$ for hydrogen like atom.

31. The wavelength of radiation emitted is λ_0 when an electron jumps from third to second orbit of hydrogen atom. For the electron to jump from the fourth to the second orbit of the hydrogen atom, the wavelength of radiation emitted will be

(1) $\frac{16}{25}\lambda_0$ (2) $\frac{20}{27}\lambda_0$ (3) $\frac{27}{20}\lambda_0$ (4) $\frac{25}{16}\lambda_0$

Sol. Answer (2)

$$\frac{1}{\lambda_0} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = \frac{5R}{36}$$

$$\frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{4^2}\right] = R\left[\frac{4-1}{16}\right] \quad \text{or} \quad \frac{1}{\lambda} = \frac{R3}{16}$$

$$\lambda = \frac{20}{27}\lambda_0$$

32. The ratio of wavelengths of the 1st line of Balmer series and that of the 1st line of Paschen series is

(1) 20 : 7 (2) 7 : 20 (3) 7 : 4 (4) 4 : 7

Sol. Answer (2)

$$\frac{1}{\lambda_B} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right]$$

$$\frac{1}{\lambda_P} = R\left[\frac{1}{3^2} - \frac{1}{4^2}\right]$$

Solve $\lambda_B : \lambda_P$

33. The shortest wavelength of Balmer series of H-atom is

(1) $\frac{4}{R}$ (2) $\frac{36}{5R}$ (3) $\frac{1}{R}$ (4) $\frac{3}{4R}$

Sol. Answer (1)

$$\frac{1}{\lambda_{\min}} = R\left[\frac{1}{1^2} - \frac{1}{\infty}\right]$$

$$\frac{1}{\lambda_{\min}} = \frac{1}{R}$$

34. An electron in a hydrogen atom makes a transition from $n = n_1$ to $n = n_2$. The time period of the electron in the initial state is eight times that in the final state. Find the ratio $\frac{n_1}{n_2}$

(1) 2 (2) 3 (3) 4 (4) 8

Sol. Answer (1)

35. Assuming Bohr's model for Li^{++} atom, the first excitation energy of ground state of Li^{++} atom is

(1) 10.2 eV (2) 91.8 eV (3) 13.6 eV (4) 3.4 eV

Sol. Answer (2)

$$E = 13.6 \times Z^2\left[\frac{1}{1^2}-\frac{1}{2^2}\right]$$

Put $Z = 3$ and solve for energy to get the answer.

36. The absorption transition between the first and the fourth energy states of hydrogen atom are 3. The emission transition between these states will be

(1) 3 (2) 4 (3) 5 (4) 6

Sol. Answer (4)

The emission transition lines between any two shells is given by $\dfrac{n(n+1)}{2}$

Since there are 3 absorption lines the shell 3 is mentioned here.

37. When a hydrogen atom emits a photon of energy 12.1 eV, its orbital angular momentum changes by (where h is Planck's constant)

(1) $\dfrac{3h}{\pi}$ (2) $\dfrac{2h}{\pi}$ (3) $\dfrac{h}{\pi}$ (4) $\dfrac{4h}{\pi}$

Sol. Answer (3)

This is the transition from 3rd shell to the first

Change in angular momentum = $\dfrac{3h}{2\pi}-\dfrac{h}{2\pi}=\dfrac{h}{\pi}$

38. Hydrogen atom in ground state is excited by a monochromatic radiation of λ = 975 Å. Number of spectral lines in the resulting spectrum emitted will be

(1) 3 (2) 2 (3) 6 (4) 10

Sol. Answer (3)

$$\frac{1}{\lambda}=R\left(\frac{1}{n_1^2}-\frac{1}{n_2^2}\right) \Rightarrow \frac{1}{975\times10^{-10}}=1.097\times10^{7}\left(\frac{1}{1^2}-\frac{1}{n_2^2}\right)$$

$n_2 = 4$

Number of spectral line = $\dfrac{n(n-1)}{2}=6$

39. Consider 3rd orbit of He^+ (Helium) using non-relativistic approach the speed of electron in this orbit will be (given $K = 9 \times 10^9$ constant $Z = 2$ and h (Planck's constant) = 6.6×10^{-34} Js).

(1) 3.0×10^8 m/s (2) 2.92×10^6 m/s (3) 1.46×10^6 m/s (4) 0.73×10^6 m/s

Sol. Answer (3)

For hydrogen like atom

$$V_n=\frac{2\pi KZe^2}{nh}$$

$$V_n=\frac{C}{137}\frac{Z}{n}=\frac{2.2\times10^6\times2}{3}=1.46\times10^6\ \text{m/s}$$

SECTION - D

Assertion-Reason Type Questions

1. A : Both the Thomson's as well as the Rutherford's models constitute an unstable system.

   R : Thomson's model is unstable electrostatically while Rutherford's model is unstable because of electromagnetic radiation of orbiting electrons.

Sol. Answer (1)

2. A : Bohr's orbits are regions where the electron may be found with large probability.

   R : The orbital picture in Bohr's model of the hydrogen atom was inconsistent with the uncertainty principle.

Sol. Answer (1)

3. A : Bohr's model with its planet-like electron is not applicable to many electron atoms.

   R : Unlike the situation in the solar system, where planet-planet gravitational forces are very small as compared to the gravitational force of the sun on each planet, the electron-electron electric force interaction is comparable in magnitude to the electron nucleus electric force.

Sol. Answer (1)

4. A : In Bohr model, the frequency of revolution of an electron in its orbit is not connected to the frequency of spectral line for smaller principal quantum number *n*.

   R : For transitions between large quantum number the frequency of revolution of an electron in its orbit is connected to the frequency of spectral line, as per Bohr's Correspondence principle.

Sol. Answer (2)

5. A : Spectral analysis can differentiate between isotopes as per the equation $\frac{1}{\lambda} = RZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$.

   R : Rydberg's constant *R* is not a universal constant and is dependent on the mass of nuclei as well.

Sol. Answer (1)

6. A : If the accelerating potential in an X-ray machine is decreased, the minimum value of the wavelength of the emitted X-rays gets increased.

   R : The minimum value of the wavelength of the emitted X-rays is inversely proportional to the accelerating potential.

Sol. Answer (1)

7. A : According to Bohr’s atomic model the ratio of angular momenta of an electron in first excited state and in ground state is 2 : 1.

   R : In a Bohr’s atom the angular momentum of the electron is directly proportional to the principal quantum number.

Sol. Answer (1)

8. A : If a beam of photons of energy 10.0 eV each, is incident on a sample of hydrogen gas containing all atoms in the ground state, then the beam of the photons is completely transmitted through the gas without absorption.

   R : The minimum energy required by an electron to make a transition to an excited state is 10.2 eV.

Sol. Answer (1)

9. A : The nature of the characteristic X-rays does not depend on accelerating potential.

   R : X-rays are electromagnetic radiation.

Sol. Answer (2)

The nature of the characteristic X-rays does not depend on characteristic accelerates potential but on the material. Both statements are true, independent facts.

10. A : If vacuum is not created inside an X-ray tube, X-rays will not be produced.

    R : Without vacuum inside the X-ray tube the electrons are not emitted by the filament.

Sol. Answer (3)

If vacuum is created inside the tube the emitted electrons will not hit the molecules of air to produce X-rays.

11. A : Gases are insulators at ordinary pressure but they start conducting at very low pressure.

    R : At low pressures, ions have a chance to reach their respective electrodes and constitute a current but at ordinary pressures, ions undergo collision with gas molecules and recombination.

Sol. Answer (1)

12. A : The oil-drops of Millikan's experiment should be of microscopic size.

    R : For larger drops the electric fields needed in the experiment will be impractically high.

Sol. Answer (1)

13. A : Stoke's formula for viscous drag is not really valid for oil-drops of extremely minute sizes.

    R : Stoke's formula is valid for motion through a homogeneous continuous medium and the size of the drop should be much larger than the intermolecular separation in the medium for this assumption to be valid.

Sol. Answer (1)

❑ ❑ ❑

Chapter 13

Nuclei

Solutions

SECTION - A

Objective Type Questions

1. The nuclear radius as compared to the atomic radius is of the order

(1) 10^{-3} (2) 10^{-5} (3) 10^{-7} (4) 10^{-9}

Sol. Answer (2)

Fact.

2. Two nuclei which are not identical but have the same number of nucleons represent

(1) Isotones (2) Isobars (3) Isotopes (4) Isotones

Sol. Answer (2)

Definition based. Fact.

3. In a nuclear fusion reaction, if the energy is released then

(1) $BE_{products} = BE_{reactants}$ (2) $BE_{reactants} > BE_{products}$

(3) $BE_{products} > BE_{reactants}$ (4) Mass of product > Mass of reactant

Sol. Answer (3)

Product is more stable than reactant and hence has more binding energy.

4. The binding energy per nucleon for a ${}_6C^{12}$ nucleus is

(Nuclear mass of ${}_6C^{12}$ = 12.00000 a.m.u.

Mass of hydrogen nucleus = 1.007825 a.m.u

Mass of neutron = 1.008665 a.m.u)

(1) 2.675 MeV (2) 7.675 MeV (3) 0 MeV (4) 3.675 MeV

Sol. Answer (2)

$\Delta m = 6m_P + (12 - 6)m_n - m_N$

m_P = mass of proton, m_n = mass of neutron, m_N = mass of nucleus.

or $\Delta m = 6 \times 1.007825 + 6(1.008665) - 12$

5. Which of the following pairs of particles cannot exert nuclear force on each other?

(1) Proton and electron (2) Neutron and electron (3) Electron and neutron (4) All of these

Sol. Answer (4)

Answer is all of these as electrons are not affected by nuclear forces at all.

6. When two nuclei of mass X and Y respectively fuse to form a nucleus of mass m alongwith the liberation of some energy, then

(1) $X + Y > m$ (2) $X - Y = m$ (3) $X + Y = m$ (4) $X + Y < m$

Sol. Answer (1)

Mass reduces and is converted into energy in fusion reactions.

7. The nuclear force between two nucleons is explained by

(1) Quark exchange theory (2) Meson exchange theory

(3) Photon exchange theory (4) Gravitation exchange theory

Sol. Answer (2)

Fact.

8. If F_{pp} , F_{pn} and F_{nn} are the magnitudes of nuclear force between proton-proton, proton-neutron and neutron-neutron respectively, then

(1) $F_{pp} = F_{pn} = F_{nn}$ (2) $F_{pp} < F_{pn} = F_{nn}$ (3) $F_{pp} > F_{pn} > F_{nn}$ (4) $F_{pp} < F_{pn} < F_{nn}$

Sol. Answer (1)

Nuclear force between all nucleons is the same.

9. The atomic mass of $_7N^{15}$ is 15.000108 a.m.u. and that of $_8O^{16}$ is 15.994915 a.m.u. If the mass of a proton is 1.007825 a.m.u. then the minimum energy provided to remove the least tightly bound proton is

(1) 0.013018 MeV (2) 12.13 MeV (3) 13.018 MeV (4) 12.13 eV

Sol. Answer (2)

Energy + $_8O^{16} \longrightarrow {}_7N^{15} + {}_1H^1$

Energy = $[(M_N + M_H) - M_0]\, c^2 = [(15.000108+1.007825) - 15.994915] \times 931.5$ MeV

10. Nuclear energy is released in fusion reaction, since binding energy per nucleon is

(1) Smaller of fusion products than for fusing nuclei (2) Same for fusion products as for fusing nuclei

(3) Larger for fusion products than for fusing nuclei (4) Sometimes larger and sometimes smaller

Sol. Answer (3)

Since binding energy is larger for products than reactants.

11. A nucleus X undergoes following transformation $\begin{matrix} X \xrightarrow{\alpha} Y \\ Y \xrightarrow[2\beta]{} Z \end{matrix}$ then

(1) X and Y are isotopes (2) X and Z are isobars (3) X and Y are isobars (4) X and Z are isotopes

Sol. Answer (4)

$x \xrightarrow{\alpha} y$

$\therefore \quad y = x_{z-2}^{m-4}$

$y \xrightarrow{2\beta} z$

$\therefore \quad z = x_{z-2+2}^{m-4}$

Hence, x and z are isotopes.

12. Consider the nuclear reaction $X^{200} \rightarrow A^{110} + B^{90}$

If the binding energy per nucleon for X, A and B is 7.4 MeV, 8.2 MeV and 8.2 MeV respectively, then the amount of the energy released is

(1) 200 MeV (2) 160 MeV (3) 110 MeV (4) 90 MeV

Sol. Answer (2)

Initial BE = 7.4 × 200 MeV

Final BE = 8.2 × 110 + 8.2 × 90 MeV

$\therefore$ Energy release = Final – Initial

= (8.2 – 7.4) × 200 = 0.8 × 200

= 160 MeV

13. The nuclei ${}_6A^{13}$ and ${}_7B^{14}$ can be described as

(1) Isotones (2) Isobars (3) Isotopes of carbon (4) Isotopes of nitrogen

Sol. Answer (1)

Number of neutrons in A = 13 – 6 = 7

Number of neutrons in B = 14 – 7 = 7

Hence, A and B are isotones.

14. Ratio of nuclear radii of ${}^{135}Cs$ to ${}^{40}Ca$ is

(1) 1.40 (2) 1.50 (3) 2.750 (4) 3.375

Sol. Answer (2)

$r \propto A^{1/3}$

$$\frac{r_{Cs}}{r_{Ca}} = \left(\frac{135}{40}\right)^{1/3}$$

$$\frac{r_{Cs}}{r_{Ca}} = \left(\frac{27}{8}\right)^{1/3}$$

$$\frac{r_{Cs}}{r_{Ca}} = \frac{3}{2}$$

15. A nucleus with Z = 92 emits the following in a sequence $\alpha, \beta^-, \beta^-, \alpha, \alpha, \alpha, \alpha, \alpha, \beta^-, \beta^-, \beta^+, \alpha, \beta^+, \alpha$. The Z of the resulting nucleus is

(1) 74 (2) 76 (3) 78 (4) 82

Sol. Answer (3)

Z = 92

If it goes through 8 alpha decays and two β^+ decays

Hence, net decrease = 8 × 2 + 2 × 1

= 18 protons

Net increase is due to β^- decays = 4 × 1

Hence, final Z = 92 – 18 + 4 = 78

16. In nuclear reactions we have the conservation of

(1) Mass only (2) Energy only

(3) Momentum only (4) Charge, total energy and momentum

Sol. Answer (4)

Fact.

17. A heavy nucleus is unstable for any value of $\frac{N}{P}$ because

(1) Electrostatic repulsion dominate over nuclear attraction

(2) Nuclear repulsion dominate over nuclear attraction

(3) Nuclear forces are absent in heavy nucleus

(4) Nuclear force is long range force

Sol. Answer (1)

In heavy nuclei repulsion between the lots of protons in the nucleus makes the nucleus unstable.

18. When ${}_{90}Th^{228}$ gets converted into ${}_{83}Bi^{212}$, then the number of α- and β-particles emitted will respectively be

(1) $4\alpha, 7\beta$ (2) $4\alpha, 1\beta$ (3) $8\alpha, 7\beta$ (4) $4\beta, 4\alpha$

Sol. Answer (2)

Initial nucleus = ${}_{90}Th^{228}$

Mass reduces by = 228 – 212

= 16 nucleons

Hence, alpha particles released are = $\frac{16}{4}$ = 4 particles

This results in atomic number reduction by 2 × 4 = 8

Now nucleus after alpha decays = x_{82}^{212}

After 1β decay Z increases by 1

$\therefore$ Number of decays = 83 – 82 = 1

Hence answer is 4 α and 1 β decays.

19. In the radioactive decay of an element it is found that the count rate reduces from 1024 to 128 in 3 minutes. Its half life will be

(1) 1 minute (2) 2 minute (3) 3 minute (4) 5 minute

Sol. Answer (1)

$$\frac{R}{R_0} = \frac{128}{1024}$$

$$\frac{R}{R_0} = \frac{1}{8}$$

or $\frac{R}{R_0} = \left(\frac{1}{2}\right)^3$

$\therefore$ $n = 3$

3 half lives in 3 minutes, 1 half life in 1 minute

20. If a radioactive material remains 25% after 16 days, then its half life will be

(1) 32 days (2) 8 days (3) 64 days (4) 28 days

Sol. Answer (2)

$$\frac{N}{N_0} = \left(\frac{N}{4 \times N}\right)$$

$$\frac{N}{N_0} = \left(\frac{1}{2}\right)^2$$

or $n = 2$

2 half lives in 16 days

∴ 1 half life is in 8 days

21. The count rate of a radioactive source at $t = 0$ was 1600 count/s and at $t = 8$ s, it was 100 count/s. The count rate (in counts) at $t = 6$ s was

(1) 150 (2) 200 (3) 300 (4) 400

Sol. Answer (2)

$$\frac{R}{R_0} = \left(\frac{1}{2}\right)^n$$

$$\frac{1}{16} = \left(\frac{1}{2}\right)^n$$

∴ $n = 4$

∴ $T_{1/2} = 2$ s

at $t = 6$ s, $\frac{R}{R_0} = \left(\frac{1}{2}\right)^3 \Rightarrow R = \frac{R_0}{8} = \frac{1600}{8} = 200$

22. The radioactivity of a sample is R_1 at a time T_1 and R_2 at a time T_2. If the half life of the specimen is T, the number of atoms that have disintegrated in the time $(T_2 - T_1)$ is proportional to

(1) $(R_1 T_1 - R_2 T_2)$ (2) $(R_1 - R_2)$ (3) $(R_1 - R_2)/T$ (4) $(R_1 - R_2)T$

Sol. Answer (4)

$R_1 = \lambda N_1$ $R_2 = \lambda N_2$

$$\Delta N = N_1 - N_2 = \frac{R_1 - R_2}{\lambda}$$

$$\Delta N = \frac{(R_1 - R_2)T}{0.693}$$ $(\lambda = 0.693)$

23. A radioactive sample at any instant has its disintegration rate 5000 disintegrations per minute. After 5 minute, the rate is 1250 disintegrations per minute. The decay constant (per minute) is

(1) 0.8 ln 2 (2) 0.4 ln 2 (3) 0.2 ln 2 (4) 0.1 ln 2

Sol. Answer (2)

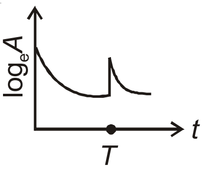
$$\frac{R}{R_0} = \left(\frac{1}{2}\right)^n$$

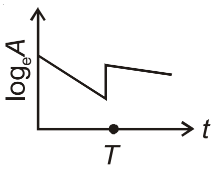
$$\frac{1250}{5000} = \left(\frac{1}{2}\right)^n$$

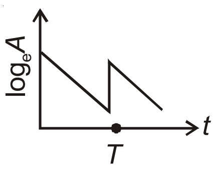
$$\frac{1}{4} = \left(\frac{1}{2}\right)^n$$

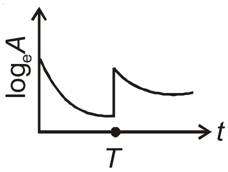
∴ $n = 2$ ∴ $T_{1/2} = \frac{5}{2} = 2.5$ minute

24. At time $t = 0$ some radioactive gas is injected into a sealed vessel. At time T some more of the gas is injected into the vessel. Which one of the following graphs best represents the logarithm of the activity A of the gas with time t?

(1) 

(2) 

(3) 

(4) 

Sol. Answer (3)

$A = A_0 e^{-\lambda t}$

$\ln A = \ln A_0 - \lambda t$

$\therefore$ Answer is (3) as it is a linear relation between ln A and t.

25. ^{40}K isotope of potassium has a half life of 1.37×10^9 years and decays to an isotope of argon which is stable. In a particular sample of moon rock, the ratio of potassium atoms to argon atoms was found to be 1 : 7. The age of the rock, assuming that originally there was no argon present, is

(1) 4.11×10^9 year (2) 2.74×10^9 year (3) 5.48×10^9 year (4) 1.37×10^9 year

Sol. Answer (1)

$T_{1/2} = 1.37 \times 10^9$ year

Ratio – Potassium : Argon = 1 : 7

Amount of Potassium left = $\frac{1}{8}$

$$\left(\frac{1}{2}\right)^n = \frac{1}{8}$$

$\therefore$ n or number of half lives = 3

26. Two radioactive isotopes P and Q have half lives 10 minutes and 15 minutes respectively. Freshly prepared samples of each isotope initially contain the same number of atoms. After 30 minutes, the ratio $\frac{\text{number of atoms of } P}{\text{number of atoms of } Q}$ will be

(1) 0.5 (2) 2.0 (3) 1.0 (4) 3.0

Sol. Answer (1)

$T_P = 10$ minute $T_Q = 15$ minute

After 30 minute P has gone 3 half lives and Q = 2 half lives

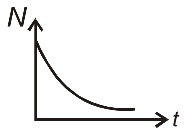
$$N_P = N_0\left(\frac{1}{2}\right)^3 \qquad N_Q = N_0\left(\frac{1}{2}\right)^2$$

$N_P : N_Q = 1 : 2$

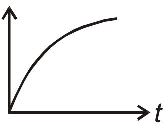
or $\frac{N_P}{N_Q} = 0.5$

27. In a radioactive decay let N be the number of residual active nuclei, D the number of daughter nuclei, R the rate of decay and M the mass of active sample at any time t. Below are shown four curves.

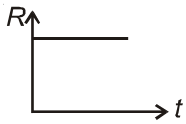
(i)



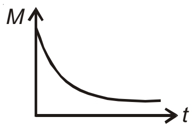
(ii)



(iii)



(iv)



The correct ones are

(1) (i), (ii) and (iv) (2) (ii), (iii) and (iv) (3) (iii), (iv) and (i) (4) All of these

Sol. Answer (1)

Daughter nuclei increase exponentially Mass of active sample and number of active nuclei decreases exponentially.

Rate decreases exponentially but since it is not shown as such (iii) is wrong.

28. A freshly-prepared radioactive source of half-life 2 h emits radiation of intensity which is 64 times the permissible safe level. The minimum time after which it would be possible to work safely with this source is

(1) 6 h (2) 12 h (3) 24 h (4) 128 h

Sol. Answer (2)

$T_{1/2}$ = 2 hours

To work safely the number of reacting molecules must decrease by 64 times.

$$N = N_0\left(\frac{1}{2}\right)^n$$

$$\frac{N}{N_0} = \left(\frac{1}{2}\right)^n$$

$$\frac{1}{64} = \left(\frac{1}{2}\right)^n$$

$n = 8$

$\therefore$ Time it will take to $T_{1/2} \times 8$ or 16 hours

29. γ-decay occurs when

(1) Pair annihilation takes place

(2) Energy is released due to conversion of neutron into proton

(3) Energy is released due to de-excitation of nucleus

(4) None of these

Sol. Answer (3)

Fact.

