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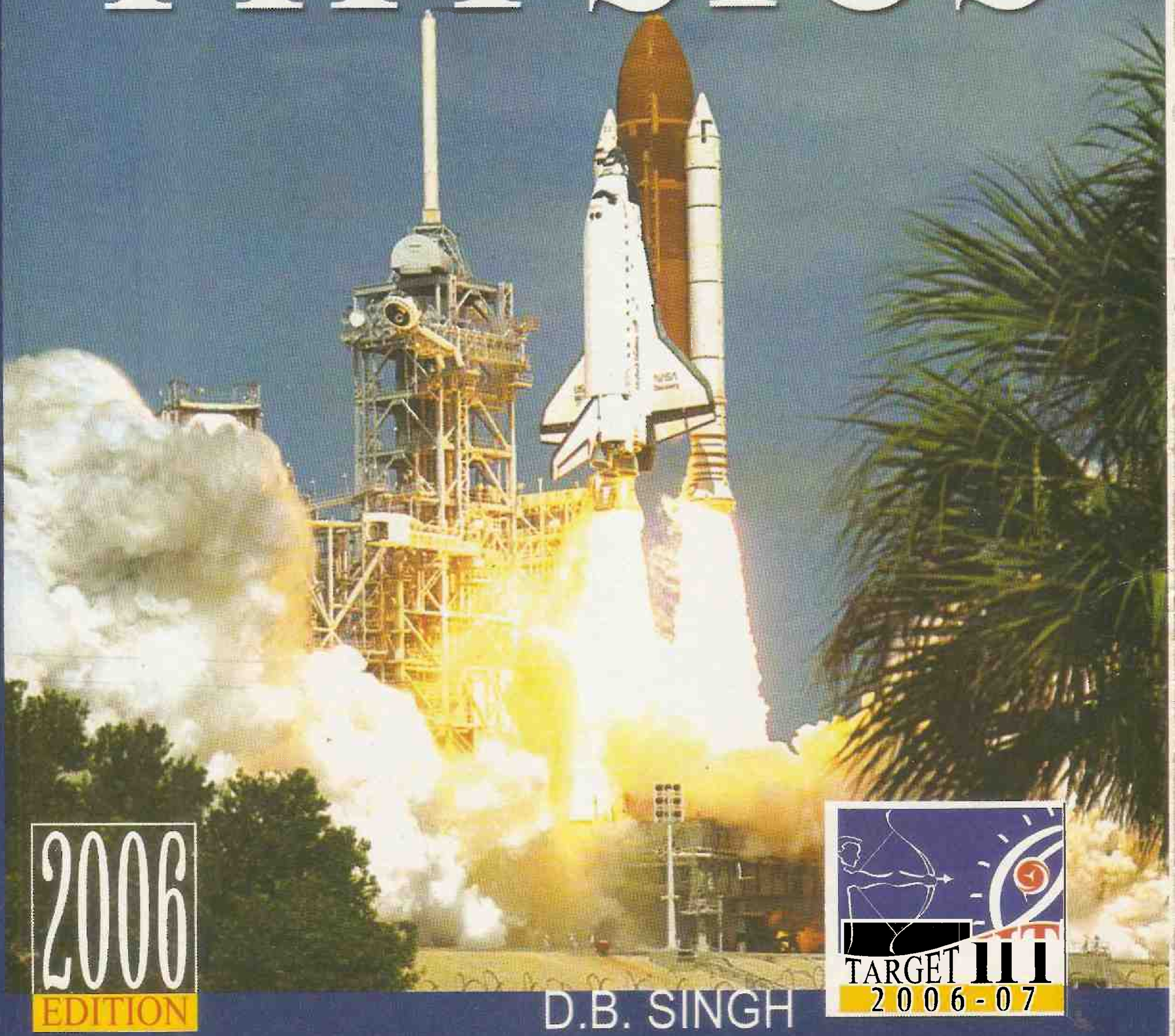

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