30. The sample of a radioactive substance has 10^6 nuclei. Its half life is 20 s. The number of nuclei that will be left after 10 s is nearly

(1) 1×10^5 (2) 2×10^5 (3) 7×10^5 (4) 11×10^5

Sol. Answer (3)

$$N = N_0\left(\frac{1}{2}\right)^n$$

$$n = \frac{1}{2}$$

$$N = 10^6\left(\frac{1}{\sqrt{2}}\right)$$

$N \approx 0.732 \times 10^6$

$N \approx 7 \times 10^5$

31. Half life of radioactive element depends upon

(1) Amount of element present (2) Temperature

(3) Pressure (4) The nature of the element

Sol. Answer (4)

Fact.

32. Neutrino is a particle which

(1) Has no charge and no spin

(2) Has no charge but has spin

(3) Is charged like an electron and has spin

(4) Has no charge but has mass nearly equal to that of a proton

Sol. Answer (2)

Fact.

33. Heavy water instead of ordinary water is used as a moderator in nuclear reactor because ordinary water

(1) Cannot slow down neutron (2) Absorbs neutrons

(3) Is expensive (4) Accelerates neutron

Sol. Answer (2)

Fact.

34. Out of the following, which one is not emitted by a natural radioactive substance?

(1) Electrons

(2) Electromagnetic radiations

(3) Helium nuclei with charge equal to that of two protons

(4) Neutrons

Sol. Answer (4)

Fact.

35. In each fission of ${}_{92}U^{235}$ energy of 200 MeV is released. How many acts of fission must occur per second to produce a power of 1kW?

(1) 3.1×10^{13} (2) 1.3×10^{16} (3) 1.3×10^{15} (4) 3.1×10^{16}

Sol. Answer (1)

Each fission 200 MeV is released

or energy released = $200 \times 10^6 \times 1.6 \times 10^{-19}$ J

Power needed = 1000 W

$$\therefore \text{ Number of fission } = \frac{1000}{200 \times 10^6 \times 1.6 \times 10^{-19}}$$

$$= 3.1 \times 10^{13}$$

36. If 1 g hydrogen is converted into 0.993 gm of helium in a thermonuclear reaction, the energy released in the reaction is

(1) 63×10^7 J (2) 63×10^{10} J (3) 63×10^{14} J (4) 63×10^{20} J

Sol. Answer (2)

1 g hydrogen converted to 0.993 g helium.

$\Delta m = 0.007$g

$\Delta m = 7 \times 10^{-6}$ g

$E = \Delta m C^2$

$E = 7 \times 10^{-6} \times 9 \times 10^{16} = 63 \times 10^{10}$

37. Thermal neutrons are those whose energy is about

(1) 1 J (2) 0.03 eV (3) 1 MeV (4) 0.03 MeV

Sol. Answer (2)

Fact.

38. A neutron strikes a ${}_{92}U^{235}$ nucleus and as a result ${}_{36}Kr^{93}$ and ${}_{56}Ba^{140}$ are produced with

(1) α-particle (2) 1-neutron (3) 3-neutron (4) 2-β-particle

Sol. Answer (3)

In the reaction sum of atomic number remains the same but mass reduces by 3.

Hence 3 neutrons were produced.

39. Control rods used in nuclear reactors are made of

(1) Stainless steel (2) Graphite (3) Cadmium (4) Plutonium

Sol. Answer (3)

Fact.

40. In the equation

$${}^{27}_{13}\text{Al} + {}^{4}_{2}\text{He} \longrightarrow {}^{30}_{15}\text{P} + \text{X},$$

The correct symbol for X is

(1) ${}^{0}_{-1}e$ (2) ${}^{1}_{1}\text{H}$ (3) ${}^{4}_{2}\text{He}$ (4) ${}^{1}_{0}\text{n}$

Sol. Answer (4)

Conserving mass and charge, net mass reduces by 1 by charge does not change. Hence, a neutron must have been released.

SECTION - B

Objective Type Questions

1. A certain stable nucleide, after absorbing a neutron, emits β-particle and the new nucleide splits spontaneously into two α-particles. The nucleide is

(1) $^{4}_{2}\text{He}$ (2) $^{7}_{3}\text{Li}$ (3) $^{6}_{4}\text{Be}$ (4) $^{6}_{3}\text{Li}$

Sol. Answer (2)

After absorbing neutron it undergoes β decay. Also it decays into 2 alpha particles

Hence, net charge after β decay must have been 4

Before β decay it must have been 3

Since it was stable initially, it must be a common nucleus of Z = 3 which is $^{7}_{3}\text{Li}$

2. After 3 hours, only 0.25 mg of a pure radioactive material is left. If initial mass was 2 mg then the half life of the substance is

(1) 1.5 hr (2) 1 hr (3) 0.5 hr (4) 2 hr

Sol. Answer (2)

Initial mass = 2 mg

Final mass = 0.25 mg

$$\therefore \quad \frac{N}{N_0} = \left(\frac{1}{2}\right)^n$$

$$\frac{0.25}{2} = \left(\frac{1}{2}\right)^n$$

$$\frac{1}{8} = \left(\frac{1}{2}\right)^n$$

∴ n = 3 and time is 3 hours

Half life is therefore 1 hour

3. Pauli suggested the emission of nutrino during β^+ decay to explain

(1) Continuous energy distribution of positrons (2) Conservation of linear momentum

(3) Conservation of mass-energy (4) All of these

Sol. Answer (1)

Fact.

4. If a heavy nucleus has N/Z ratio higher than that required for stability, then

(1) It emits β^- (2) It emits β^+

(3) It emits α particle (4) It will undergo K electron capture

Sol. Answer (1)

If $\frac{N}{Z}$ ratio is higher it will try to increase number of protons by β decay.

5. Half lives for α and β emission of a radioactive material are 16 years and 48 years respectively. When material decays giving α and β emission simultaneously then time in which $\frac{3}{4}$th of the material decays is

(1) 29 years (2) 24 years (3) 64 years (4) 12 years

Sol. Answer (2)

1 material is giving two products

Let initial number be = N_0

Let time when $\frac{3}{4}N_0$ decay be t

Effective half life = $\frac{T_1T_2}{T_1+T_2}$ = 12 years

$$\frac{N}{N_0}=\left(\frac{1}{2}\right)^n$$

$$\frac{1}{4}=\left(\frac{1}{2}\right)^n \qquad n = 2$$

Hence, time will be 24 years

6. Two radioactive samples A and B have half lives T_1 and T_2 ($T_1 > T_2$) respectively. At $t = 0$, the activity of B was twice the activity of A. Their activity will become equal after a time

(1) $\frac{T_1T_2}{T_1-T_2}$ (2) $\frac{T_1-T_2}{2}$ (3) $\frac{T_1+T_2}{2}$ (4) $\frac{T_1T_2}{T_1+T_2}$

Sol. Answer (1)

$2R_A = R_B$

$2\lambda_1N_1 = \lambda_2N_2$ ....(i)

Radio-activity is same after say time t

$\lambda_1N_1e^{-\lambda_1t} = \lambda_2N_2e^{-\lambda_2t}$ ....(ii)

Dividing (i) by (ii)

$$2e^{\lambda_1t} = e^{\lambda_2t}$$

$$2 = e^{(\lambda_2-\lambda_1)t}$$

Taking ln on both sides

$0.693 = (\lambda_2 - \lambda_1)t$

$$1=\left(\frac{1}{T_2}-\frac{1}{T_1}\right)t$$

$$\frac{T_2T_1}{T_1-T_2}=t$$

7. Choose the correct statement

(1) The nuclear force becomes strong if the nucleus contains too many protons compared to neutrons

(2) The nuclear force becomes strong if the nucleus contains too many neutrons compared to protons

(3) Nuclei with atomic number less than 82 shows a tendency to disintegrate

(4) The nuclear force becomes weak if the nucleus contains a large number of nucleons

Sol. Answer (4)

Nuclear force being a short range force becomes unstable with too many nucleons.

8. N atoms of a radioactive element emit n number of α-particles per second. Mean life of the element in seconds, is

(1) $\frac{n}{N}$ (2) $\frac{N}{n}$ (3) $0.693\frac{N}{n}$ (4) $0.693\frac{n}{N}$

Sol. Answer (2)

n is the rate of decay $n \propto N$

or $n = \lambda N$

Mean life is $\frac{1}{\lambda}$ or $\frac{N}{n}$

9. Ten percent of a radioactive sample has decayed in 1 day. After 2 days, the decayed percentage of nuclei will be

(1) 81% (2) 19% (3) 20% (4) 100%

Sol. Answer (2)

$N_1 = N_0 - N_0e^{-\lambda t}$

Since $N_1 = \frac{N_0}{10}$

$N_0e^{-\lambda t} = \frac{9N_0}{10}$

$\therefore \quad e^{-\lambda t} = \frac{9}{10}$

Amount left $= \frac{9N_0}{10}$

$N_2 = N_0 - N_0e^{-2\lambda t}$

or $N_2 = N_0 - \frac{81}{100}N_0$

or N_2 = 19% of N_0

10. A sample of radioactive element has a mass of 10 gm at an instant $t = 0$. The approximate mass of this element in the sample after two mean lives is

(1) 2.50 gm (2) 1.35 gm (3) 6.30 gm (4) 3.70 gm

Sol. Answer (2)

$m = 10$ g at $t = 0$

$m = m_0e^{-\lambda t}$

where $t = \frac{2}{\lambda}$

$m = \frac{m_0}{e^2}$

11. During mean life of a radioactive element, the fraction that disintegrates is

(1) e (2) $\frac{e-1}{e}$ (3) $\frac{1}{e}$ (4) $\frac{e}{e-1}$

Sol. Answer (2)

In mean life $t = \frac{1}{\lambda}$

Fraction that disintegrates is $\frac{N_0 - N_0 e^{-\lambda \times \frac{1}{\lambda}}}{N_0} = \left(\frac{1-e}{e}\right)$ Or magnitude $\left(\frac{1-e}{e}\right)$

12. An element A decays by a two step process into element C

$A \rightarrow B + {}_2\text{He}^4$

$B \rightarrow C + 2e^-$

Then,

(1) A and B are isobars (2) A and C are isobars (3) A and B are isotopes (4) A and C are isotopes

Sol. Answer (4)

First A loses two protons. Then by β minus decay it gains two protons.

Hence, atomic number Z is same for A and C and they are isotopes.

13. After five half lives percentage of original radioactive atoms left is

(1) 1% (2) 0.3% (3) 3.125% (4) 0.2%

Sol. Answer (3)

$N = N_0\left(\frac{1}{2}\right)^n$ where $n = 5$

$\therefore \quad N = \frac{N_0}{32}$

$N = 3.125\%$ of N_0

14. The radioactivity of a certain radioactive elements drops to $\frac{1}{64}$ of its initial value in 30 seconds. Its half life is

(1) 8 seconds (2) 15 seconds (3) 7.5 seconds (4) 5 seconds

Sol. Answer (4)

$$\frac{N}{N_0} = \left(\frac{1}{2}\right)^n$$

$$\frac{1}{64} = \left(\frac{1}{2}\right)^n$$

$n = 6$

Hence half life is 5 seconds

15. Find the decay rate of the substance having 4×10^{15} atoms. Half life of a radioactive substance in α-decay is 1.2×10^7 s

(1) 2.3×10^8 atom/s (2) 3.2×10^8 atom/s (3) 2.3×10^{11} atom/s (4) 3.2×10^{11} atom/s

Sol. Answer (1)

$N_0 = 4 \times 10^{15}$ atoms

$T_{1/2} = 1.2 \times 10^7 \text{ s} = \dfrac{0.693}{\lambda}$

$$\therefore \quad \lambda = \frac{0.693}{1.2 \times 10^7}$$

$$-\frac{dN}{dt} = \lambda N_0$$

$$-\frac{dN}{dt} = \frac{0.693}{1.2 \times 10^7} \times 4 \times 10^{15}$$

or $\dfrac{dN}{dt} = 2.3 \times 10^8$ atom/s

16. The average binding energy per nucleon in the nucleus of atom is approximately

(1) 8 J (2) 8 KeV (3) 8 eV (4) 8 MeV

Sol. Answer (4)

Fact.

17. For the nuclear fusion reaction ${}_1^2\text{H} + {}_1^3\text{H} \rightarrow {}_2^4\text{He} + {}_0^1\text{n}$ temperature to which gases must be heated is 3.7×10^9 K. Potential energy between two nuclei is closest to (Boltzmann's constant $k = 1.38 \times 10^{-23}$ J/K)

(1) -10^{-10} J (2) -10^{-12} J (3) -10^{-14} J (4) -10^{-16} J

Sol. Answer (4)

KE of nuclei = $\dfrac{3}{2}kt = 7.659 \times 10^{-14}$ (for fusion)

Potential energy between nuclei must be much less than the initiating KE so that the nuclei have enough KE for reaction to take place.

18. A nucleus ${}^{220}\text{X}$ at rest decays emitting an α-particle. If energy of daughter nucleus is 0.2 MeV, Q value of the reaction is

(1) 10.8 MeV (2) 10.9 MeV (3) 11 MeV (4) 11.1 MeV

Sol. Answer (3)

Energy of daughter nucleus = 0.2 MeV

$$0.2 \text{ MeV} = \frac{m_\alpha}{m_\alpha + m_D} Q$$

$$0.2 \text{ MeV} = \frac{4}{220} Q$$

$$\frac{0.2 \times 220}{4} MeV = Q$$

$$\frac{2 \times 55}{10} = Q$$

$Q = 11$ MeV

19. Radioactive nuclei P and Q disintegrate into R with half lives 1 month and 2 months respectively. At time t = 0, number of nuclei of each P and Q is x. Time at which rate of disintegration of P and Q are equal, number of nuclei of R is

(1) x (2) 1.25 x (3) 1.5 x (4) 1.75 x

Sol. Answer (2)

Let time be t

$$\lambda_1 \times e^{-\lambda_1 t} = \lambda_2 \times e^{-\lambda_2 t}$$

$$\lambda_1 e^{-\lambda_1 t} = \lambda_2 e^{-\lambda_2 t}$$

$$\frac{\lambda_1}{\lambda_2} = e^{(\lambda_1 - \lambda_2)t}$$

$$\text{In}\,\frac{\lambda_1}{\lambda_2} = (\lambda_1 - \lambda_2)t$$

In 1 – In 2 = $(\lambda_1 - \lambda_2)t$

0.693 = $(\lambda_1 - \lambda_2)t$

20. A radioactive element X emits six α-particles and four β-particles leading to end product ${}^{208}_{82}Pb$. X is

(1) ${}^{238}_{92}U$ (2) ${}^{230}_{90}Th$ (3) ${}^{232}_{90}Th$ (4) ${}^{239}_{92}U$

Sol. Answer (3)

Calculating Z_x = 82 + 6 × 2 – 4

= 90

A_x = 208 + 6 × 4 = 232

21. In nature, ratio of isotopes of Boron, ${}_5B^{10}$ and ${}_5B^{11}$, is (given that atomic weight of boron is 10.81)

(1) 81 : 19 (2) 21 : 44 (3) 19 : 81 (4) 44 : 21

Sol. Answer (3)

Atomic weight = 10.81

Weighted mean is hence = 10.81

$$10.81 = \frac{10 \times x + 11 \times (100 - x)}{100}$$

1081 = 10x + 1100 – 11x

x = 19

Hence, B^{10} : B^{11} = 19 : 81

22. Q-value of the decay ${}^{22}_{11}\text{Na} \to {}^{22}_{10}\text{Ne} + e^+ + \nu$ is

(1) $[m({}^{22}_{11}\text{Na}) - m({}^{22}_{10}\text{Ne})]c^2$ (2) $[m({}^{22}_{11}\text{Na}) - m({}^{22}_{10}\text{Ne}) - m_e]c^2$

(3) $[m({}^{22}_{11}\text{Na}) - m({}^{22}_{10}\text{Ne}) - 2m_e]c^2$ (4) $[m({}^{22}_{11}\text{Na}) - m({}^{22}_{10}\text{Ne}) - 3m_e]c^2$

Sol. Answer (3)

23. Which of the alternatives gives correct match of Column-I with Column-II?

	Column-I		**Column-II**
a.	Binding energy per nucleon for ^{56}Fe	(i)	5.5 M eV
b.	Energy of α-particle in Geiger Marsden experiment	(ii)	200 M eV
c.	Energy of photon of visible light	(iii)	8.75 M eV
d.	Energy released in fission of a uranium nucleus	(iv)	2 eV

(1) a(i), b(iii), c(iv), d(ii) (2) a(iii), b(i), c(ii), d(iv) (3) a(iii), b(i), c(iv), d(ii) (4) a(i), b(iv), c(ii), d(iii)

Sol. Answer (3)

Fact.

24. Correct increasing order of penetrating powers of α, β particles and γ-rays, all moving with same kinetic energy is

(1) α, β, γ

(2) β, α, γ

(3) γ, β, α

(4) All have same penetrating power as all have same kinetic energy

Sol. Answer (1)

Fact.

25. In proton-proton cycle, four hydrogen atoms combine to release energy

(1) 2.67 MeV (2) 2.67 KeV (3) 26.7 MeV (4) 26.7 KeV

Sol. Answer (3)

Fact.

In proton-proton cycle four hydrogen nuclei combine to form helium.

26. 37 Rutherford equals

(1) 1 milli bacquerel (2) 1 milli curie (3) 1 micro bacquerel (4) 1 micro curie

Sol. Answer (1)

Fact.

27. Which of these is incorrect about nuclear forces?

(1) They are independent of charge

(2) Nuclear forces are derived from quark-quark interaction

(3) Hadrons do not experience strong nuclear force

(4) Nuclear force is not a central force

Sol. Answer (3)

Fact.

SECTION - C

Previous Years Questions

1. If the nucleus $^{27}_{13}\text{Al}$ has a nuclear radius of about 3.6 fm, then $^{125}_{52}\text{Te}$ would have its radius approximately as

(1) 9.6 fm (2) 12.0 fm (3) 4.8 fm (4) 6.0 fm

Sol. Answer (4)

$R \propto A^{1/3}$

$$\frac{R_{AL}}{R_{Te}} = \frac{A_{AL}^{1/3}}{A_{Te}^{1/3}}$$

$$R_{AL} \times \frac{A_{Te}^{1/3}}{A_{Al}^{1/3}} = R_{Te}$$

$$3.6fm \times \frac{125^{1/3}}{27^{1/3}} = R_{Te}$$

$$3.6 \times \frac{5}{3} = R_{Te}$$

$R_{Te} = 6\ fm$

2. The volume occupied by an atom is greater than the volume of the nucleus by a factor of about

(1) 10^1 (2) 10^5 (3) 10^{10} (4) 10^{15}

Sol. Answer (4)

Fact.

3. Two nuclei have their mass numbers in the ratio of 1 : 3. The ratio of their nuclear densities would be

(1) 1 : 1 (2) 1 : 3 (3) 3 : 1 (4) $(3)^{1/3} : 1$

Sol. Answer (1)

Nuclear densities are always roughly same.

4. Alpha particles are

(1) Neutrally charged (2) Positron (3) Protons (4) Ionized helium atoms

Sol. Answer (4)

Fact.

5. The mass number of a nucleus is

(1) Always less than its atomic number

(2) Always more than its atomic number

(3) Sometimes equal to its atomic number

(4) Sometimes less than and sometimes more than its atomic number

Sol. Answer (3)

It is sometimes equal to its atomic number

6. The radius of germanium (Ge) nuclide is measured to be twice the radius of ${}^{9}_{4}\text{Be}$. The number of nucleons in Ge are

(1) 72 (2) 73 (3) 74 (4) 75

Sol. Answer (1)

$R \propto A^{1/3}$

$$\frac{R_{Be}}{R_{Ge}} = \frac{A_{Be}^{1/3}}{A_{Ge}^{1/3}}$$

or $\frac{1}{2} = \frac{9^{1/3}}{A_{Ge}^{1/3}}$

$A_{Ge}^{1/3} = 2 \times 9^{1/3}$

Taking cube on both sides

$A_{Ge} = 8 \times 9 = 72$ nucleons

7. A nucleus ${}^{m}_{n}X$ emits one α particle and two β-particles. The resulting nucleus is

(1) ${}^{m-4}_{n-2}Y$ (2) ${}^{m-6}_{n-4}Z$ (3) ${}^{m-6}_{n}Z$ (4) ${}^{m-4}_{n}X$

Sol. Answer (4)

Final number of nucleons = $m - 4$

Final number of protons = $n - 2 + 2 = n$

$\therefore$ Resulting nucleus $= {}^{m-4}_{n}Z$

8. What is the respective number of α and β-particles emitted in the following radioactive decay?

${}^{200}X_{90} \rightarrow {}^{168}Y_{80}$

(1) 8 and 8 (2) 8 and 6 (3) 6 and 8 (4) 6 and 6

Sol. Answer (2)

Number of alpha particles : $\frac{200-168}{4} = 8$

After alpha decay number of protons left = $90 - 8 \times 2 = 74$

Number of particles = $80 - 74 = 6$

9. A nucleus ruptures into two nuclear parts, which have their velocity ratio equal to 2 : 1. What will be the ratio of their nuclear size (nuclear radius)?

(1) $3^{1/2} : 1$ (2) $1 : 3^{1/2}$ (3) $2^{1/3} : 1$ (4) $1 : 2^{1/3}$

Sol. Answer (4)

$m_1 v_1 = m_2 v_2$ or $\frac{m_1}{m_2} = \frac{v_2}{v_1}$

or $\frac{r_1^3}{r_2^3} = \frac{1}{2}$ or $\frac{r_1}{r_2} = \frac{1}{2^{1/3}}$

10. The most penetrating radiation out of the following are

(1) β-rays (2) γ-rays (3) X-rays (4) α-rays

Sol. Answer (2)

Gamma rays are most penetrating.

11. Complete the equation for the following fission process ${}_{92}U^{235} + {}_{0}n^{1} \rightarrow {}_{38}Sr^{90} + \ldots$

(1) ${}_{57}X^{142} + 3{}_{0}n^{1}$ (2) ${}_{54}X^{145} + 3{}_{0}n^{1}$ (3) ${}_{54}X^{143} + 3{}_{0}n^{1}$ (4) ${}_{54}X^{142} + {}_{0}n^{1}$

Sol. Answer (3)

${}_{92}U^{235} + {}_{0}n^{1} \longrightarrow {}_{38}Sr^{90}$

Conerving mass :

Initial mass → 236

Final mass → $90 + m_x + Nn_0^{\,1}$

$146 = m_x + N_0^{\,1}$

Among option only (3) meets the criteria.

12. After 1α and 2β^-emissions

(1) Mass number reduces by 6 (2) Mass number reduces by 4

(3) Mass number reduces by 2 (4) Atomic number reduces by 4

Sol. Answer (2)

In alpha emission mass number reduces by 4. In β decay no subsequent reduction of mass takes place.

13. For the given reaction, the particle X is ${}_{6}C^{11} \rightarrow {}_{5}B^{11} + \beta^{+} + X$

(1) Neutron (2) Anti-neutrino (3) Neutrino (4) Proton

Sol. Answer (3)

Mass since this is a β positive decay x will be an neutrino.

14. X(n, α) ${}^{7}_{3}\text{Li}$, then X will be

(1) ${}^{10}_{5}\text{B}$ (2) ${}^{9}_{5}\text{B}$ (3) ${}^{11}_{4}\text{Be}$ (4) ${}^{4}_{2}\text{He}$

Sol. Answer (1)

$x + n_0^1 \longrightarrow {}^{7}_{3}Li + {}^{4}_{2}He$

Conserving charge $Z_x = 5$

Conserving mass = $M_x = 7 + 4 - 1 = 10$

x must be ${}^{10}_{5}B$

15. M_n and M_p represent the mass of neutron and proton respectively. An element having mass M has N-neutron and Z-protons, then the correct relation will be

(1) $M < \{N \,.\, M_n + Z \,.\, M_p\}$ (2) $M > \{N \,.\, M_n + Z \,.\, M_p\}$ (3) $M = \{N \,.\, M_m + Z \,.\, M_p\}$ (4) $M = N\{M_n + M_p\}$

Sol. Answer (1)

Mass $M = N + Z$

Due to mass defect $M < NM_n + ZM_p$

16. Which rays contain (positive) charged particle?

(1) α-rays (2) β-rays (3) γ-rays (4) X-rays

Sol. Answer (1)

Fact.

17. A deutron is bombarded on $_8O^{16}$ nucleus then α-particle is emitted. The product nucleus is

(1) $_7N^{13}$ (2) $_5B^{10}$ (3) $_4Be^9$ (4) $_7N^{14}$

Sol. Answer (4)

$$O_8^{16} + {}_1^2H \longrightarrow {}_2^4He + X_{8+1-2}^{16+2-4}$$

$$X = N_7^{14}$$

18. A nuclear reaction given by ${}_zX^A \longrightarrow {}_{z+1}Y^A + {}_{-1}e^0 + \overline{\nu}$ represents

(1) β-decay (2) γ-decay (3) Fussion (4) Fission

Sol. Answer (1)

It represents β decay as atomic number changes with a change in mass.

19. If in a nuclear fusion process the masses of the fusing nuclei be m_1 and m_2 and the mass of the resultant nucleus be m_3, then

(1) $m_3 = m_1 + m_2$ (2) $m_3 = |m_1 - m_2|$ (3) $m_3 < (m_1 + m_2)$ (4) $m_3 > (m_1 + m_2)$

Sol. Answer (3)

Due to mass defect $m_3 < (m_1 + m_2)$

20. M_p denotes the mass of a proton and M_n that of a neutron. A given nucleus, of binding energy B, contains Z protons and N neutrons. The mass $M(N, Z)$ of the nucleus is given by (c is the velocity of light)

(1) $M(N, Z) = NM_n + ZM_p - Bc^2$ (2) $M(N, Z) = NM_n + ZM_p + Bc^2$

(3) $M(N, Z) = NM_n + ZM_p - B/c^2$ (4) $M(N, Z) = NM_n + ZM_p + B/c^2$

Sol. Answer (3)

$M_p \rightarrow$ Denotes mass of proton

$M_n \rightarrow$ Neutron

Binding energy B

$M(N, Z) = NM_n + Zm_D - \dfrac{B}{C^2}$ as $\dfrac{B}{C^2}$ is the mass defect

21. The mass of proton is 1.0073 u and that of neutron is 1.0087 u (u = atomic mass unit). The binding energy of ${}_2^4He$ is (Given helium nucleus mass = 4.0015 u)

(1) 0.0305 J (2) 0.0305 erg (3) 28.4 MeV (4) 0.061 n

Sol. Answer (3)

Mass of He $\rightarrow$ 4.0015

Mass defect = 2 × 1.0073 + 2 × 1.0087 – 4.0015

= 2.0146 + 2.0174 – 4.0015 = 232

= 0.0305 amu

Binding energy = 0.0305 × 931.5 MeV

= 28.4 MeV

22. A nucleus represented by the symbol ${}_Z^AX$ has

(1) Z neutrons and $(A - Z)$ protons (2) Z protons and $(A - Z)$ neutrons

(3) Z protons and A neutrons (4) A protons and $(Z - A)$ neutrons

Sol. Answer (2)

Number of neutrons = $(A - Z)$

Atomic number = Z = Number of protons

23. In the reaction ${}^{2}_{1}H + {}^{3}_{1}H \rightarrow {}^{4}_{2}He + {}^{1}_{0}n$, if the binding energies of ${}^{2}_{1}H$, ${}^{3}_{1}H$ and ${}^{4}_{2}He$ are respectively *a, b* and *c* (in MeV), then the energy (in MeV) released in this reaction is

(1) $a + b + c$ (2) $a + b - c$ (3) $c - a - b$ (4) $c + a - b$

Sol. Answer (3)

Binding energy of reactants = Binding energy of product + Energy released

24. The nuclei of which one of the following pairs of nuclei are isotones?

(1) $_{34}Se^{74}$, $_{31}Ga^{71}$ (2) $_{38}Sr^{84}$, $_{38}Sr^{86}$ (3) $_{42}Mo^{92}$, $_{40}Zr^{92}$ (4) $_{20}Ca^{40}$, $_{16}S^{32}$

Sol. Answer (1)

Isotones have same nuclei numbers but different atomic number.

25. A nucleus ${}^{A}_{Z}X$ has mass represented by M (A, Z). If M_p and M_n denote the mass of proton and neutron respectively and B.E. is the binding energy, then

(1) B.E. = $[ZM_p + (A - Z)M_n - M(A, Z)]c^2$ (2) B.E. = $[ZM_p + AM_n - M(A, Z)]c^2$

(3) B.E. = $M(A, Z) - ZM_p - (A - Z)M_n$ (4) B.E. = $[M(A, Z) - ZM_p - (A - Z)M_n]c^2$

Sol. Answer (1)

Binding energy = Mass defect $(\Delta m)C^2$

Δm = Mass of individual protons + Mass of individual neutrons – Mass of nucleus

26. In a radioactive decay process, the negatively charged emitted β-particles are

(1) The electrons produced as a result of the decay of neutrons inside the nucleus

(2) The electrons produced as a result of collisions between atoms

(3) The electrons orbiting around the nucleus

(4) The electrons present inside the nucleus

Sol. Answer (1)

By definition.

27. The number of beta particles emitted by a radioactive substance is twice the number of alpha particles emitted by it. The resulting daughter is an

(1) Isotope of parent (2) Isobar of parent (3) Isomer of parent (4) Isotone of parent

Sol. Answer (1)

Atomic number of initial and final nuclei will be same.

28. In the nuclear decay given below

$${}^{A}_{Z}X \rightarrow {}_{Z+1}^{A}Y \rightarrow {}^{A-4}_{Z-1}B^{*} \rightarrow {}^{A-4}_{Z-1}B$$

The particles emitted in the sequence are

(1) α, β, γ (2) β, α, γ (3) γ, β, α (4) β, γ, α

Sol. Answer (2)

First β particle reduces atomic nucleus without changing mass.

Then alpha decay occurs but β is in an excited state.

β gets to lower energy state by emitting a photon.

29. How many elementary particles are emitted when ${}^{14}_{6}\mathrm{C}$ transforms to ${}^{14}_{7}\mathrm{N}$?

(1) One (2) Two (3) Three (4) Four

Sol. Answer (2)

${}^{14}_{6}C$ can be converted to nitrogen by a single β decay in which an electron and a neutrino get emitted.

30. *Q* value of a nuclear reaction is positive. The reaction is

(1) Exothermic (2) Endothermic

(3) Elastic (4) Both exothermic and endothermic

Sol. Answer (1)

Fact.

31. Choose the correct product of nuclear reaction, ${}_{7}\mathrm{N}^{14} + {}_{0}\mathrm{n}^{1} \longrightarrow {}_{6}\mathrm{C}^{14} + ...$

(1) Proton (2) Neutron (3) Deutron (4) Electron

Sol. Answer (1)

Conserving mass and charge in the reactants and products, answer will be proton.

32. A mixture consists of two radioactive materials A_1 and A_2 with half lives of 20 s and 10 s respectively. Initially the mixture has 40 g of A_1 and 160 g of A_2. The amount of the two in the mixture will become equal after

(1) 20 s (2) 40 s (3) 60 s (4) 80 s

Sol. Answer (2)

$m_{2f} = m_2\left(\frac{1}{2}\right)^{n_2}$ $m_{1f} = m_1\left(\frac{1}{2}\right)^{n_1}$

$m_{2f} = m_{1f}$ and $n_2 = 2n_1$

$$m_2\left(\frac{1}{2}\right)^{n_2} = m_1\left(\frac{1}{2}\right)^{n_1}$$

$$m_2\left(\frac{1}{2}\right)^{2n_1} = m_1\left(\frac{1}{2}\right)^{n_1}$$

$$m_2 2^{-n_1} = m_1$$

$$\frac{160}{2^{n_1}} = 40$$

Hence, they will become equal after = 2 × 20 = 40 s

33. The half life of a radioactive nucleus is 50 days. The time interval ($t_2 - t_1$) between the time t_2 when $\frac{2}{3}$ of it has decayed and the time t_1 when $\frac{1}{3}$ of it had decayed as

(1) 30 days (2) 50 days (3) 60 days (4) 15 days

Sol. Answer (2)

$$\frac{2N_0}{3} = N_0 e^{-\lambda t_1}$$

at t_2 $$\frac{N_0}{3} = N_0 e^{-\lambda t_2}$$

$$2 = e^{\lambda(t_2 - t_1)}$$

$$\lambda(t_2 - t_1) = \ln 2$$

$$t_2 - t_1 = \frac{\ln 2}{\lambda} = T_{1/2} = 50 \text{ days}$$

34. The power obtained in a reactor using U^{235} disintegration is 1000 kW. The mass decay of U^{235} per hour is

(1) 1 microgram (2) 10 microgram (3) 20 microgram (4) 40 microgram

Sol. Answer (4)

Power obtained = 1000 kW

By the formula $E = \Delta mc^2$

$$1000 \times 10^3 = \Delta m \times (3 \times 10^8)^2$$

$$\frac{10^6}{9 \times 10^{16}} = \Delta m \text{ per second}$$

$$\Delta m \text{ per hour} = \frac{10^6 \times 60 \times 60}{9 \times 10^{16}} = \frac{36}{9} \times 10^{-8} = 4 \times 10^{-8}$$

or 40 μg

35. The half life of a radioactive isotope X is 50 years. It decays to another element Y which is stable. The two elements X and Y were found to be in the ratio of 1 : 15 in a sample of a given rock. The age of the rock was estimated to be

(1) 100 years (2) 150 years (3) 200 years (4) 250 years

Sol. Answer (3)

T_x = 50 years

Amount of x left = $\frac{1}{16}$

$$\frac{x_0}{16} = x_0 \left(\frac{1}{2}\right)^n$$

$n = 4$

Hence, age of the rock is 200 years

36. Fusion reaction takes place at high temperature because

(1) Molecules break up at high temperature

(2) Nuclei break up at high temperature

(3) Atoms get ionised at high temperature

(4) Kinetic energy is high enough to overcome the coulomb repulsion between nuclei

Sol. Answer (4)

Fact.

37. Two radioactive nuclei P and Q in a given sample decay into a stable nucleus R. At time $t = 0$, number of P species are $4N_0$ and that of Q are N_0. Half-life of P (for conversion to R) is 1 minute whereas that of Q is 2 minutes. Initially there are no nuclei of R present in the sample. When number of nuclei of P and Q are equal the number of nuclei of R present in the sample would be :

(1) $\frac{5N_0}{2}$ (2) $2N_0$ (3) $3N_0$ (4) $\frac{9N_0}{2}$

Sol. Answer (4)

Number of nuclei of $P = 4N_0$

Number of nuclei of $Q = N_0$

$4N_0e^{-2\lambda t} = N_0e^{-\lambda t}$

$4 = e^{\lambda t}$

$$2\ln 2 = \frac{\ln 2}{2}\cdot t$$

$t = 4$ minutes

$$P = \left(4N_0 - \frac{N_0}{4}\right) + \left(N_0 - \frac{N_0}{4}\right) = \frac{9N_0}{2}$$

38. When two nuclei (with $A = 8$) join to form a heavier nucleus, the binding energy (B.E.) per nucleon of the heavier nuclei is

(1) More than the B.E. per nucleon of the lighter nuclei

(2) Same as the B.E. per nucleon of the lighter nuclei

(3) Less than the B.E. per nucleon of the lighter nuclei

(4) Double the B.E. per nucleon of the lighter nuclei

Sol. Answer (1)

The daughter nucleus is more stable hence binding energy per nucleon will be higher

39. When helium nuclei bombard beryllium nuclei, then

(1) Electrons are emitted (2) Protons are emitted

(3) Neutrons are emitted (4) Protons and neutrons are emitted

Sol. Answer (3)

Fact.

40. The binding energies per nucleon for a deuteron and an α-particle are x_1 and x_2 respectively. The energy Q released in the reaction ${}^2H_1 + {}^2H_1 \rightarrow {}^4He_2 + Q$, is

(1) $4(x_1 + x_2)$ (2) $4(x_2 - x_1)$ (3) $2(x_2 - x_1)$ (4) $2(x_1 + x_2)$

Sol. Answer (2)

Final Binding energy – Initial binding energy

$= 4 \times x_2 - 4 \times x_1$

$= 4(x_2 - x_1)$

41. The count rate of a Geiger Muller counter for the radiation of the a radioactive material of half-life of 30 minutes decreases to 5 second^{-1} after 2 hours. The initial count rate was

(1) 80 second^{-1} (2) 625 second^{-1} (3) 20 second^{-1} (4) 25 second^{-1}

Sol. Answer (1)

$T_{1/2}$ = 30 minutes

Time = 2 hours

$$R = R_0\left(\frac{1}{2}\right)^n \qquad n = \frac{2\times 60}{30} = 4$$

$5 \times 2^4 = R_0$

R_0 = 80 second^{-1}

42. Half-lives of two radioactive substances *A* and *B* are respectively 20 minutes and 40 minutes. Initially the samples of *A* and *B* have equal number of nuclei. After 80 minutes the ratio of remaining numbers of *A* and *B* nuclei is

(1) 1 : 4 (2) 4 : 1 (3) 1 : 16 (4) 1 : 1

Sol. Answer (1)

N_0 is same

$$N_A = N_0\left(\frac{1}{2}\right)^4 \qquad N_B = N_0\left(\frac{1}{2}\right)^2$$

$N_A : N_B = 1 : 4$

43. The relation between λ and $T_{1/2}$ as ($T_{1/2}$ → half life)

(1) $T_{1/2} = \frac{\ln 2}{\lambda}$ (2) $T_{1/2}\ln 2 = \lambda$ (3) $T_{1/2} = \frac{1}{\lambda}$ (4) $(\lambda + T_{1/2}) = \ln 2$

Sol. Answer (1)

Fact.

$$T_{1/2} = \frac{\ln 2}{\lambda}$$

44. Nuclear-Fission is best explained by

(1) Liquid drop model (2) Yukawa π-meson theory

(3) Independent particle model of the nucleus (4) Proton-proton cycle

Sol. Answer (1)

Fact.

45. Half life of a radioactive element is 12.5 hour and its quantity is 256 gm. After how much time its quantity will remain 1 g?

(1) 50 hrs (2) 100 hrs (3) 150 hrs (4) 200 hrs

Sol. Answer (2)

$$\frac{N}{N_0} = \left(\frac{1}{2}\right)^n$$

$$\frac{1}{256} = \left(\frac{1}{2}\right)^n$$

$n = 8$

Hence, time = $T_{1/2} \times 8 = 12.5 \times 8 = 100$ hours

46. Energy released in nuclear fission is due to
    (1) Some mass is converted into charge
    (2) Total binding energy of fragments is more than the binding energy of parental element
    (3) Total binding energy of fragments is less than the binding energy of parental element
    (4) Total binding energy of fragments is equals to the binding energy of parental element

Sol. Answer (2)

Fact.

47. A sample of radioactive element contains 4 x 10^{16} active nuclei. Half life of element is 10 days, then number of decayed nuclei after 30 days

(1) 0.5×10^{16} (2) 2×10^{16} (3) 3.5×10^{16} (4) 1×10^{16}

Sol. Answer (3)

$\frac{N}{N_0} = \left(\frac{1}{2}\right)^3$ as $n = \frac{30}{T_{1/2}} = 3$

$N = 4 \times 10^{16} \times \frac{1}{8}$

$N = 0.5 \times 10^{16}$

48. A sample of radioactive element has a mass of 10 g at an instant $t = 0$. The approximate mass of this element in the sample after two mean lives is

(1) 1.35 g (2) 2.50 g (3) 3.70 g (4) 6.30 g

Sol. Answer (1)

$t = \frac{2}{\lambda}$

$m = m_0 e^{-\lambda t}$

$m = \frac{m_0}{e^2}$

49. The half life of radium is about 1600 years. Of 100 g of radium existing now, 25 g will remain unchanged after

(1) 4800 years (2) 6400 years (3) 2400 years (4) 3200 years

Sol. Answer (4)

$T_{1/2} = 1600$

$\frac{m}{m_0} = \left(\frac{1}{2}\right)^n$

$\frac{1}{4} = \left(\frac{1}{2}\right)^n$

$\therefore \quad n = 2$

Hence, answer is 1600 × 2 = 3200

50. In any fission process the ratio $\frac{\text{mass of fission products}}{\text{mass of parent nucleus}}$ is

(1) Equal to 1 (2) Greater than 1

(3) Less than 1 (4) Depends on the mass of the parent nucleus

Sol. Answer (3)

In fission process energy is released by converting same mass into energy

Hence, mass of fission product < mass of parent nucleus

51. Fission of nuclei is possible because the binding energy per nucleon in them

(1) Increases with mass number at low mass numbers

(2) Decreases with mass number at low mass numbers

(3) Increases with mass number at high mass numbers

(4) Decreases with mass number at high mass numbers

Sol. Answer (4)

The mpre the binding energy the more stable the nucleus. Energy is released when fission occurs by going from less stable to more stable configuration.

52. In a radioactive material the activity at time t_1 is R_1 and at a later time t_2, it is R_2. If the decay constant of the material is λ. Then

(1) $R_1 = R_2$ (2) $R_1 = R_2 e^{-\lambda(t_1-t_2)}$ (3) $R_1 = R_2 e^{\lambda(t_1-t_2)}$ (4) $R_1 = R_2(t_2/t_1)$

Sol. Answer (2)

Simply by formula of radioactive disintegration

$$R_1 = R_2 e^{-\lambda(t_1-t_2)}$$

53. The binding energy of deuteron is 2.2 MeV and that of ${}^4_2\text{He}$ is 28 MeV. If two deuterons are fused to form one ${}^4_2\text{He}$ then the energy released is

(1) 30.2 MeV (2) 25.8 MeV (3) 23.6 MeV (4) 19.2 MeV

Sol. Answer (3)

Binding energy = 2.2 MeV for ${}^2\text{H}_1$ and = 28 MeV for ${}^4_2\text{He}$

Energy released = Final BE – Initial BE

= 28 – 2 × 2.2 MeV = 23.6 MeV

54. Two radioactive substances A and B have decay-constants 5λ and λ respectively. At $t = 0$ they have the same number of nuclei. The ratio of number of nuclei of A to those of B will be $(1/e)^2$ after a time interval

(1) $\frac{4}{\lambda}$ (2) $\frac{2}{\lambda}$ (3) $\frac{1}{2\lambda}$ (4) $\frac{1}{4\lambda}$

Sol. Answer (3)

$N_A = N_0 e^{-5\lambda t}$ $N_B = N_0 e^{-\lambda t}$

$N_A : N_B = 1 : e^2$

$$\frac{N_0 e^{-5\lambda t}}{N_0 e^{-\lambda t}} = \frac{1}{e^2}$$

$$e^{\frac{1}{4\lambda t}} = \frac{1}{e^2}$$

$4\lambda t = 2$

$$t = \frac{1}{2\lambda}$$

55. The activity of a radioactive sample is measured as N_0 counts per minute at $t = 0$ and N_0/e counts per minute at $t = 5$ minutes. The time (in minutes) at which the activity reduces to half its value is

(1) $5\log_e 2$ (2) $\log_e \frac{2}{5}$ (3) $\frac{5}{\log_e 2}$ (4) $5\log_{10} 5$

Sol. Answer (1)

$R = R_0 e^{-\lambda t}$

$\frac{N_0}{e} = N_0 e^{-\lambda t}$

1 mean life has passed

$\lambda t = 1$

$t = \frac{1}{\lambda}$

$\therefore$ 5 minutes $= \frac{1}{\lambda}$

$\lambda = \frac{1}{5}$

$T_{1/2} = \ln 2$

$T_{1/2} = 5\ln 2$

56. The mass of a ${}^{7}_{3}\text{Li}$ nucleus is 0.042 u less than the sum of the masses of all its nucleons. The binding energy per nucleon of ${}^{7}_{3}\text{Li}$ nucleus is nearly

(1) 23 MeV (2) 46 MeV (3) 5.6 MeV (4) 3.9 MeV

Sol. Answer (3)

Binding energy = ΔmC^2

1 amu = 931 MeV

$\Delta mC^2 = 0.042 \times 931$ MeV

$= 39.123$

Binding energy per nucleon = 5.589

57. The decay constant of a radio isotope is λ. If A_1 and A_2 are its activities at times t_1 and t_2 respectively, the number of nuclei which have decayed during the time $(t_1 - t_2)$

(1) $A_1t_1 - A_2t_2$ (2) $A_1 - A_2$ (3) $(A_1 - A_2)/\lambda$ (4) $\lambda(A_1 - A_2)$

Sol. Answer (3)

$A = A_0 e^{-\lambda t}$

$A_1 = A_0 e^{-\lambda t_1}$ $A_2 = A_0 e^{-\lambda t_2}$

58. When ${}_{90}\text{Th}^{288}$ gets converted into ${}_{83}\text{Bi}^{272}$, then the number of α and β-particle emitted will be respectively

(1) $4\alpha, 7\beta$ (2) $4\alpha, 1\beta$ (3) $8\alpha, 7\beta$ (4) $4\alpha, 4\beta$

Sol. Answer (2)

Number of alpha particles emitted $= \frac{(288-272)}{4} = 4\alpha$ particles

Atomic number will reduce by $= 4 \times 2 = 8$

Number of β decays = 1

59. A radioactive substance has 10^8 nuclei. Its half life is 30 s. The number of nuclei left after 15 s is nearly

(1) 2×10^5 (2) 3×10^6 (3) 7×10^7 (4) 5×10^8

Sol. Answer (2)

$N = N_0 e^{-\lambda t}$

$$N = 10^8 e^{-\frac{0.693 \times t}{T}}$$

$N = 10^8 e^{-0.693/2}$

$$N = \frac{10^8}{\sqrt{2}}$$

60. A certain stable nucleide, after absorbing a neutron, emits β-particle and the new nucleide splits spontaneously into two α-particles. The nucleide is

(1) ${}^{4}_{2}\text{He}$ (2) ${}^{7}_{3}\text{Li}$ (3) ${}^{6}_{4}\text{Be}$ (4) ${}^{6}_{3}\text{Li}$

Sol. Answer (2)

Let nucleus be $_PX^A$

It adds a neutron and a proton also due to β decay

$_{P+1}X^{A+1}$

Since it splits into 2α particles

$A + 1 = 8$

$P + 1 = 4$

$\therefore\ _PX^A = {}_3\text{Li}^7$

61. Pauli suggested the emission of nutrino during β^+ decay to explain

(1) Continuous energy distribution of positrons (2) Conservation of linear momentum

(3) Conservation of mass-energy (4) All of these

Sol. Answer (1)

Fact.

62. In a nuclear reaction transforming a nucleus into another with the emission of a positron, the neutron proton ratio

(1) Decreases (2) Increases

(3) Remains same (4) May decrease or increase

Sol. Answer (2)

β^+ decays occurs when proton reduces to neutron.

Hence, $\frac{N}{P}$ ratio will increase.

63. If a heavy nucleus has N/Z ratio higher than that required for stability, then

(1) It emits β^- (2) It emits β^+

(3) It emits α particle (4) It will undergo K electron capture

Sol. Answer (1)

β^- decay will reduce its $\frac{N}{Z}$ ratio

64. The half-life of I^{131} is 8 days. Given a sample of I^{131} at time $t = 0$, we can assert that

(1) No nucleus will decay before $t = 4$ days (2) No nucleus will decay before $t = 8$ days

(3) All nuclei will decay before $t = 16$ days (4) A given nucleus may decay at $t = 0$

Sol. Answer (4)

Nuclear reactions are completely spontaneous and unpredictable.

65. Which of the following is used as a moderator in nuclear reactor?

(1) Cadmium (2) Plutonium (3) Uranium (4) Heavy water

Sol. Answer (4)

Fact.

66. Which of the following are suitable for the fusion process?

(1) Light nuclei

(2) Heavy nuclei

(3) Element must be lying in the middle of the periodic table

(4) Middle elements, which are lying on binding energy curve

Sol. Answer (1)

Fact.

67. Solar energy is mainly caused due to

(1) Burning of hydrogen in the oxygen

(2) Fission of uranium present in the Sun

(3) Fusion of protons during synthesis of heavier elements

(4) Gravitational contraction

Sol. Answer (3)

Fusion reaction in the sun is the fusion of hydrogen nuclei.

68. The binding energy per nucleon of ${}^{7}_{3}\text{Li}$ and ${}^{4}_{2}\text{He}$ nuclei are 5.60 MeV and 7.06 MeV, respectively. In the nuclear reaction ${}^{7}_{3}\text{Li} + {}^{1}_{1}\text{H} \rightarrow {}^{4}_{2}\text{He} + {}^{4}_{2}\text{He} + Q$, the value of energy Q released is

(1) 19.6 MeV (2) –2.4 MeV (3) 8.4 MeV (4) 17.3 MeV

Sol. Answer (4)

$Q = 2\,(4 \times 7.06) - (7 \times 5.60)$

$Q = 17.3$ MeV

69. A radio isotope X with a half life 1.4×10^9 years decays of Y which is stable. A sample of the rock from a cave was found to contain X and Y in the ratio 1 : 7. The age of the rock is

(1) 1.96×10^9 years (2) 3.92×10^9 years (3) 4.20×10^9 years (4) 8.40×10^9 years

Sol. Answer (3)

$X : Y = 1 : 7$ then $X = \frac{1}{8}$, $Y = \frac{7}{8}$

$\left(\frac{1}{2}\right)^n = \frac{1}{8} \Rightarrow n = 3$

$$\frac{t}{t_{1/2}} = 3 \Rightarrow t = 3 \times t_{1/2} = 3 \times 1.4 \times 10^9$$

$t = 4.2 \times 10^9$ years.

70. If radius of the ${}^{27}_{13}\text{Al}$ nucleus is taken to be R_{Al}, then the radius of ${}^{125}_{53}\text{Te}$ nucleus is nearly

(1) $\left(\frac{13}{53}\right)^{1/3} R_{\text{Al}}$ (2) $\left(\frac{53}{13}\right)^{1/3} R_{\text{Al}}$ (3) $\frac{5}{3}R_{\text{Al}}$ (4) $\frac{3}{5}R_{\text{Al}}$

Sol. Answer (3)

$$R = R_0 A^{\frac{1}{3}}$$

For, ${}^{27}_{13}\text{Al}$ $\quad R_{\text{Al}} = R_0(27)^{\frac{1}{3}} = 3R_0 \quad$ ...(i)

For, ${}^{125}_{53}\text{Te}$ $\quad R_{\text{Te}} = R_0(125)^{\frac{1}{3}} = 5R_0 \quad$ ...(ii)

$\frac{\text{(ii)}}{\text{(i)}}$,

$$\frac{R_{\text{Te}}}{R_{\text{Al}}} = \frac{5R_0}{3R_0}$$

$$R_{\text{Te}} = \frac{5}{3}R_{\text{Al}}$$

SECTION - D

Assertion-Reason Type Questions

1. A : Uncertainty principle demands that an electron confined to a nucleus must have very high energy so that the electron cannot reside in a nucleus.

R : The electrostatic attraction between electron and proton is large at such a small distance but is not enough to bind such a high-energy electron.

Sol. Answer (1)

2. A : A free proton is stable but inside a nucleus, a proton gets converted into a neutron, positron and neutrino ($p \rightarrow n + e^+ + \nu$).

R : Inside a nucleus, neutron decay ($n \rightarrow p + e^- + \bar{\nu}$) as well as proton decay are possible, since other nucleons can share energy and momentum to conserve energy as well as momentum and both the decays are in dynamic equilibrium.

Sol. Answer (1)

3. A : Exothermic reactions are possible when two light nuclei fuse or when a heavy nucleus undergoes fission into intermediate mass nuclei.

R : The nature of nuclear binding energy curve is such that it rises for lighter nuclei and slightly decreasing for heavier nuclei.

Sol. Answer (1)

4. A : For fusion, the light nuclei must have sufficient initial energy to cross the Coulomb barrier. Hence, fusion requires high temperature, however, the actual temperature required is somewhat less than expected classically.

R : It is due to quantum mechanical tunneling of the potential barrier.

Sol. Answer (1)

5. A : Only in low or medium energy nuclear reactions, the number of protons and number of neutrons are separately conserved.

R : In high energy reactions, protons and neutrons can be converted into other particles and a new quantum number, the Baryon number is however, always conserved.

Sol. Answer (2)

6. A : Nuclear density is almost same for all nuclei.

R : The radius (r) of a nucleus depends only on the mass number (A) as $r \propto A^{1/3}$.

Sol. Answer (1)

Mass = A

$v = \frac{4}{3}\pi r^3$ $\qquad r \propto A^{1/3}$

$v = \frac{4}{3}\pi KA$

Density = $\frac{A}{V} = \frac{1}{\frac{4}{3}\pi K}$ = constant

7. A : During radioactive disintegration an α-particle and a β-particle do not emit simultaneously from any nucleus.

R : An α-particle emits from a nucleus when the N/Z ratio is less than the stability range (where N = number of neutrons and Z = number of protons in a nucleus).

Sol. Answer (2)

The two common modes of radioactive decay are alpha and beta types. In both these decays the other particle is not ejected.

8. A : In β-decay an electron is emitted by the nucleus.

R : Electrons are not present inside the nucleus.

Sol. Answer (2)

9. A : A radioactive substance has half life of 1 hour. Therefore, if two nuclei of the substance are present initially, after 1 hour only one will remain undissociated.

R : When a nucleus makes a transition from excited state to ground state, it emits a β-particle.

Sol. Answer (4)

Both the statements are wrong. Nuclear reaction being spontaneous may occur at any time.

10. A : Fast moving neutrons do not cause fission of a uranium nucleus.

R : A fast moving neutron spends very little time inside the nucleus.

Sol. Answer (1)

❑ ❑ ❑

Chapter 14

Semiconductor Electronics : Materials, Devices and Simple Circuits

Solutions

SECTION - A

Objective Type Questions

1. The semiconductors are generally

(1) Monovalent (2) Divalent (3) Trivalent (4) Tetravalent

Sol. Answer (4)

Semiconductors are generally tetravalent like silicon and gallium.

2. The resistivity of a semiconductor depends upon

(1) Size of the atom (2) The nature of atoms

(3) Type of bonds (4) Size and types of motion

Sol. Answer (2)

The resistivity of a semiconductor depends mainly on the kind of atoms and the valence electrons they possess.

3. The impurity atoms with which pure silicon should be doped to make a *p*-type semiconductor are those of

(1) Phosphorus (2) Antimony (3) Boron (4) Copper

Sol. Answer (3)

The impurities needed to make holes it should be a trivalent substance, of the third group which happens to be boron.

4. In semiconductors, which of the following relations is correct at thermal equilibrium?

(1) $n_i = n_e = n_h$ (2) $n_i^2 = n_e n_h$ (3) $n_i = \frac{n_e}{n_h}$ (4) $n_i = n_e + n_h$

Sol. Answer (2)

$n_1^2 = n_e \times n_h$ Due to conservation of charge

5. A pure semiconductor has

(1) An infinite resistance at 0°C

(2) A finite resistance which does not depend upon temperature

(3) A finite resistance which increases with temperature

(4) A finite resistance which decreases with temperature

Sol. Answer (4)

A simple semiconductor has a finite resistance. An increase in temperature increases number of charge carries and increases conductivity.

6. The rate of recombination or generation are governed by the law(s) of

(1) Mass conservation (2) Electrical neutrality (3) Thermodynamics (4) Chromodynamics

Sol. Answer (3)

Carriers flow from higher to lower concentration like heat.

7. An *n*-type semiconductor is electrically

(1) Positive (2) Negative

(3) May be positive or negative (4) Neutral

Sol. Answer (4)

The presence of charge carries does not mean a semiconductors has any net charge.

8. A solid having uppermost energy band partially filled with electrons is called

(1) An insulator (2) A conductor (3) A semiconductor (4) None of these

Sol. Answer (2)

A solid which has uppermost energy band partially filled with electron is called a conductor.

9. The energy gap for an insulator may be

(1) 1.1 eV (2) 0.02 eV (3) 6 eV (4) 0.7 eV

Sol. Answer (3)

The energy gap for an insulators is very high around 6 eV.

10. In an intrinsic semiconductor, the density of conduction electrons is 7.07×10^{15} m^{-3}. When it is doped with indium, the density of holes becomes 5×10^{22} m^{-3}. Find the density of conduction electrons in doped semiconductor

(1) Zero (2) 1×10^{9} m^{-3} (3) 7×10^{15} m^{-3} (4) 5×10^{22} m^{-3}

Sol. Answer (2)

$n_e \cdot n_h = n_i^2$

and $n_e = n_h = n_i$ initially

or $n_i = 7.07 \times 10^{15}$ m^{-3}

$$n_e = \frac{(7.07 \times 10^{15})^2}{5 \times 10^{22}}$$

on $n_e \approx 1 \times 10^{9}$ m^{-3}

11. If N_A is number density of acceptor atoms added and N_D is number density of donor atoms added to a semiconductor, n_e and n_h are the number density of electrons and holes in it, then

(1) $n_e = N_D$, $n_h = N_A$ (2) $n_e = N_A$, $n_h = N_D$ (3) $n_e + N_D = n_h + N_A$ (4) $n_e + N_A = n_h + N_D$

Sol. Answer (4)

Donor atoms increase number of conduction electron and must be added to available electrons.

Similarly for holes and acceptor atoms.

The equation is formed according to the law of electrical neutrality.

12. In an unbiased p-n junction which of the following is correct?

    (1) *p*-side is at higher potential than *n*-side

    (2) *n*-side is at higher potential than *p*-side

    (3) Both p-side and n-side are at the same potential

    (4) Any of the above is possible depending upon the carrier density in the two sides

Sol. Answer (2)

In the depletion region n-side has positive ions and p-side is with negative ion. Hence n-side has longer potential.

13. In a full wave rectifier circuit operating from 50 Hz mains frequency, the fundamental frequency in the ripple would be

    (1) 25 Hz (2) 50 Hz (3) 70.7 Hz (4) 100 Hz

Sol. Answer (4)

If mains frequency is 50 Hz after full wave rectification the frequency becomes double that of mains.

So answer is 100 Hz.

14. In a semiconductor diode, the reverse biased current is due to drift of free electrons and holes caused by

    (1) Thermal excitations only (2) Impurity atoms only

    (3) Both (1) & (2) (4) Neither (1) nor (2)

Sol. Answer (1)

In case of reverse bias the reverse current is independent of reverse bias voltage but depends only on temperature of junction.

15. The value of form factor in case of half wave rectifier is

    (1) 1.11 (2) 1.57 (3) 1.27 (4) 0.48

Sol. Answer (2)

$$\text{Form factor} = \frac{\text{rms of out put voltage}}{\text{average value of out put voltage}}$$

$$\text{or}\quad \text{form factor} = \frac{v_{\text{max}}/2}{v_{\text{max}}/\pi} = \frac{\pi}{2} = 1.57$$

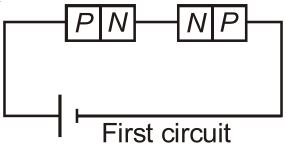
16. In a semiconductor diode, *P*-side is earthed and *N*-side is put at potential of –2 V, the diode shall

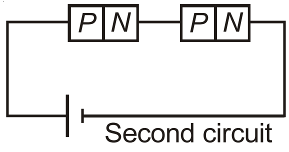
    (1) Conduct (2) Not conduct (3) Conduct partially (4) Break down

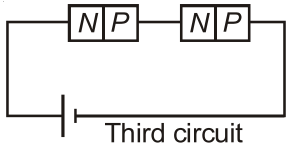
Sol. Answer (1)

P side is put at higher potential than *N* side hence the diode will conduct.

17. Two identical *p*-*n* junctions may be connected in series with a battery in three ways as shown in the adjoining figure. The potential drop across the *p*-*n* junctions are equal in







    (1) First and second circuits (2) Second and third circuits

    (3) Third and first circuits (4) All of these

Sol. Answer (2)

First is not bias second and third are bias and have same potential drop across diodes.

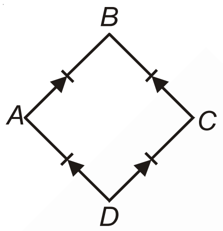
18. The zener diode is used for

(1) Rectification (2) Amplification (3) Stabilization (4) All of these

Sol. Answer (3)

Zener diode is a reverse biased transistor used for voltage stabilisation.

19. In the diagram shown below, the input is across the terminals *A* and *C* and the output is across *B* and *D*. Then the output is



(1) Zero (2) Same as input (3) Full wave rectified (4) Half wave rectified

Sol. Answer (3)

The diagram is an example of a full wave rectifying circuit.

20. A junction diode, in which one of the *p* or *n*-sections is made very thin, can be used to convert light energy into electrical energy, then the diode is called

(1) Light emitting diode (2) Zener diode (3) Solar cell (4) Photo diode

Sol. Answer (3)

A diode used to convert light energy to electrical energy is called a photo diode.

21. The material suitable for making a solar cell is

(1) PbS (2) GaAs (3) CdSe (4) Ge

Sol. Answer (2)

Ga As has a band gap close to 1.5 eV which in same as maximum intensity of solar radiation spectrum.

22. In which of the configurations of a transistor, the power gain is highest?

(1) Common base (2) Common emitter (3) Common collector (4) Same in all the three

Sol. Answer (2)

The power gain is highest in the case common emitter type transistor.

23. In a common base amplifier, the phase difference between the input signal voltage and the output voltage (across collector and base) is

(1) 0 (2) $\frac{\pi}{4}$ (3) $\frac{\pi}{2}$ (4) π

Sol. Answer (1)

24. The current gain β of a transistor is 50. The input resistance of the transistor, when used in the common emitter configuration, is 1 kΩ. The peak value of the collector a.c. current for an alternating peak input voltage 0.01V is

(1) 100 μA (2) 250 μA (3) 500 μA (4) 800 μA

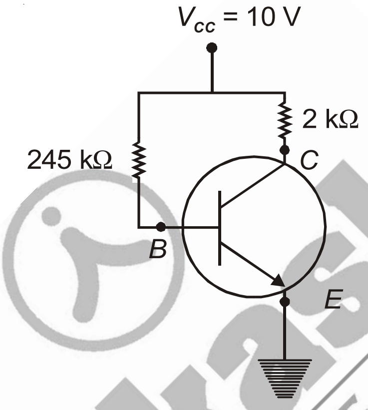
Sol. Answer (3)

$$\frac{i_c}{i_b} = 50$$

$$\frac{R_i i_c}{V_i} = 50$$

$$i_c = \frac{50 \times .01}{10^3} = 500\ \mu\text{A}$$

25. In a common emitter transistor circuit, the base current is 40 μA, then V_{BE} is

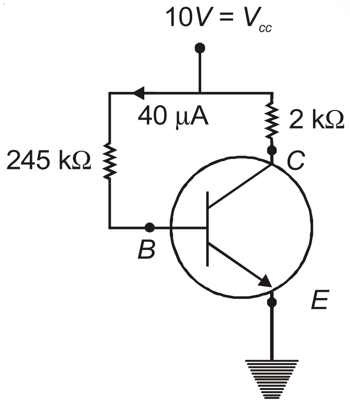


(1) 2 V (2) 0.2 V (3) 0.8 V (4) Zero

Sol. Answer (2)

Applying kirchoff

$10 - 245 \times 40 \times 10^{-3} = V_{BE}$



26. In a transistor the base is very lightly doped as compared to the emitter because by doing so

(1) The flow across the base region is mainly because of electrons

(2) The flow across the base region is mainly because of holes

(3) Recombination is decreased in the base region

(4) Base current is high

Sol. Answer (3)

Base is lightly doped because if it had more of its charge carries. It would recombine with the majority charge carrier of the transistor, reducing conductivity.

27. A transistor is operated in CE configuration at V_{cc} = 2V such that a change in base current from 100 μA to 200 μA produces a change in the collector current from 9 mA to 16.5 mA. The value of current gain, β is

(1) 45 (2) 50 (3) 60 (4) 75

Sol. Answer (4)

$$\beta = \frac{\Delta I_C}{\Delta I_B}$$

$$= \frac{7.5 \times 10^{-3}}{100 \times 10^{-6}}$$

$\therefore$ β = 75

28. The input resistance of a silicon transistor is 1 kΩ. If base current is changed by 100 μA, it causes the change in collector current by 2 mA. This transistor is used as a CE amplifier with a load resistance of 5 kΩ. What is the ac voltage gain of amplifier?

(1) 10 (2) 100 (3) 500 (4) 200

Sol. Answer (2)

$$A_v = \beta \frac{R_2}{R_i} \qquad R_i = 1\text{ k}\Omega;\ R_2 = 3\text{ k}\Omega$$

$$\beta = \frac{\Delta I_C}{\Delta I_B} = \frac{2 \times 10^{-3}}{100 \times 10^{-6}} \qquad \Delta I_B = 100\ \mu\text{A}$$

ΔI_C = 2 mA

$$A_v = \frac{20 \times 5 \times 10^{-2}}{1 \times 10^{-2}} = 100$$

29. The relationship between α and β is given by

(1) α = β (2) $\alpha = \frac{1}{\beta}$ (3) $\beta = \frac{\alpha}{1-\alpha}$ (4) $\beta = \frac{\alpha}{1+\alpha}$

Sol. Answer (3)

Relation between α and β is given by $\beta = \frac{\alpha}{1-\alpha}$

30. Input signal to a common emitter amplifier having a voltage gain of 1000 is given by v_i = (0.004 V) sin (ω*t* + π/2). The corresponding output signal is

(1) (40V) sin (ω*t* + π/2) (2) (0.004V) cos (ω*t* + π/2) (3) (4V) cos (ω*t* – π/2) (4) (4V) sin (ω*t* – π/2)

Sol. Answer (4)

A_v = 1000

V_i = 0.004 sin(ω*t* + 90º)

V_0 = ?

$$A_v = \frac{V_0}{V_i}$$

$$V_0 = A_v \times V_i = 1000 \times 4 \times 10^{-3} = 4$$

$$\therefore \quad V_0 = 4 \sin\left(\omega t - \frac{\pi}{2}\right)$$

31. In a common base transistor circuit, the current gain is 0.98. On changing emitter current by 5.00 mA, the change in collector current is

(1) 0.196 mA (2) 2.45 mA (3) 4.9 mA (4) 5.1 mA

Sol. Answer (3)

CB - configuration

$\alpha = 0.98$ $\qquad$ $\alpha = \frac{\Delta I_C}{\Delta I_E}$

$\Delta I_E = 5$ mA

$\Delta I_C = \alpha\, \Delta I_E = 0.98 \times 5 \times 10^{-3}$

$= 4.9 \times 10^{-3}$ A

$= 4.9$ mA

32. For a transistor amplifier power gain and voltage gain are 7.5 and 2.5 respectively. The value of the current gain will be

(1) 0.33 (2) 0.66 (3) 0.99 (4) 3

Sol. Answer (4)

Power gain = Voltage gain × Current gain

Amplifier power gain = 7.5

and voltage gain is 2.5

$$\text{Current gain} = \frac{7.5}{2.5} = 3$$

33. The input resistance of a common-emitter amplifier is 2 kΩ and a.c. current gain is 20. If the load resistor used is 5 kΩ, calculate the transconductance of the transistor used

(1) $0.01\ \Omega^{-1}$ (2) $0.03\ \Omega^{-1}$ (3) $0.04\ \Omega^{-1}$ (4) $0.07\ \Omega^{-1}$

Sol. Answer (1)

$R_i = 2$ kΩ

$\beta = 20$

$R_L = 5$ kΩ

$$g_m = \frac{\beta}{R_i} = \frac{20}{2 \times 10^3} = 0.01\,\Omega^{-1}$$

34. In a silicon transistor, a change of 7.89 mA is the emitter current produces a change of 7.8 mA in the collector current. What change in the base current is necessary to produce an equivalent change in the collector current?

(1) 9 mA (2) 0.9 mA (3) 0.09 mA (4) Zero

Sol. Answer (3)

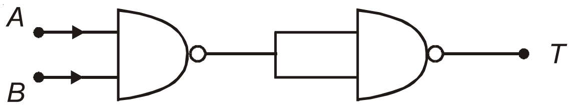
$I_E = 7.89$ mA

$I_C = 7.8$ mA

$\Delta I_E = \Delta I_C + \Delta I_B$

$\therefore \quad \Delta I_B = 0.09$ mA

35. The adjoining logic symbol is equivalent to



(1) OR gate (2) AND gate (3) NOT gate (4) NAND gate

Sol. Answer (2)

Let after 1st NAND gate the result is Z.

$$Z = \overline{A \cdot B}$$

2nd NAND gate with common input behave like a NOT, result $y = \overline{Z} = \overline{\overline{A.B}} = A.B$

36. Which of the following gates corresponds to the truth table given below?

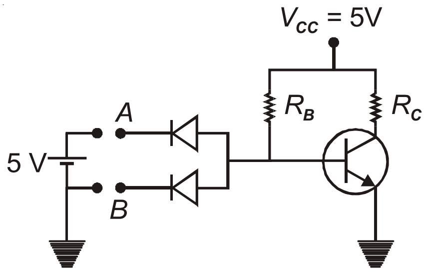
A	B	Y
1	1	0
1	0	1
0	1	1
0	0	1

(1) NAND (2) NOR (3) XOR (4) OR

Sol. Answer (1)

$$y = \overline{A.\,B}$$

37. Figure shows the practical realisation of a logic gate. Identify the logic gate

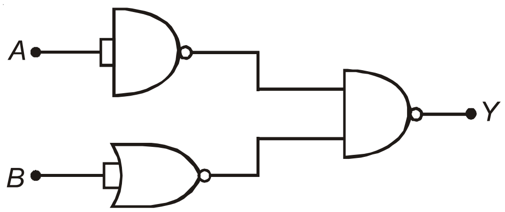


(1) NAND (2) NOR (3) XOR (4) XNOR

Sol. Answer (1)

The inputs A and B are both high when zero signal is observed only. Hence it is as NAND gate.

38. The combination of gates shown in the circuit is equivalent to



(1) OR (2) AND (3) NAND (4) NOR

Sol. Answer (1)

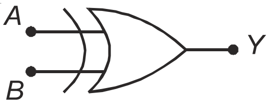
NAND and NOR with common input behave line a NOT.

Output of 1st = $\overline{A}$

Output of 2nd = $\overline{B}$

Feed to the NAND gate

$$Y = \overline{\overline{A}.\overline{B}} = \overline{\overline{A}} + \overline{\overline{B}} = A + B\,(OR)$$

39. 

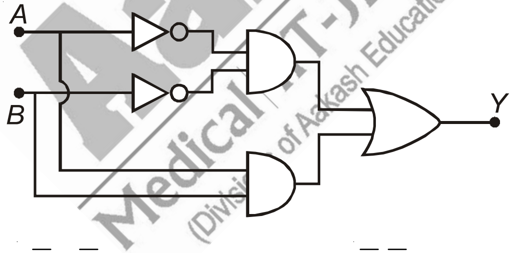
The gate is

(1) OR gate (2) AND gate (3) XOR gate (4) NOR gate

Sol. Answer (3)

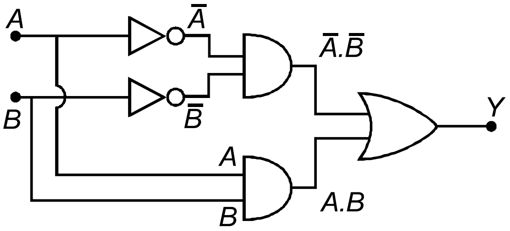
It is a symbol for XOR gate.

40. Write down the boolean expression for output Y of a system shown in figure



(1) $A\overline{B} + \overline{A}B$ (2) $(\overline{A} + \overline{B})(A + B)$ (3) $\overline{A}\,\overline{B} + AB$ (4) $A.B + (\overline{A} + \overline{B})$

Sol. Answer (3)



$$Y = \overline{A}.\overline{B} + A.B$$

41. Copper has face centred cubic lattice with interatomic spacing 2.5 Å. The value of lattice constant will be about

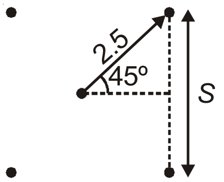
(1) 0.35 Å (2) 3.5 Å (3) 7.0 Å (4) 1.5 Å

Sol. Answer (2)

Lattice constant is the side of the cubic crystal.

$$S = \frac{2.5}{\sqrt{2}} \times 2$$

$$= 3.5 \text{ Å}$$



42. Distance between body centred atom and a corner atom in sodium is (where *a* = lattice constant)

(1) $\frac{a\sqrt{3}}{2}$ (2) $a\sqrt{3}$ (3) $\frac{a\sqrt{3}}{4}$ (4) $a\sqrt{2}$

Sol. Answer (1)

Body centred atoms are in the centre of the cube. Value will be half the body diagonal .

Body diagonal = $a\sqrt{3}$

Distance = $\frac{a\sqrt{3}}{2}$

43. Liquid crystal display monitors are made of

(1) Monocrystals (2) Single crystals (3) Liquid crystals (4) Polycrystals

Sol. Answer (3)

44. Which of the following cannot be obtained from an IC?

(1) Resistor (2) Diode (3) Inductor (4) Capacitor

Sol. Answer (3)

IC consists of many passive components like *R* and *C* (not *L*).

45. Operational amplifier is a

(1) Digital IC (2) Linear IC (3) OR gate (4) AND gate

Sol. Answer (2)

Operational amplifier is one of the very useful linear IC.

SECTION - B

Objective Type Questions

1. In a zener diode, break down occurs in reverse bias due to

(1) Impact ionisation (2) Internal field emission

(3) High doping concentration (4) All of these

Sol. Answer (2)

2. In an *n-p-n* transistor working in active mode, the depletion region

(1) Is not formed

(2) At emitter-base junction is wider than that at collector-base junction

(3) At emitter-base junction is thinner than that at collector-base junction

(4) At the two junctions have equals width

Sol. Answer (3)

Emitter base junction is forward biased and collector base junction is reverse biased.

3. A transistor has a current amplification factor of 60. In a CE amplifier, input resistance is 1 kΩ and output voltage is 0.01 V. The transconductance is (in SI units)

(1) 10^{-5} (2) 6×10^{-2} (3) 6×10^{4} (4) 10

Sol. Answer (2)

$\beta = \dfrac{\Delta I_C}{\Delta I_B} = 60$ $R_i = 1\ \text{k}\Omega,\ V_0 = 0.01\ \text{V}$

$$gm = \frac{\beta}{R_i} = \frac{60}{1 \times 10^3} = 6 \times 10^{-2}$$

4. A common emitter amplifier is designed with *NPN* transistor ($\alpha = 0.99$). The input impedance is 1 kΩ and load is 10 kΩ. The voltage gain will be

(1) 9.9 (2) 99 (3) 990 (4) 9900

Sol. Answer (3)

$\alpha = 0.99$ $R_i = 1\ \text{k}\Omega$ $R_L = 10\ \text{k}\Omega$

$$A_V = \alpha\left[\frac{R_L}{R_i}\right] = 0.99 \times \frac{10 \times 10^3}{1 \times 10^3} = 9.9$$

5. Pure Si at 300 K has hole and electron densities are $1.5 \times 10^{16}\ \text{m}^{-3}$. Doping it by an impurity increases the hole density n_h to $4.5 \times 10^{22}\ \text{m}^{-3}$. Electron density in the doped silicon is

(1) $1.5 \times 10^{16}\ \text{m}^{-3}$ (2) $3.0 \times 10^{22}\ \text{m}^{-3}$ (3) $5 \times 10^{9}\ \text{m}^{-3}$ (4) $3 \times 10^{6}\ \text{m}^{-3}$

Sol. Answer (3)

$n_i^2 = n_e \times n_h$ $n_i = 1.5 \times 10^{16}$ $n_h = 4.5 \times 10^{22}$

$$n_e = \frac{n_i^2}{n_e}$$

$n_e = 3 \times 10^6$

6. A common emitter transistor amplifier has a current gain of 50. If the load resistance is 9 kΩ and the input resistance is 500 Ω, the voltage gain of the amplifier will be

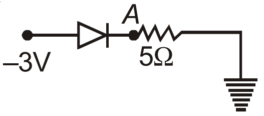
(1) 900 (2) 300 (3) 200 (4) 100

Sol. Answer (1)

$\alpha = 50$ $R_i = 500$ $R_L = 9\ \text{k}\Omega$

$$A_v = \alpha \times \frac{R_L}{R_i} = \frac{50 \times 9 \times 10^3}{500} = 900$$

7. In the figure given, voltage of point *A* is



(1) 0 V (2) –3 V (3) –2.3 V (4) –2.7 V

Sol. Answer (1)

The diode is reverse biased.

Since no current flows in circuit no voltage drop occurs in resistor.

8. A *p-n* photodiode is manufactured from a semiconductor with band gap of 3.1 eV. Which of the following wavelengths can be detected by it?

(1) 4000 Å (2) 3900 Å (3) 4200 Å (4) Both (1) & (2)

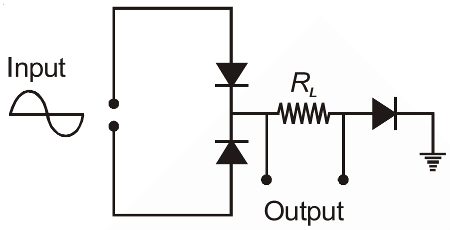
Sol. Answer (4)

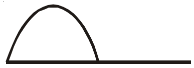
Energy of photons = $\frac{hc}{\lambda}$ J

For current to flow : $\frac{hce}{\lambda} > 3.1\,\text{eV}$

λ < 4010 Å

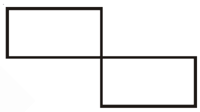
9. In the circuit shown, the input waveform is given. Which of the following correctly gives the output waveform across R_L?



(1) 

(2) 

(3) 

(4) 

Sol. Answer (2)

The circuit diagram is like a full wave rectifier and current through R_L flows only in one direction.

10. The electrical conductivity of a semiconductor increases when electromagnetic radiation of wavelength shorter than 2480 nm is incident on it. The band gap of the semiconductor is

(1) 0.3 eV (2) 0.5 eV (3) 0.7 eV (4) 1.1 eV

Sol. Answer (2)

λ = 24800Å

Energy correspond to this wavelength = $\frac{hc}{\lambda}$

11. Zener breakdown takes place if

(1) Doped impurity is low (2) Doped impurity is high

(3) Less impurity in N-part (4) Less impurity in *p*-type

Sol. Answer (2)

Zener breakdown is more easily possible when doped impurity is higher as there is greater conductive tendency in the diode and a larger depletion zone.

12. In a *p-n* junction solar cell, the value of photo-electromotive force produced by monochromatic light is proportional to the

(1) Voltage applied at the p-n junction (2) Barrier voltage at the p-n junction

(3) Intensity of light falling on the cell (4) Frequency of light falling on the cell

Sol. Answer (3)

13. In a transistor the collector current is always less than the emitter current because

(1) Collector side is reverse biased and the emitter side is forward biased

(2) Collector being reverse biased, attracts less electrons

(3) A few electrons are lost in the base and only remaining one's reach the collector

(4) Collector side is forward biased and emitter side is reverse biased

Sol. Answer (3)

14. The depletion region of *p*-*n* junction has a thickness of the order of

(1) 10^{-12} m (2) 10^{-6} m (3) 10^{-3} m (4) 10^{-2} m

Sol. Answer (2)

15. In an *n*-*p*-*n* transistor, the collector current is 10 mA. If 90% of the electrons emitted reach the collector, then the emitter current will be

(1) 9 mA (2) 11 mA (3) 1 mA (4) 0.1 mA

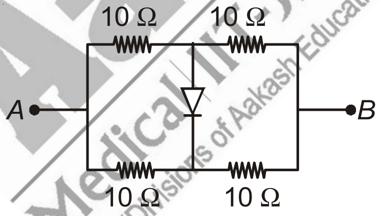
Sol. Answer (2)

$i_e = i_b + i_c$

$$i_e = \frac{100}{90} \times i_c$$

$i_e = 11.1$ mA or 11 mA

16. Four equal resistors, each of resistance 10 Ω, are connected as shown in the circuit diagram. The equivalent resistance between *A* and *B* is



(1) 5 Ω (2) 10 Ω (3) 20 Ω (4) 40 Ω

Sol. Answer (2)

It is a simple wheat stone's bridge and no current will flow through the middle wire because of lack of potential difference across transistor.

$$R_{\text{eq}} = \frac{20 \times 20}{20 + 20} = 10\,\Omega$$

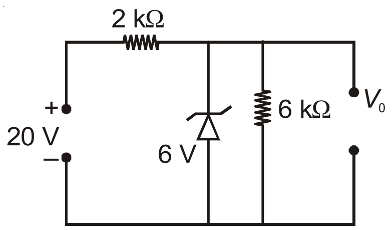
17. A transistor cannot be used as an

(1) Amplifier (2) Oscillator (3) Modulator (4) Rectifier

Sol. Answer (4)

A transistor cannot be used as a Rectifier.

18. What is the value of output voltage V_0 in the circuit shown in the figure?



(1) 6 V (2) 14 V (3) 20 V (4) 26 V

Sol. Answer (1)

The zener diode maintains a voltage of 6 V across its ends and voltage remains equal to breakdown voltage as 6 V.

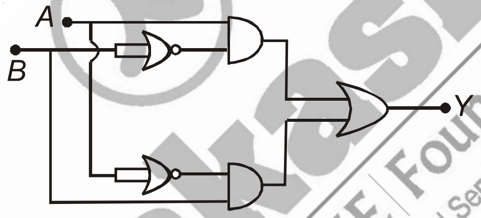
19. What is the power gain in a CE amplifier, where input resistance is 3k Ω and load resistance 24k Ω given $\beta = 6$?

(1) 180 (2) 288 (3) 240 (4) 480

Sol. Answer (2)

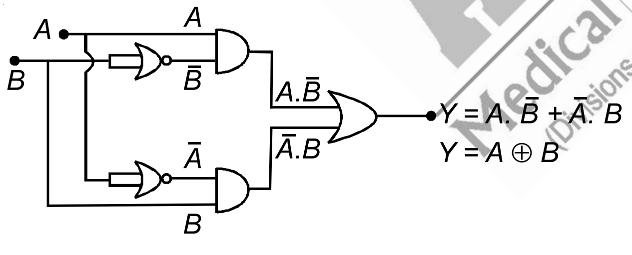
$$\text{Power gain} = \beta^2 \frac{R_L}{R_i} = (6)^2\left(\frac{24}{3}\right) = 288$$

20. For inputs (A, B) and output (Y) of the following gate can be expressed as

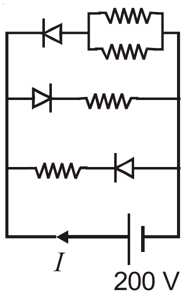


(1) A ⊕ B (2) A.B (3) A + B (4) $\overline{A} + \overline{B}$

Sol. Answer (1)



21. Calculate the current *I* in the following circuit, if all the diodes are ideal. All resistances are of 200Ω.



(1) Zero (2) 1 A (3) 2 A (4) 4 A

Sol. Answer (2)

Only the forward biased transistor allows flow of current.

Hence $I = \frac{V}{R} = 1$ A

22. A transistor having $\alpha = 0.99$ is used in a common base amplifier. If the load resistance is 4.5k Ω and the dynamic resistance of the emitter junction is 50Ω the voltage gain of the amplifier will be

(1) 79.1 (2) 89.1 (3) 78.2 (4) 450

Sol. Answer (2)

$\alpha = 0.99$ $R_L = 4.5$ kΩ $R_l = 50$ Ω

$$A_v = \alpha \cdot \frac{R_L}{R_l} = 0.99 \times \frac{4.5}{50} \times 10^3$$

$\therefore$ $A_v = 0.0891 \times 10^3 = 89.1$

23. A potential difference of 2.5 V is applied across the faces of a germanium crystal plate. The face area of the crystal is 1 cm² and its thickness is 1.0 mm. The free electron concentration in germanium is 2×10^{19} m^{-3} and the electron and holes mobilities are 0.33 m²/V s and 0.17 m²/V s respectively. The current across the plate will be

(1) 0.2A (2) 0.4A (3) 0.6A (4) 0.8A

Sol. Answer (2)

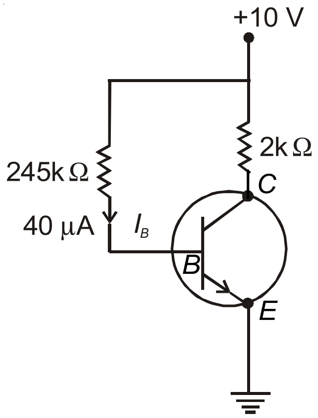
l = 1 mm V = 2.5 volt

$\mu_e = 0.33$ m²/vs, $\mu_n = 0.17$ m²/vs

$n_e = n_n = 2 \times 10^{-19}$ m^{-3}

$$i = \frac{eAv}{l}(n_e\mu_e + n_n\mu_n)$$

24. In the following transistor amplifier circuit $\beta = 50$. V_{CE} of the transistor is



(1) 4 V (2) 6 V (3) 10 V (4) 8 V

Sol. Answer (2)

$\beta = 50$

$\frac{I_C}{I_B} = 50$, $I_B = 40\ \mu_A$

$I_C = 50 \times 40 \times 10^{-6}$

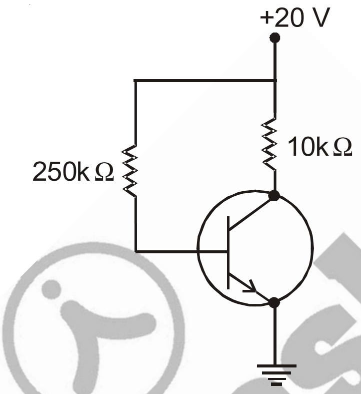
$= 2 \times 10^{-3}$ A

$V_{CE} = V_{CC} - I_C R_C$

$= 10 - 2 \times 10^{-3} \times 2 \times 10^{3}$

$= 6\ V$

25. The given transistor amplifier connection is



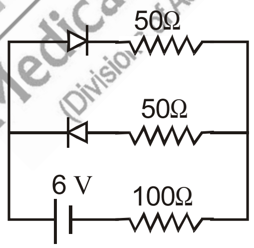
(1) Common base connection (2) Common emitter connection

(3) Common collector connection (4) All of these

Sol. Answer (2)

In this case the emitter is grounded here, it is a common emitter configuration.

26. The circuit shown in the figure contains two diodes each with a forward resistance of 50Ω and with infinite backward resistance. If the battery of 6 V is connected in the circuit, then the current through the 100Ω resistance is



(1) Zero (2) 0.02 A (3) 0.03 A (4) 0.036 A

Sol. Answer (3)

Only the forward biased diode will allow the transfer of current.

$$I = \frac{v}{R} = \frac{6}{150} = 0.04 \text{ A}$$

Current 0.4 ≈ 0.036 A hence answer is (4).

27. Three amplifiers each having voltage gain 10, are connected in series. The resultant gain would be

(1) 10 (2) 30 (3) 1000 (4) $\frac{10}{3}$

Sol. Answer (3)

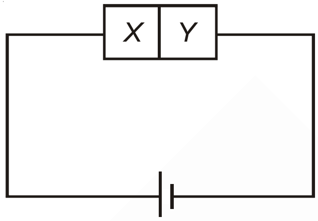
Each multiplies initial power by 10 times.

Hence final voltage compared to initial voltage

$V = 10 \times 10 \times 10\ V_0$

or $V = 1000\ V_0$

28. A semiconductor *X* is made by doping a germanium crystal with arsenic (Z = 33). A second semiconductor *Y* is made by doping germanium with indium (Z = 49). *X* and *Y* are used to form a junction as shown in figure and connected to a battery as shown. Which of following statement is correct?



(1) X is p-type, Y is n-type and the junction is forward biased

(2) X is n-type, Y is p-type and the junction is forward biased

(3) X is p-type, Y is n-type and the junction is reverse biased

(4) X is n-type, Y is p-type and the junction is reverse biased

Sol. Answer (4)

Group 5 elements like arsenic are used to create, N type semiconductors and indium is used to create P type semiconductor.

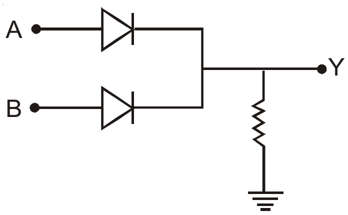
29. The maximum efficiency of a full wave rectifier is

(1) $\frac{4}{\pi^2}\times 100\ \%$ (2) $\frac{8}{\pi^2}\times 100\ \%$ (3) 40% (4) 80%

Sol. Answer (2)

Maximum efficiency of a full wave rectifier is $\frac{8}{\pi^2}\times 100\%$

30. Logic gate realised from pn junctions shown in figure is

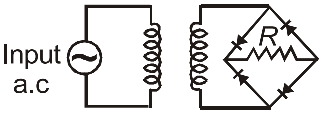


(1) OR gate (2) AND gate (3) NOT gate (4) NOR gate

Sol. Answer (1)

It is an OR gate as the current will flow through resistor if any one *A* or *B* is of correct input.

31. The output across the load resistance R is



(1) Half wave rectified
(2) Full wave rectified
(3) Quarter wave rectified
(4) ac

Sol. Answer (2)

It is a full wave rectifier.

32. Which of the following pn junction is not used in reverse bias?

(1) LED (2) Solar cell (3) Zener diode (4) Both (1) & (2)

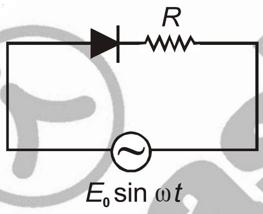
Sol. Answer (4)

33. Which of the following break down of pn junction is reversible?

(1) Avalanche breakdown (2) Zener breakdown (3) Dielectric breakdown (4) All of these

Sol. Answer (2)

34. In the circuit shown, the average power dissipated in the resistor is (assume diode to be ideal)



(1) $\frac{E_0^2}{2R}$ (2) $\frac{E_0^2}{4R}$ (3) $\frac{E_0^2}{R}$ (4) Zero

Sol. Answer (2)

It's a half wave rectification $E_{rms} = \frac{E_0}{2}$

$$P_{av} = \frac{(E_{rms})^2}{R}$$

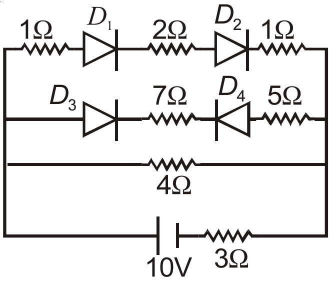
$$= \frac{E_0^2}{4R}$$

35. A crystal has bcc structure and its lattice constant is 3.6 Å. What is the atomic radius?

(1) 3.6 Å (2) 1.8 Å (3) 1.27 Å (4) 1.56 Å

Sol. Answer (4)

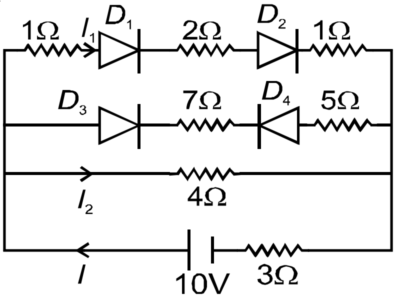
36. All the diodes are ideal. The current flowing in 2Ω resistor connected between the diodes D_1 and D_2 is



(1) 1A (2) 2A (3) 3A (4) Zero

Sol. Answer (1)

D_1 and D_2 are forward bias



$i = \frac{10}{3+2}$

i = 2A

Branch resistors are same

$\therefore i_1 = i_2 = 1\text{A}$

37. In a transistor (β = 50), the voltage across 5kΩ load resistance in collector circuit is 5V. The base current is

(1) 0.02mA (2) 0.03mA (3) 0.08mA (4) 0.09mA

Sol. Answer (1)

$\beta = \frac{I_C}{I_B},\ I_C = \frac{5}{50 \times 10^3}$

$I_B = \frac{I_C}{\beta}$

SECTION - C

Previous Years Questions

1. A *p-n* photodiode is made of a material with a band gap of 2.0 eV. The minimum frequency of the radiation that can be absorbed by the material is nearly

(1) 20×10^{14} Hz (2) 10×10^{14} Hz (3) 5×10^{14} Hz (4) 1×10^{14} Hz

Sol. Answer (3)

$2 \times 1.6 \times 10^{-19} = hf$

$f = \frac{2 \times 1.6 \times 10^{-19}}{6.6 \times 10^{-34}} = 4.828 \times 10^{14}\ \text{Hz}$

$\approx 5 \times 10^{14}$ Hz

2. The cations and anions are arranged in alternate form in

(1) Metallic crystal (2) Ionic crystal (3) Covalent crystal (4) Semi-conductor crystal

Sol. Answer (2)

Ionic crystal consisting the cation and anion as basic constituents

3. In semiconductors at room temperature

(1) The valence band is partially empty and the conduction band is partially filled

(2) The valence band is completely filled and the conduction band is partially filled

(3) The valence band is completely filled

(4) The conduction band is completely empty

Sol. Answer (1)

Due to excitation energy provided by room temperature.

4. Carbon, silicon and germanium atoms have four valence electrons each. Their valence and conduction bands are separated by energy band gaps represented by $(E_g)_C$, $(E_g)_{Si}$ and $(E_g)_{Ge}$ respectively. Which one of the following relationships is true in their case?

(1) $(E_g)_C > (E_g)_{Si}$ (2) $(E_g)_C < (E_g)_{Si}$ (3) $(E_g)_C = (E_g)_{Si}$ (4) $(E_g)_C < (E_g)_{Ge}$

Sol. Answer (1)

Carbon is a dielectric and has higher forbidden energy gap.

5. Which one of the following bonds produces a solid that reflects light in the visible region and whose electrical conductivity decreases with temperature and has high melting point?

(1) Covalent bonding (2) Metallic bonding (3) van der Waal's bonding (4) Ionic bonding

Sol. Answer (2)

The description is of a metal and is produced a special bond called metallic bond.

6. In good conductors of electricity, the type of bonding that exists is

(1) Metallic (2) van der Waal's (3) Ionic (4) Covalent

Sol. Answer (1)

Good conductor and conduct electricity both due to their property of metallic bonds.

7. In an insulator, the forbidden energy gap between the valence band and conduction band is of the order of

(1) 1 MeV (2) 0.1 MeV (3) 1 eV (4) 5 eV

Sol. Answer (4)

In an insulator there is a high energy gap of the order.

8. A *p-n* junction has a depletion layer thickness of the order of

(1) 10^{-10} m (2) 10^{-8} m (3) 10^{-6} m (4) 10^{-4} m

Sol. Answer (3)

9. Pure Si at 300 K has hole and electron densities are 1.5×10^{16} m^{-3}. Doping it by an impurity increases the hole density n_h to 4.5×10^{22} m^{-3}. Electron density in the doped silicon is

(1) 1.5×10^{16} m^{-3} (2) 3.0×10^{22} m^{-3} (3) 5×10^{9} m^{-3} (4) 3×10^{6} m^{-3}

Sol. Answer (3)

$$n_i^2 = \sqrt{n_e \cdot n_n}$$

$$(1.5\times10^{16})^2 = \frac{2.25\times10^{32}}{4.5\times10^{22}} = 5\times10^{9}\ \text{m}^{-3}$$

10. If a small amount of antimony is added to germanium crystal

(1) Its resistance is increased

(2) It becomes a p-type semiconductor

(3) The antimony becomes an acceptor atom

(4) There will be more free electrons than hole in the semiconductor

Sol. Answer (4)

Antimony in pentavalent atom.

11. In forward biasing of the *p*-*n* junction

(1) The positive terminal of the battery in connected to *p*-side and the depletion region becomes thin

(2) The positive terminal of the battery is connected to *p*-side and the depletion region becomes thick

(3) The positive terminal of the battery is connected to *n*-side and the depletion region becomes thin

(4) The positive terminal of the battery is connected to *n*-side and the depletion region becomes thick

Sol. Answer (1)

12. In a reverse-biased *p*-*n* junction, when the applied bias voltage is equal to the breakdown voltage, then

(1) Current remains constant while voltage increase sharply

(2) Voltage remains constant while current increases sharply

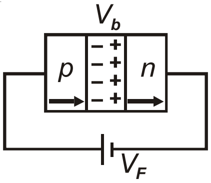
(3) Current and voltage increase

(4) Current and voltage decrease

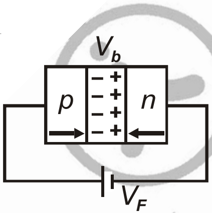
Sol. Answer (2)

13. In the case of forward biased of *p*-*n* junction, which one of the following figures correctly depicts the direction of flow of carriers?

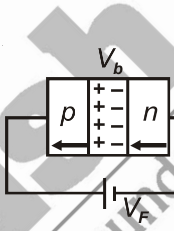
(1)



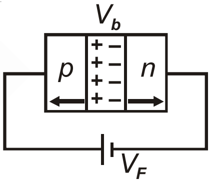
(2)



(3)



(4)



Sol. Answer (2)

Holes will move in the direction of current in the P region and electrons will move in the direction opposite to current.

14. When arsenic is added as an impurity to silicon, the resulting material is

(1) *n*-type conductor
(2) *n*-type semiconductor
(3) *p*-type semiconductor
(4) *p*-type conductor

Sol. Answer (2)

Arsenic is pentavalent atom.

15. To obtain a *p*-type germanium semiconductor, it must be doped with

(1) Indium
(2) Phosphorus
(3) Arsenic
(4) Antimony

Sol. Answer (1)

Indium is an acceptor doping agent and it increases number of holes.

16. The cause of the potential barrier in a p-n diode is

(1) Depletion of negative charges near the junction

(2) Concentration of positive charges near the junction

(3) Depletion of positive charges near the junction

(4) Concentration of positive and negative charges near the junction

Sol. Answer (4)

The depletion layer causes the potential barriers.

17. A semi-conducting device is connected in a series circuit with a battery and a resistance. A current is found to pass through the circuit. If the polarity of the battery is reversed, the current drops to almost zero. The device may be

(1) A *p*-type semi-conductor
(2) An intrinsic semi-conductor
(3) A *p-n* junction
(4) An *n*-type semi-conductor

Sol. Answer (3)

The P–N junction initially in forward bias and finally in reverse bias is described.

18. A *p-n* junction diode can be used as

(1) Condenser (2) Oscillator (3) Amplifier (4) Rectifier

Sol. Answer (4)

19. In a p-type semiconductor, the majority carriers of current are

(1) Protons (2) Electrons (3) Holes (4) Neutrons

Sol. Answer (3)

20. In forward bias, the width of potential barrier in a *p-n* junction diode

(1) Remains constant (2) Decreases (3) Increases (4) First (1) then (2)

Sol. Answer (2)

21. Depletion layer consists of

(1) Mobile ions (2) Protons (3) Electrons (4) Immobile ions

Sol. Answer (4)

22. In a junction diode, the holes are due to

(1) Extra electrons (2) Neutrons (3) Protons (4) Missing of electrons

Sol. Answer (4)

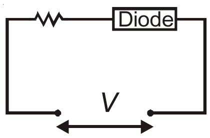
Holes are created due to electron vacancy.

23. In a *PN* junction

(1) High potential at *N* side and low potential at *P* side
(2) High potential *P* side and low potential at *N* side
(3) *P* and *N* both are at same potential
(4) Undetermined

Sol. Answer (1)

24. For the given circuit of ideal *P-N* junction diode which is correct



(1) In forward bias the voltage across *R* is *V*
(2) In reverse bias the voltage across *R* is *V*
(3) In forward bias the voltage across *R* is 2*V*
(4) In reverse bias the voltage across *R* is 2*V*

Sol. Answer (1)

In forward bias P – N situation is thaught to have very low or negligible resistance. Hence entire voltage drop is across resistor.

25. Reverse bias applied to a junction diode

(1) Lowers the potential barrier (2) Raises the potential barrier

(3) Increases the majority carrier current (4) Increases the minority carrier current

Sol. Answer (2)

Reverse bias increases depletion layer and hence the potential barrier.

26. Barrier potential of a *p-n* junction diode does not depend on

(1) Diode design (2) Temperature (3) Forward bias (4) Doping density

Sol. Answer (1)

Barrier potential does not depend on diode design but the other three factors in options.

27. In a *p-n* junction photo cell, the value of the photo-electromotive force produced by monochromatic light is proportional to

(1) The barrier voltage at the *p-n* junction (2) The intensity of the light falling on the cell

(3) The frequency of the light falling on the cell (4) The voltage applied at the *p-n* junction

Sol. Answer (2)

Photo emf depends on intensity.

28. Choose the only *false* statement from the following

(1) In conductors the valence and conduction bands overlap

(2) Substances with energy gap of the order of 10 eV are insulators

(3) The resistivity of a semiconductor increases with increase in temperature

(4) The conductivity of a semiconductor increases with increase in temperature

Sol. Answer (3)

Resistivity of semiconductor decreases with increase in temperature, due to availability of more carrier particles.

29. Zener diode is used as

(1) Amplification (2) Rectification

(3) Stabilisation (4) Producing oscillations in an oscillator

Sol. Answer (3)

Zener diode is used as a voltage stabiliser.

30. Application of a forward bias to a *p-n* junction

(1) Widens the depiction zone

(2) Increases the potential difference across the depletion zone

(3) Increases the diffusion of conduction electrons from *n* side to *p* side

(4) Increases the electric field in the depletion zone

Sol. Answer (3)

Increases the diffusion current.

31. A forward biased diode is

(1) 

(2) 

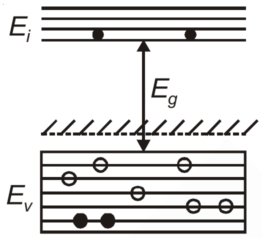
(3) 

(4) 

Sol. Answer (1)

Higher to lower potential is achieved in forward bias in option (1) only.

32. In the energy band diagram of a material shown below, the open circles and filled circles denote holes and electrons respectively. The material is



(1) An insulator
(2) A metal
(3) A *n*-type semiconductor
(4) A *p*-type semiconductor

Sol. Answer (4)

Holes are more in numbers

33. In a zener diode, break down occurs in reverse bias due to

(1) Impact ionisation
(2) Internal field emission
(3) High doping concentration
(4) All of these

Sol. Answer (2)

34. A *p*-*n* photodiode is fabricated from a semiconductor with a band gap of 2.5 eV. It can detect a signal of wavelength

(1) 4000 Å
(2) 6000 Å
(3) 4000 nm
(4) 6000 nm

Sol. Answer (1)

$$\frac{hc}{\lambda} = 2.5 \text{ eV}$$

$$\lambda_{\max} = \frac{6.6\times10^{-34}\times3\times10^{8}}{2.5\times1.6\times10^{-19}}$$

$$= 4.95 \times 10^{-7}$$

$$= 4.950 \times 10^{-10}$$

$$= 4950 \text{ Å}$$

Hence λ is less than $\lambda_{\max}$.

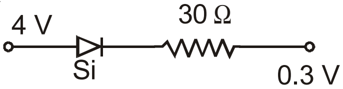
35. In a *p*-*n* junction, depletion region contains

(1) No charges at all
(2) Equal number of conduction electrons and holes
(3) Equal number of donor and acceptor ions
(4) More conduction holes than electrons

Sol. Answer (3)

Answer is option (3) in order to maintain charge neutrality.

36. In the given circuit, the value of current is



(1) 1 ampere (2) 0.1 ampere (3) 0.5 ampere (4) Zero

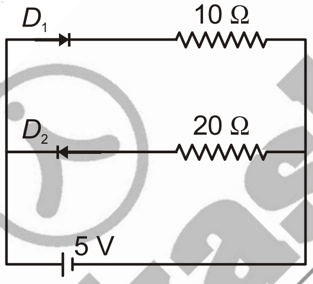
Sol. Answer (2)

Voltage drop across silicon P – N junction is forward bias = 0.7 V

$$I = \frac{\Delta V}{R}$$

or $I = \frac{4 - 0.7 - 0.3}{30} = 0.1\,\text{A}$

37. Two ideal diodes are connected to a battery as shown in the circuit. The current supplied by the battery is



(1) 0.25 A (2) 0.5 A (3) 0.75 A (4) Zero

Sol. Answer (2)

Current = $\frac{V}{R} = \frac{5}{10} = 0.5$ A

A_2 is reverse biased and it is assumed in this questions that current does not pass through it.

38. C and Si both have same lattice structure, having 4 bonding electrons in each. However, C is insulator whereas Si is intrinsic semiconductor. This is because

(1) The four bonding electrons in the case of C lie in the second orbit, whereas in the case of Si they lie in the third

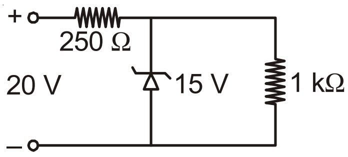
(2) The four bonding electrons in the case of C lie in the third orbit, whereas for Si they lie in the fourth orbit.

(3) In case of C the valance band is not completely filled at absolute zero temperature

(4) In case of C the conduction band is partly filled even at absolute zero temperature

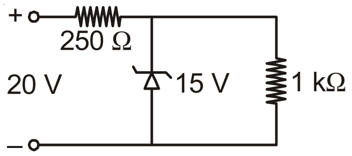
Sol. Answer (1)

39. A zener diode, having breakdown voltage equal to 15 V is used in a voltage regulator circuit shown in figure. The current through the diode is :



(1) 20 mA (2) 5 mA (3) 10 mA (4) 15 mA

Sol. Answer (2)



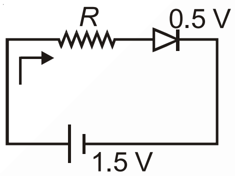
Potential through zener diode is maintained 15 V.

Current through 1000 Ω = $\frac{15}{1000}$ = 0.015 A

Current through 250 Ω = $\frac{5}{250} = \frac{1}{50}$ = 0.02 A

∴ Current through diode = 0.02 – 0.015 = 0.005 A

40. The diode used in the circuit shown in the figure has a constant voltage drop at 0.5 V at all currents and a maximum power rating of 100 milli watt. What should be the value of the resistor *R*, connected in series and with diode for obtaining maximum current?



(1) 6.76 Ω (2) 20 Ω (3) 5 Ω (4) 5.6 Ω

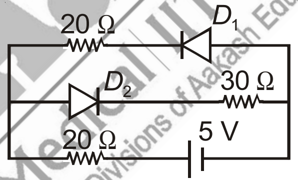
Sol. Answer (3)

Max curent through diode

$i = \frac{0.1\text{ watt}}{0.5\text{ watt}} = .2\text{A}$

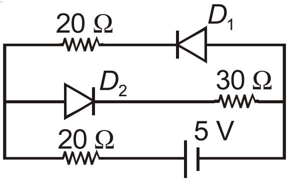
$R = \frac{1\text{ Volt}}{.2\text{ A}} = 5\ \Omega$

41. The current in the circuit will be



(1) $\frac{5}{40}$ A (2) $\frac{5}{50}$ A (3) $\frac{5}{10}$ A (4) $\frac{5}{20}$ A

Sol. Answer (2)



D_1 is reverse biased, no current flows through it.

D_2 is forward biased so current flows with minimum resistance.

$i = \frac{5}{50}$A

42. If a full wave rectifier circuit is operating from 50 Hz mains, the fundamental frequency in the ripple will be

(1) 25 Hz (2) 50 Hz (3) 70.7 Hz (4) 100 Hz

Sol. Answer (4)

Frequency of full wave rectifier = 2 × Frequency of mains = 100 Hz.

43. The peak voltage in the output of a half-wave diode rectifier fed with a sinusoidal signal without filter is 10 V. The D.C. component of the output voltage is

(1) $\frac{10}{\sqrt{2}}$ V (2) $\frac{10}{\pi}$ V (3) 10 V (4) $\frac{20}{\pi}$ V

Sol. Answer (2)

$$\text{D.C. component of output voltage} = \frac{\text{Peak voltage}}{\pi}$$

44. Which of the following statement is False?

(1) The resistance of intrinisic semiconductor decreases with increase of temperature

(2) Pure Si doped with trival ent impurities gives a *p*-type semiconductor

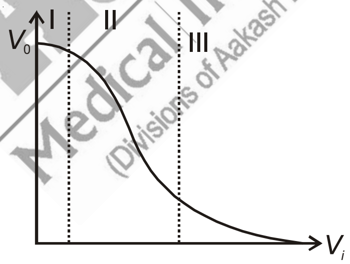
(3) Majority carries in a *n*-type semiconductors are holes

(4) Minority carries in a *p*-type semiconductor are electrons

Sol. Answer (3)

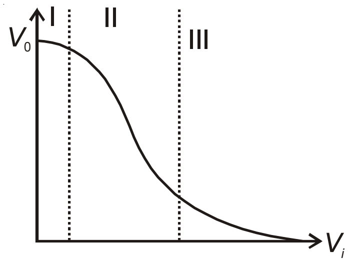
Majority carries in N-type semiconductor as electron. Hence option (3) is correct.

45. Transfer characteristics [output voltage (V_0) vs input voltage (V_i)] for a base biased transistor in CE configuration is as shown in the figure. For using transistor as a switch, it is used



(1) In region II (2) In region I (3) In region III (4) Both in region (I) & (III)

Sol. Answer (4)



To use it as a switch it must be used cut off and in saturation region which are I and III.

46. In a CE transistor amplifier, the audio signal voltage across the collector resistance of 2 kΩ is 2 V. If the base resistance is 1 kΩ and the current amplification of the transistor is 100, the input signal voltage is

(1) 1 mV (2) 10 mV (3) 0.1 V (4) 1.0 V

Sol. Answer (2)

$R_C = 2\ \text{k}\Omega$

$v_{CE} = 2V = V_0$ $\beta = 100$

$R_b = 1\ \text{k}\Omega$

$$A_v = \beta\frac{R_c}{R_b} = \frac{100\times2\times10^3}{1\times10^3} = 200$$

$$A_v = \frac{V_0}{V_1} = \frac{2}{V_i} = 200 \Rightarrow V_i = \frac{2}{200} = 10\ \text{mV}$$

47. The input resistance of a silicon transistor is 100 Ω. Base current is changed by 40 μA which results in a change in collector current by 2 mA. This transistor is used as a common emitter amplifier with a load resistance of 4 kΩ. The voltage gain of the amplifier is

(1) 2000 (2) 3000 (3) 4000 (4) 1000

Sol. Answer (1)

$r_i = 100\ \Omega$ $R_L = 4\ \text{k}\Omega$ $A_v = \beta\frac{R_L}{R_i}$ $I_B = 40\ \mu\text{A}$

$$\beta = \frac{\Delta I_C}{\Delta I_B} = \frac{2\times10^{-3}}{40\times10^{-6}} = \frac{2000}{40} = 50$$

$$A_v = \frac{50\times4\times10^3}{10^2} = 2000$$

48. A transistor is operated in common emitter configuration at $V_C = 2$ V such that a change in the base current from 100 μA to 300 μA produces a change in the collector current from 10 mA to 20 mA. The current gain is

(1) 25 (2) 50 (3) 75 (4) 100

Sol. Answer (2)

$v_c = 2$ V $\Delta I_B = (300 - 100)\ \mu\text{A} = 200\ \mu\text{A}$ $\Delta I_c = (20 - 10)\ \text{mA} = 10\ \text{mA}$

$$\beta = \frac{\Delta I_c}{\Delta I_b} = \frac{10\times10^{-3}}{200\times10^{-6}} = \frac{10\times10^{-3}}{200} = \frac{100}{2} = 50$$

49. When NPN transistor is used as an amplifier, then

(1) Electrons move from collector to base (2) Holes move from collector to base

(3) Holes move from base to collector (4) Electrons move from emitter to base

Sol. Answer (4)

Emitter base junction is forward bias.

50. The voltage gain of an amplifier with 9% negative feedback is 10. The voltage gain without feedback will be

(1) 100
(2) 90
(3) 10
(4) 1.25

Sol. Answer (1)

$$A_{fb} = \frac{A}{1-mA}$$

A_{fb}= Voltage gain with feed back = 10

A = Voltage gain without feed back

$$m = \frac{A}{1+\frac{9A}{100}}$$

$$10+\frac{9}{10}A = A$$

A = 100

51. An oscillator is nothing but an amplifier with

(1) Positive feedback
(2) Negative feedback
(3) Voltage gain
(4) No feedback

Sol. Answer (1)

52. The correct relationship between the two current gains α and β in a transistor is

(1) $\alpha = \frac{\beta}{1-\beta}$
(2) $\alpha = \frac{1+\beta}{\beta}$
(3) $\beta = \frac{\alpha}{1+\alpha}$
(4) $\beta = \frac{\alpha}{1-\alpha}$

Sol. Answer (4)

53. The transfer ratio β of a transistor is 50. The input resistance of the transistor when used in the common-emitter configuration is 1 kΩ. The peak value of the collector A.C. current for an A.C. input voltage of 0.01 V peak is

(1) 0.25 mA
(2) 0.01 mA
(3) 100 μA
(4) 500 μA

Sol. Answer (4)

$$\beta = \frac{I_C}{I_B},\ I_B = \frac{V_i}{R_i}$$

$$\beta = \frac{I_C R_i}{V_i}$$

$$I_c = \frac{\beta V_i}{R_i}$$

$$= \frac{50(.01)}{10^3}$$

$$= 500\ \mu A$$

54. For a common emitter circuit if $\frac{I_C}{I_E}$ = 0.98 then current gain for common emitter circuit will be

(1) 49×10^{-2} (2) 98 (3) 4.9×10^{1} (4) 25.5

Sol. Answer (3)

$\frac{I_C}{I_E} = \alpha = 0.98$ $\beta = ?$

$$\beta = \frac{\alpha}{1-\alpha} = \frac{0.98}{0.02} = 49 = 4.9 \times 10$$

55. A *n-p-n* transistor conducts in active mode when

(1) Both collector and emitter are positive with respect to the base

(2) Collector is positive and emitter is negative with respect to the base

(3) Collector is positive and emitter is at same potential as the base

(4) Both collector and emitter are negative with respect to the base

Sol. Answer (2)

56. A transistor-oscillator using a resonant circuit with an inductor L (of negligible resistance) and a capacitor C in series produce oscillations of frequency f. If L is doubled and C is changed to $4C$, the frequency will be

(1) $\frac{f}{2}$ (2) $\frac{f}{4}$ (3) $8f$ (4) $\frac{f}{2\sqrt{2}}$

Sol. Answer (4)

At resonance condition $f = \frac{1}{2\pi\sqrt{LC}}$

$$f_1 = \frac{1}{2\pi\sqrt{8LC}} = \frac{1}{4\sqrt{2}\pi\sqrt{LC}} = \frac{f}{2\sqrt{2}}$$

$$f_1 = \frac{f}{2\sqrt{2}}$$

57. A common emitter amplifier has a voltage gain of 50, an input impedance of 100 Ω and an output impedence of 200 Ω. The power gain of the amplifier is

(1) 1000 (2) 1250 (3) 100 (4) 500

Sol. Answer (2)

$A_v = 50$ $R_1 = 100\ \Omega$ $R_2 = 200\ \Omega$

$$A_v = \beta\frac{R_2}{R_1}$$

Power gain $= A_v\beta$

$$= A_V\left(A_V\frac{R_1}{R_2}\right)$$

$$= A_V^2\frac{R_1}{R_2}$$

58. The device that can act as a complete electronic circuit is

(1) Zener diode (2) Junction diode (3) Integrated circuit (4) Junction transistor

Sol. Answer (3)

59. For transistor action

(a) Base, emitter and collector regions should have similar size and doping concentrations.

(b) The base region must be very thin and lightly doped.

(c) The emitter-base junction is forward biased and base-collector junction is reverse biased.

(d) Both the emitter-base junction as well as the base collector junction are forward biased.

Which one of the following pairs of statements is correct?

(1) (a), (d) (2) (a), (b) (3) (b), (c) (4) (c), (d)

Sol. Answer (3)

60. In an *n-p-n* transistor working in active mode, the depletion region

(1) Is not formed

(2) At emitter-base junction is wider than that at collector-base junction

(3) At emitter-base junction is thinner than that at collector-base junction

(4) At the two junctions have equals width

Sol. Answer (3)

61. A transistor has a current amplification factor of 60. In a CE amplifier, input resistance is 1 kΩ and output voltage is 0.01 V. The transconductance is (in SI units)

(1) 10^{-5} (2) 6×10^{-2} (3) 6×10^{4} (4) 10

Sol. Answer (2)

$\beta = 60$ $R_1 = 1\ \text{k}\Omega$ $V_0 = 0.01\ \text{V}$ $g_m = ?$

$$g_m = \frac{\beta}{R_i} = \frac{60}{10^3} = 6\times10^{-2}$$

62. Which of the conditions must be satisfied to operate a transistor amplifier?

(1) Emitter-base and collector-base junctions are forward biased

(2) Emitter-base is forward biased junctions collector-base is reverse biased

(3) Emitter-base and collector-base junctions both are reverse biased

(4) Emitter-base is reverse biased collector-base is forward biased

Sol. Answer (2)

63. In a common emitter configuration base current is 40 μA and current gain is 100. The collector current will be

(1) 4 mA (2) 4 μA (3) 1 mA (4) 1 μA

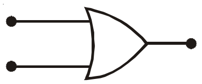
Sol. Answer (1)

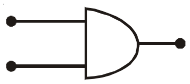
$I_B = 40\ \mu\text{A} = 40 \times 10^{-6}$ A $\quad \beta = 100 \quad I_C = ?$

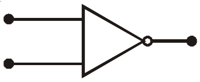
$I_C = \beta I_B$

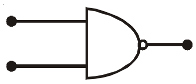
$100 \times 40 \times 10^{-6} = 4 \times 10^{-3} = 4$ mA

64. Symbolic representation of four logic gates are shown as

(i) 

(ii) 

(iii) 

(iv) 

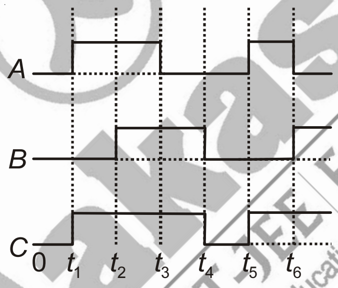
Pick out which ones are for AND, NAND and NOT gates, respectively :

(1) (ii), (iv) & (iii) (2) (ii), (iii) & (iv) (3) (iii), (ii) & (i) (4) (iii), (ii) & (iv)

Sol. Answer (1)

Fact.

65. The figure shows a logic circuit with two inputs A and B and the output C. The voltage wave forms across A, B and C are as given. The logic circuit gate is

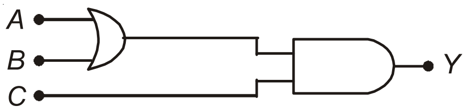


(1) AND gate (2) NAND gate (3) OR gate (4) NOR gate

Sol. Answer (3)

When any of A or B is high C is high. Hence it is an OR gate.

66. To get an output $Y = 1$ in given circuit which of the following input will be correct



	A	B	C
(1)	1	0	0
(2)	1	0	1
(3)	1	1	0
(4)	0	1	0

Sol. Answer (2)

To get output $y = 1$ C must be 1 and $A + B$ must be 1. Hence answer is option (2).

67. Which one of the following gates correspond to the truth table given below?

A	*B*	*Y*
1	1	0
1	0	1
0	1	1
0	0	1

(1) NAND (2) NOR (3) XOR (4) OR

Sol. Answer (1)

It is opposite of truth table of and gate hence it is a nand gate.

68. A truth table is given. Which of the following has this type of truth table?

A	*B*	*Y*
0	0	1
1	0	0
0	1	0
1	1	0

(1) AND gate (2) OR gate (3) XOR gate (4) NOR gate

Sol. Answer (4)

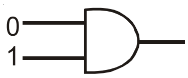
It is opposite of truth table of an OR gate hence it is or NOR gate.

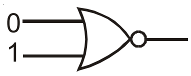
69. This symbol represents

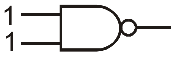
(1) AND gate (2) NOR gate (3) NAND gate (4) OR gate

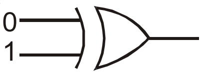
Sol. Answer (3)

70. Which of the following gates will have an output of 1?

(1) 

(2) 

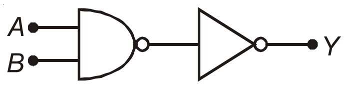
(3) 

(4) 

Sol. Answer (4)

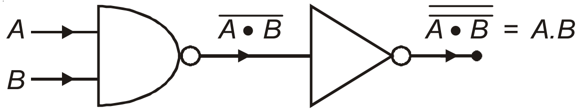
It is a XOR gate

71. Following diagram performs the logic function of



(1) AND gate (2) NAND gate (3) OR gate (4) XOR gate

Sol. Answer (1)



Hence it is an AND gate.

72. The output of OR gate is 1

(1) If both inputs are zero

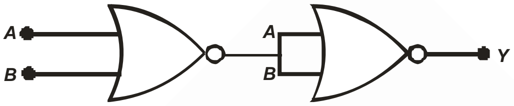
(2) If either or both inputs are 1

(3) Only if both inputs are 1

(4) If either input is zero

Sol. Answer (2)

73. In the following circuit, the output Y for all possible inputs A and B is expressed by the truth table



(1)

A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

(2)

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0

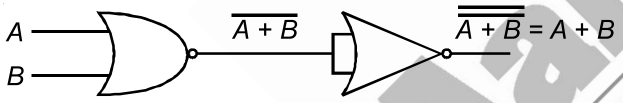
(3)

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

(4)

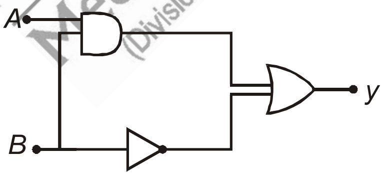
A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

Sol. Answer (3)



Hence it is an OR gate.

74. In the figure shown if $A = 1$ and $B = 0$ then y will be



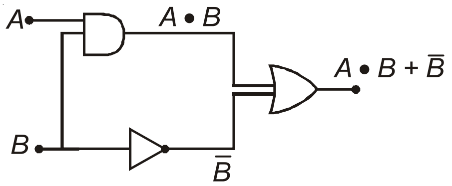
(1) 0

(2) 1

(3) 2

(4) Any of these

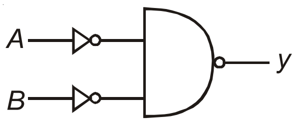
Sol. Answer (2)



$X = 0.1 + \overline{0}$ [$A = 1$ $B = 0$]

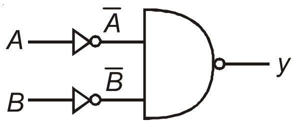
$X = 1$

75. Symbol given below represents



(1) AND (2) OR (3) NAND (4) NOR

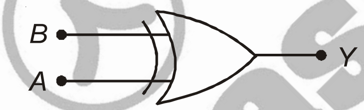
Sol. Answer (2)



$y = \overline{\bar{A} \bullet \bar{B}}$

$y = \bar{\bar{A}} + \bar{\bar{B}} = A + B$

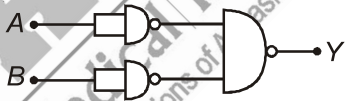
76. The given symbol represents the



(1) AND gate (2) NAND gate (3) NOR gate (4) XOR gate

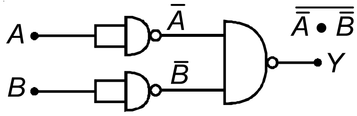
Sol. Answer (4)

77. Output Y of the gate shown in figure



(1) $Y = A \cdot B$ (2) $Y = A + B$ (3) $Y = A \oplus B$ (4) $Y = \overline{A \oplus B}$

Sol. Answer (2)



$\overline{\bar{A} \bullet \bar{B}} = \bar{\bar{A}} + \bar{\bar{B}} = A + B$

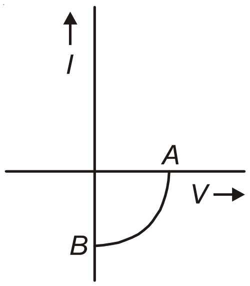
$Y = A + B$

78. Which of the following is the boolean expression for XOR gate?

(1) $y = A\bar{B} + \bar{A}B$ (2) $y = (A\bar{B}) \bullet (\bar{A}B)$ (3) $y = (A + \bar{B}) \bullet (\bar{A} + B)$ (4) $y = (AB)\,(\overline{AB})$

Sol. Answer (1)

79. The given graph represents *V*-*I* characteristic for a semiconductor device.



Which of the following statement is **correct**?

(1) It is *V*-*I* characteristic for solar cell where point *A* represents open circuit voltage and point *B* short circuit current

(2) It is for a solar cell and points *A* and *B* represent open circuit voltage and current, respectively

(3) It is for a photodiode and points *A* and *B* represent open circuit voltage and current, respectively

(4) It is for an LED and points *A* and *B* represent open circuit voltage and short circuit current respectively

Sol. Answer (1)

Voltage at *A* will be V_{OC} *i.e.*, open circuit voltage *i.e.*, cell supplies no current to circuit, at pont *B* condition of short circuit current.

80. The barrier potential of a *p*-*n* junction depends on :

a. Type of semiconductor material

b. Amount of doping

c. Temperature

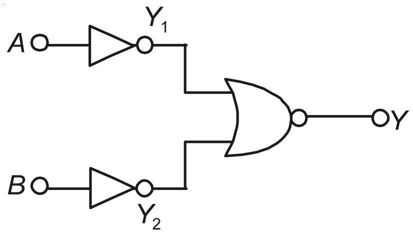
Which one of the following is correct?

(1) a and b only (2) b only (3) b and c only (4) a, b and c

Sol. Answer (4)

Barier potential depends upon types of semiconductor amount of dopping.

81. Which logic gate is represented by the following combination of logic gates?



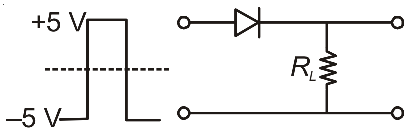
(1) NOR (2) OR (3) NAND (4) AND

Sol. Answer (4)

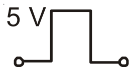
From boolean

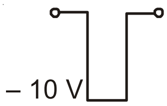
$$\overline{\overline{A} + \overline{B}} = A \cdot B$$

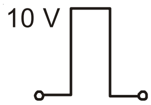
82. If in a p-n junction, a square input signal of 10 V is applied, as shown



then the output across R_L will be :

(1)


(2)


(3)


(4)


Sol. Answer (1)

SECTION - D

Assertion-Reason Type Questions

1. A : The conductivity of an intrinsic semiconductor at zero kelvin is zero.

   R : The bond strength of the semiconductor at zero kelvin is much higher as compared to the bond strength at room temperature.

Sol. Answer (3)

2. A : When base region has larger width, the collector current is small.

   R : At larger width of the base region the rate of electron-hole recombination is more which results in larger value of base current.

Sol. Answer (1)

3. A : The conductivity of a pure semiconductor increases on doping.

   R : Doping causes the reduction in bond strength.

Sol. Answer (3)

4. A : Semiconductors do not obey Ohm's law.

   R : In semiconductors the rate of flow of charge not only depends on the applied electric field but also on the availability of charge carriers.

Sol. Answer (1)

5. A : When a pure semiconductor is doped with a pentavalent impurity, the number of conduction electrons is increased while the number of holes is decreased.

   R : Some of the holes get recombined with the conduction electrons as the concentration of the conduction electrons is increased.

Sol. Answer (1)

6. A : In transistor common emitter mode as an amplifier is preferred over common base mode.

   R : In common emitter mode, the input signal is connect in series with the voltage applied to the base emitter junction.

Sol. Answer (2)

7. A : The energy gap between the valence band and conduction band is greater in silicon than in germanium.

   R : Thermal energy produces fewer minority carriers in silicon than in germanium.

Sol. Answer (2)

8. A : Light emitting diode (LED) emits spontaneous radiation.

   R : LED are forward biased *p*-*n* junctions.

Sol. Answer (1)

The flow of current through forward wired P – N junction career radial.

9. A : NAND or NOR gates are called digital building blocks.

   R : The repeated use of NAND (or NOR) gates can produce all the basic or complicated gates.

Sol. Answer (1)

10. A : In NPN transistors, electrons are current carriers inside as well as outside the transistor circuits.

    R : In PNP transistors, holes are responsible for current inside the transistors but outside the transistor, electrons are the current carriers.

Sol. Answer (2)

❑ ❑ ❑

Chapter 15

Communication System

Solutions

SECTION - A

Objective Type Questions

1. Out of the following, which is not an essential element of a communication system?

(1) Transmitter (2) Transducer (3) Receiver (4) Communication channel

Sol. Answer (2)

A tranducer is a device to convert energy from one form to the other.

2. A device which provides output in electrical form or it has input in electrical form is called a

(1) Transmitter (2) Receiver (3) Repeater (4) Transducer

Sol. Answer (4)

A tranducer converts energy from electrical to sound or vice versa.

3. Decrease in signal strength due to energy losses is called

(1) Distortion (2) Interference (3) Attenuation (4) Noise

Sol. Answer (3)

Fact.

4. The disturbance or distortion in the transmission and processing of message signals is called

(1) Noise (2) Attenuation (3) Interference (4) None of these

Sol. Answer (1)

Fact.

5. A repeater is a combination of

(1) Receiver (2) Amplifier (3) Transmitter (4) All of these

Sol. Answer (4)

A repeater receives signals from a place and further transmits it. It needs the help of all three components.

6. The audible range of frequencies is

(1) 20 kHz to 20 MHz (2) 20 Hz to 20 kHz (3) 20 Hz to 20 MHz (4) None of these

Sol. Answer (2)

Fact.

7. The frequency band of FM broadcast is

(1) 88 MHz to 108 MHz (2) 88 Hz to 88 kHz

(3) 800 kHz to 8000 MHz (4) None of these

Sol. Answer (1)

Fact.

8. If λ is wavelength of radio signals to be transmitted, then the length of Hertz antenna is

(1) λ (2) $\frac{\lambda}{4}$ (3) $\frac{\lambda}{2}$ (4) 2λ

Sol. Answer (3)

Fact.

9. Modulation is necessary

(1) To select suitable size of antenna

(2) To increase effective power radiated by antenna

(3) To avoid mixing up of signals from different transmitters

(4) All of these

Sol. Answer (4)

Fact.

10. A device that connects one computer to another across ordinary telephone lines is called

(1) Transducer (2) Fax (3) Modem (4) None of these

Sol. Answer (3)

Modem.

11. Three waves *A*, *B* and *C* of frequencies 1600 kHz, 5 MHz and 60 MHz, respectively are to be transmitted from one place to another. Which of the following is the most appropriate mode of communication?

(1) *A* is transmitted via space wave while *B* and *C* are transmitted via sky wave

(2) *A* is transmitted via ground wave, *B* via sky wave and *C* via space wave

(3) *B* and *C* are transmitted via ground wave while *A* is transmitted via sky wave

(4) *B* is transmitted via ground wave while *A* and *C* are transmitted via space wave

Sol. Answer (2)

12. A speech signal of 3 kHz used to modulate a carrier signal of frequency 1 MHz, using amplitude modulation. The frequencies of the side bands will be

(1) 1.003 MHz and 0.997 MHz (2) 3001 kHz and 2997 kHz

(3) 1003 kHz and 1000 kHz (4) 1 MHz and 0.997 MHz

Sol. Answer (1)

Side band frequency = $W_c + W_m$ and $W_c - W_m$

13. The velocity of electromagnetic waves in a dielectric medium (refractive index $\mu = 4$) is

(1) 3×10^8 metre/second
(2) 1.5×10^8 metre/second
(3) 6×10^8 metre/second
(4) 7.5×10^7 metre/second

Sol. Answer (4)

$$v = \frac{c}{\mu} = 7.5 \times 10^7 \text{ m/s}$$

14. An 'antenna' is

(1) Inductive
(2) Capacitative
(3) Resistive above its resonance frequency
(4) None of these

Sol. Answer (1)

Fact.

15. A message signal of frequency ω_m is superposed on a carrier wave of frequency ω_c to get an amplitude modulated wave (AM). The frequency of the AM wave will be

(1) ω_m
(2) ω_c
(3) $\frac{\omega_c + \omega_m}{2}$
(4) $\frac{\omega_c - \omega_m}{2}$

Sol. Answer (2)

Frequency of AM wave = Frequency of carrier wave.

16. A male voice after modulation-transmission sounds like that of a female to the receiver. The problem is due to

(1) Poor selection of modulation index (selected $0 < m < 1$)
(2) Poor bandwidth selection of amplifiers
(3) Poor selection of carrier frequency
(4) Loss of energy in transmission

Sol. Answer (2)

Fact/Theory.

17. A basic communication system consists of

A. Transmitter
B. Information source
C. User of information
D. Channel
E. Receiver

Choose the correct sequence in which these are arranged in a basic communication system

(1) ABCDE
(2) BADEC
(3) BDACE
(4) BEADC

Sol. Answer (2)

Fact.

18. Identify the mathematical expression for amplitude modulated wave

(1) $(A_c + A_m \sin\omega_m t)\cos(\omega_c t + \phi)$ (2) $A_c \sin\{\omega_c t + \phi + k_2 \nu_m(t)\}$

(3) $\{A_c + k_2 \nu_m(t)\}\sin(\omega_c t + \phi)$ (4) $A_c \nu_m(t)\sin[\omega_c t + \phi]$

Sol. Answer (1)

General equation of AM wave is

$(A_c + A_m \sin \omega_m t) \cos(\omega_c t + \phi)$

19. The distance between consecutive maxima and minima is given by

(1) $\lambda/2$ (2) 2λ (3) λ (4) $\lambda/4$

Sol. Answer (4)

Fact.

20. Long distance short-wave radio broad-casting uses

(1) Ground wave (2) Ionospheric wave (3) Direct wave (4) Sky wave

Sol. Answer (2)

Fact.

21. Broadcasting antennas are generally

(1) Omnidirectional type (2) Vertical type (3) Horizontal type (4) None of these

Sol. Answer (2)

Fact.

22. For television broadcasting, the frequency employed is normally

(1) 30 - 300 MHz (2) 30 - 300 GHz (3) 30 - 300 kHz (4) 30 - 300 Hz

Sol. Answer (1)

Fact.

23. The sound waves after being converted into electrical waves are not transmitted as such because

(1) They travel with the speed of sound

(2) The frequency is not constant

(3) They are highly absorbed by the atmosphere

(4) The height of antenna has to be increased several times

Sol. Answer (3)

Fact.

24. The process of superimposing signal frequency (*i.e.*, audio wave) on the carrier wave is known as

(1) Transmission (2) Reception (3) Modulation (4) Detection

Sol. Answer (3)

By definition/Fact.

25. In an amplitude modulated wave for audio -frequency of 500 cycles/second, the appropriate carrier frequency will be

(1) 50 cycles/s	(2) 100 cycles/s	(3) 500 cycles/s	(4) 50,000 cycles/s

Sol. Answer (4)

Frequency of carrier wave must be more than modulating wave. Hence answer is (4).

26. If there were no atmosphere, the average temperature on the surface of earth would be

(1) Lower	(2) Higher	(3) Same as now	(4) 0°C

Sol. Answer (1)

The atmosphere traps heat and keeps the earth warmer.

27. The T.V. transmission tower in Delhi has a height of 240 m. The distance up to which the broadcast can be received, (taking the radius of earth to be 6.4×10^6 m) is

(1) 100 km	(2) 60 km	(3) 55 km	(4) 50 km

Sol. Answer (3)

Height of TV tower h = 240 m

Distance = $\sqrt{2Rh}$ = $\sqrt{2\times6.4\times10^6\times240}$ = 55425 km = 55.425 km

28. Radio wave of constant amplitude can be generated with

(1) Filter	(2) Rectifier	(3) FET	(4) Oscillator

Sol. Answer (4)

Fact.

29. Ozone layer above earth's atmosphere will not

(1) Prevent infrared radiations from sun reaching earth

(2) Prevent infrared rays reflected from earth from escaping earth's atmosphere

(3) Prevent ultraviolet rays from sun

(4) Reflect back radiowaves

Sol. Answer (4)

Fact.

30. An audio signal of 0.1 V is used in amplitude modulation of a career wave of amplitude 0.3. The modulation index is

(1) 3	(2) $\frac{1}{3}$	(3) 0.03	(4) None of these

Sol. Answer (2)

$\mu = \frac{A_m}{A_c}$ or $\mu = \frac{0.1}{0.3}$

31. The frequency of amplitude modulated wave is equal to

(1) Frequency of carrier wave (f_c)
(2) Frequency of modulating signal (f_m)
(3) $\frac{f_c + f_m}{2}$
(4) $\frac{f_c - f_m}{2}$

Sol. Answer (1)

Fact/By definition.

32. The radio waves of frequency ranging from 2 MHz to 30 MHz are called

(1) Sky waves
(2) Ground waves
(3) Space waves
(4) None of these

Sol. Answer (1)

Fact.

33. A device which connects one computer to another is known as

(1) Photostat machine
(2) Laser lazer
(3) Modem
(4) FAX

Sol. Answer (3)

Fact.

34. Loss of strength of a signal is known as

(1) Noise
(2) Attenuation
(3) Modulation
(4) De-modulation

Sol. Answer (2)

By definition/Fact.

35. Which of the following is an advantage of FM over AM?

(1) Less noise
(2) Larger bandwidth
(3) More circuit complexity
(4) Can be transmitted to longer distance

Sol. Answer (1)

Fact.

36. The process of changing some characteristic of a carrier wave in accordance with the signal to be transmitted is called

(1) Amplification
(2) Rectification
(3) Modulation
(4) None of these

Sol. Answer (3)

By definition/Fact.

37. Modulation is done in

(1) Transmitter
(2) Radio receiver
(3) Communication channel
(4) None of these

Sol. Answer (1)

Fact.

38. "Need for modulation" arises due to which of the following reasons?

(1) Power radiated by an antenna $\propto \left(\frac{1}{\lambda}\right)^2$
(2) It allows multiple user-friendly communication
(3) Height of antenna required $\propto \left(\frac{\lambda}{4}\right)$
(4) All of these

Sol. Answer (4)

All of the reasons are true.

39. A ground receiver station is receiving a signal at 500 MHz transmitted from a ground transmitter at a height of 300 m located at a distance of 500 km. It is coming via

(1) Ground wave (2) Space wave (3) Sky wave (4) Satellite communication

Sol. Answer (4)

40. The area of the region covered by the T.V., broadcast by a T.V. tower of height 100 m is (in m^2)

(1) $8.4\pi \times 10^8$ m^2 (2) $1.28\pi \times 10^9$ m^2 (3) $1.92\pi \times 10^8$ m^2 (4) $8.4\pi \times 10^9$ m^2

Sol. Answer (2)

$A = 2\pi Rh$

Take $R = 6.4 \times 10^6$ and $h = 1000$

41. An information signal of 150 MHz is to be sent across a distance of 40 km. Which mode of communication is suitable?

(1) Ground wave propagation
(2) Space wave propagation
(3) Sky wave propagation
(4) Satellite communication

Sol. Answer (2)

Fact.

42. For VHF television broadcasting, the frequency employed is generally

(1) 54 - 72 MHz (2) 420 - 890 MHz (3) 540 - 1600 kHz (4) 88 - 108 kHz

Sol. Answer (1)

Fact.

43. Line of sight (LOS) communication is also known as

(1) Ground wave communication
(2) Space wave communication
(3) Sky wave communication
(4) Ionospheric communication

Sol. Answer (2)

By definition/Fact.

44. If a carrier of 1000 kHz is used to carry the signal, the length of transmitting antenna will be equal to

(1) 3 m (2) 30 m (3) 75 m (4) 3000 mn

Sol. Answer (3)

Wavelength = $\frac{C}{10^6}$ = 300 m

Size of antenna = $\frac{\lambda}{4} = \frac{300}{4} = 75$ m

45. Modem is a device used for

(1) Converting digital to analog signals (2) Converting analog signal to digital signals

(3) Either of these (4) None of these

Sol. Answer (3)

By definition.

46. The communication satellite are parked at a height of (from surface of earth)

(1) 36 km (2) 360 km (3) 3600 km (4) 36000 km

Sol. Answer (4)

Fact.

47. 3-30 MHz frequency range is known as

(1) HF (2) VHF (3) UHF (4) MF

Sol. Answer (1)

Fact.

48. Long distance short wave radio broadcasting uses

(1) Ground wave (2) Sky wave (3) Direct wave (4) Space wave

Sol. Answer (2)

Fact.

49. A photodetector is made from a compound semiconductor with band gap 0.73 eV. The maximum wavelength it can detect is

(1) 12400 Å (2) 17030 Å (3) 6200 Å (4) 1703 Å

Sol. Answer (2)

$\frac{hC}{\lambda} = 0.73 \times 1.6 \times 10^{-19}$

Solve for λ

50. Satellite communication is generally carried out for frequencies above

(1) 1 MHz (2) 1 kHz (3) 20 MHz (4) 20 kHz

Sol. Answer (3)

Fact.

SECTION - B

Objective Type Questions

1. A demodulator circuit contains

(1) A diode
(2) A transistor
(3) A solar cell
(4) Logic gate

Sol. Answer (1)

Fact.

2. An AM broadcasting station has a vertical telescopic transmitting antenna and a receiver has a vertical telescopic antenna. The receiver will respond to

(1) Electric component of the electromagnetic wave produced by antenna
(2) Magnetic component of the electromagnetic wave produced by antenna
(3) Both electric and magnetic components of electromagnetic wave produced by antenna
(4) 50% of both components of electromagnetic wave produced by antenna

Sol. Answer (1)

3. The intensity of a light pulse travelling along an optical fibre decreases exponentially with distance according to the relation $I = I_0e^{-0.0693x}$ where x is in km and I_0 is intensity of incident pulse. The intensity of pulse reduces to $\frac{1}{4}$ after travelling a distance

(1) 1 km
(2) 10 km
(3) 20 km
(4) 40 km

Sol. Answer (3)

$I = I_0e^{-0.0693x}$

$\frac{I_0}{4} = I_0e^{-0.0693x}$

$\frac{1}{4} = e^{-0.0693x}$

$\log_e\left(\frac{1}{4}\right) = -0.0632\ x$

$\log_e 1 - \log_e 4 = -\ 0.06932\ x$

$0 - 2.300 \times 2 \log_{10}2 = -\ 0.06932\ x$

$x = 20$ km

4. An audio signal of amplitude one half the carrier amplitude is used in an amplitude modulation. The modulation index is

(1) 2
(2) 0.25
(3) 0.50
(4) 0.125

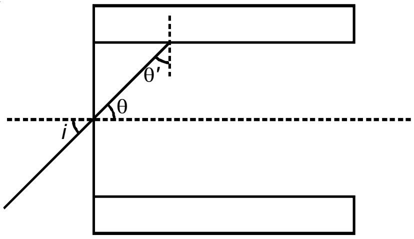
Sol. Answer (3)

$\mu = \frac{A_m}{A_c} = 0.5$

5. Numerical aperture of an optical fibre (w.r.t. air) having core and cladding refractive indices n_1 and n_2 respectively is

(1) $\sqrt{n_1^2 - n_2^2}$
(2) $\sin^{-1}\sqrt{n_1^2 - n_2^2}$
(3) $\cos^{-1}\sqrt{n_1^2 - n_2^2}$
(4) $\tan^{-1}\sqrt{n_1^2 - n_2^2}$

Sol. Answer (1)



$n_1 = \mu$ of core

$n_2 = \mu$ of cladding

$\theta' = 90 - \theta$

$n_1 \sin\theta_c = n_2 \sin 90^\circ$

$\therefore \quad n_1 \sin\theta' = n_2$

$\therefore \quad \sin\theta' = \frac{n_2}{n_1}$

Numerical Perture = $n_1 \sin\theta = n_1 \sin(90 - \theta') = n_1 \cos\theta_c$

Numerical aperture = $n_1\sqrt{1-\sin^2\theta_c} = \sqrt{n_1^2 - n_2^2}$

6. A device which converts one type of energy into other is known as

(1) Attenuator (2) Transmitter (3) Receiver (4) Transducer

Sol. Answer (4)

By definition.

7. On a particular day, the maximum frequency reflected from the ionosphere is 10 MHz. The maximum electron density in ionosphere is

(1) $10^6/\text{m}^2$ (2) $10^{12}/\text{m}^3$ (3) $1.23 \times 10^{12}/\text{m}^3$ (4) $1/9 \times 10^6/\text{m}^3$

Sol. Answer (3)

$f_c = 9\sqrt{(N_{\text{max}})}$

8. "Need for modulation" arises due to which of the following reasons?

(1) Power radiated by an antenna $\propto \left(\frac{1}{\lambda}\right)^2$ (2) It allows multiple user-friendly communication

(3) Height of antenna required $\propto \left(\frac{\lambda}{4}\right)$ (4) All of these

Sol. Answer (4)

Fact/Theory.

9. The area of the region covered by the T.V., broadcast by a T.V. tower of height 100 m is (in m^2)

(1) $8.4\pi \times 10^8$ (2) $1.28\pi \times 10^9$ (3) $1.92\pi \times 10^8$ (4) $8.4\pi \times 10^9$

Sol. Answer (2)

$A = 2\pi RH$ where $h = 100$ m; $R = 6.4 \times 10^6$

10. An optical fibre having core of refractive index $\sqrt{3}$ and cladding of refractive index 1.5 is kept in air. The maximum angle of acceptance is

(1) 60° (2) 45° (3) 30° (4) 15°

Sol. Answer (1)

$$\sin\theta_c = \frac{1}{1.5} \quad ....(i)$$

$$\mu = \frac{\sin i}{\sin r}$$

$$\sqrt{3} = \frac{\sin i}{\sin r} \quad ....(ii)$$

$$r + \theta_c = \frac{\pi}{2} \quad ....(iii)$$

Solve for *i*

11. The communication satellites are parked at an altitude of

(1) 36 km (2) 360 km (3) 3600 km (4) 36000 km

Sol. Answer (4)

Fact.

12. A photodetector is made of a compound semiconductor with the band gap of 0.73eV. The maximum wavelength it can detect is

(1) 12400 Å (2) 17030 Å (3) 6200 Å (4) 1703 Å

Sol. Answer (2)

$$\frac{\lambda C}{\lambda_{\max}} = 1.6 \times 10^{-19} \times 0.73$$

Solve for $\lambda_{\max}$

13. Modem is a device used for

(1) Modulation (2) Demodulation

(3) Converting physical variables into electrical form (4) Both (1) & (2)

Sol. Answer (4)

By definition/Fact.

14. If a carrier wave of 1000 kHz is used to carry the signal, the length of transmitting antenna will be equal to

(1) 3 m (2) 30 m (3) 75 m (4) 3000 m

Sol. Answer (3)

$$\lambda = \frac{c}{f} = \frac{c}{10^6} = 300 \text{ m}$$

Length of antenna = $\frac{\lambda}{4}$

15. A ground receiver station is receiving a signal at 100 MHz transmitted from a ground transmitter at a height of 300 m located at a distance of 1000 km. It is coming via

(1) Ground wave (2) Space wave (3) Sky wave (4) Satellite communication

Sol. Answer (4)

Fact.

16. In an AM wave for audio frequency of 3400 cycle/s, the appropriate carrier frequency will be

(1) 1000 Hz (2) 34000 MHz (3) 60000 Hz (4) 800,000 Hz

Sol. Answer (4)

Fact.

17. In frequency modulation, the amount of frequency deviation depends on the

(1) Frequency of audio signal (2) Amplitude of audio signal

(3) Both the frequency and amplitude of audio signal (4) None of these

Sol. Answer (2)

Fact.

18. The 'Facsimile Transmission (FAX)' involves

(1) Speech communication (2) Telegraphy

(3) Exact reproduction of a document or static picture (4) Taking photograph

Sol. Answer (3)

Fact.

19. If μ_1 and μ_2 are the refractive indices of the material of core and cladding respectively of an optical fiber, then

(1) $\mu_1 > \mu_2$ (2) $\mu_1 < \mu_2$ (3) $\mu_1 = \mu_2$ (4) $\mu_1 \leq \mu_2$

Sol. Answer (1)

Refractive index of core is always greater than cladding in an optical fibre.

20. A transmitting antenna at the top of tower has a height 32 m and height of receiving antenna is 50 m. Minimum distance between them for satisfactory LOS mode of communication is

(1) 40 km (2) 45 km (3) 60 km (4) 100 km

Sol. Answer (2)

$\because\ d = \sqrt{2RH_T} + \sqrt{2RH_R} = 45536 \text{ m} = 45.536 \text{ km}$

21. Which of the following modulation index produces noise?

(1) 0.5 (2) 0.8 (3) 1.2 (4) 0.7

Sol. Answer (3)

Medulation index greater than one produces noise. We keep modulation index less than 1.

SECTION - C

Previous Years Questions

1. The radiowaves of frequency 300 MHz to 3000 MHz belong to

(1) High frequency band (2) Very high frequency band

(3) Ultra high frequency band (4) Super high frequency band

Sol. Answer (3)

Fact.

2. Range of frequencies alotted for commerical FM radio broad cast is

(1) 88 to 108 MHz (2) 88 to 108 kHz (3) 8 to 88 MHz (4) 88 to 108 GHz

Sol. Answer (1)

Fact.

3. The length of a half wave dipole antenna at 30 MHz is

(1) 10 m (2) 50 m (3) 5 m (4) 100 m

Sol. Answer (3)

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{3 \times 10^7} = 10 \text{ m}$$

Length of half wave antenna = $\frac{\lambda}{2}$ = 5 m

4. In a single reflection from the ionosphere, the sky waves cover a distance on ground not more than

(1) 400 m (2) 4000 m (3) 400 km (4) 4000 km

Sol. Answer (4)

Fact.

5. The maximum range of ground or surface wave propagation depends on

(1) The frequency of radiowaves only (2) Power of the transmitter only

(3) Both on frequency as well as power (4) Wavelength of radiowaves

Sol. Answer (3)

Fact.

6. Refractive index of ionosphere is

(1) Zero (2) More than one (3) Less than one (4) One

Sol. Answer (3)

Refractive index of ionosphere is less than 1.

7. For sky wave propagation of a 10 MHz signal, what should be the minimum electron density in ionosphere?

(1) 1.2×10^8 m^{-3} (2) 1.2×10^{12} m^{-3} (3) 1.2×10^{14} m^{-3} (4) 1.2×10^{16} m^{-3}

Sol. Answer (2)

$$f_c = 9\sqrt{N_{\max}}$$

8. The TV tower has a height of 100 m. What is the maximum distance upto which the T.V. transmission can be received ?

(1) 34.77 km (2) 32.70 km (3) 35.2 km (4) 40.70 km

Sol. Answer (3)

Maximum distance is given by $d = \sqrt{2Rh}$

$R = 6.4 \times 10^6$m $h = 100$ m

9. If both the length of the antenna and the wavelength of the signal to the transmitted are doubled, the power radiated by the antenna

(1) Remains constant (2) Is doubled (3) Is halved (4) Increases 16 times

Sol. Answer (1)

$$\because \ P \propto \left(\frac{L}{\lambda}\right)^2$$

10. Arrange the following communication frequency bands in the increasing order of frequencies

a. AM broadcast b. Cellular mobile radio c. FM broadcast d. Television UHF

e. Satellite communication

(1) a, b, c, d, e (2) a, c, b, d, e (3) e, b, d, c, a (4) a, c, d, b, e

Sol. Answer (4)

Fact.

11. Modulation is the process of superposing

(1) Low frequency radio signal on low frequency audiowaves

(2) Low frequency audio signal on high frequency waves

(3) High frequency radio signal on low frequency audio signal

(4) High frequency audio signal on low frequency radiowaves

Sol. Answer (2)

By definition/Fact.

12. The waves used by artificial satellites for communication purposes are

(1) Microwaves (2) AM radiowaves (3) X-rays (4) FM radiowaves

Sol. Answer (1)

Fact.

13. In communication with help of antenna, if height is doubled, then the range covered which was initially '*r*' would become

(1) $\sqrt{2}r$ (2) $3r$ (3) $4r$ (4) $5r$

Sol. Answer (1)

Range(r) = $\sqrt{2Rh}$

$$r_2 = \sqrt{2R2h}$$

$$r_2 = \sqrt{2}r$$

14. Which range of frequencies can be transmitted suitably by sky wave propagation?

(1) 5 kHz to 500 kHz (2) 1 MHz to 2 MHz (3) 2 MHz to 20 MHz (4) Above 50 MHz

Sol. Answer (3)

Fact.

15. In an optical fibre, the light signal is transmitted by

    (1) Refraction at the core-cladding interface

    (2) Interference between the incident and inflected waves

    (3) Repeated total internal reflections at the core and cladding interface

    (4) Polarisation of optical signals

Sol. Answer (3)

Fact.

16. Fraction of total power carried by the side bands (P_S/P_T) is given by

    (1) m^2 (2) $\frac{2+m^2}{m^2}$ (3) $\frac{2+m}{m}$ (4) $\frac{m^2}{2+m^2}$

Sol. Answer (4)

Fact.

17. The band width of amplitude modulation is

    (1) Equal to frequency of aduio signal (2) Double the frequency of audio signal

    (3) Half the frequency of carrier wave (4) Double the frequency of carrier wave

Sol. Answer (2)

Band width = $2\omega_m$

18. Electromagnetic waves with frequencies greater than the critical frequency of ionosphere cannot be used for communication using sky wave propagation because

    (1) The refractive index of ionosphere becomes very high for $f > f_c$

    (2) The refractive index of ionosphere becomes very low for $f > f_c$

    (3) The refractive index of ionosphere becomes very high for $f < f_c$

    (4) The refractive index of ionosphere becomes very low for $f < f_c$

Sol. Answer (1)

SECTION - D

Assertion-Reason Type Questions

1. A : Modulator is an essential component of a transmitter.

   R : Modulator superimposes a low frequency message signal on a high frequency carrier wave.

Sol. Answer (2)

2. A : Short wave bands are used for transmission of radio waves to a large distance.

   R : Short waves are reflected by ionosphere.

Sol. Answer (1)

3. A : If the amplitude of a message signal is half of the amplitude of the carrier wave, then the index of modulation is 50%.

   R : In amplitude modulation the amplitude of the carrier wave varies in accordance with the signal voltage of the message signal.

Sol. Answer (2)

$\mu = \frac{A_m}{A_c}$. Hence assertion is true.

4. A : The bandwidth of a modulated signal is $2f_m$ in amplitude modulation, where f_m is the frequency of the modulating signal.

   R : In case of amplitude modulation the frequency of a modulated signal is equal to the frequency of the carrier wave.

Sol. Answer (2)

5. A : The process of demodulation is carried out to retrieve the message signal.

   R : The range of the line-of-sight propagation is limited mainly due to earth's curvature.

Sol. Answer (2)

6. A : Transducer in communication system converts electrical signal into a physical quantity.

   R : For information signal to be transmitted directly to long distances, modulation is not a necessary process.

Sol. Answer (4)

7. A : Microwave propagation is better than the skywave propagation.

   R : Microwaves have frequencies 100 to 300 GHz which have very good directional properties.

Sol. Answer (1)

8. A : In satellite communication, generally we keep different uplink and downlink frequencies.

   R : In case of failures, the detection of faulty link becomes easier if frequencies are kept different.

Sol. Answer (1)

9. A : Remote sensing satellites can send continuous pictures of the earth even when clouds are present or it is dark night.

   R : These satellites use infrared as well as microwaves apart from visible light photography.

Sol. Answer (1)

10. A : Optical communication system is more economical than other systems of communications.

    R : The information carrying capacity of a communication system is directly proportional to its band width.

Sol. Answer (1)

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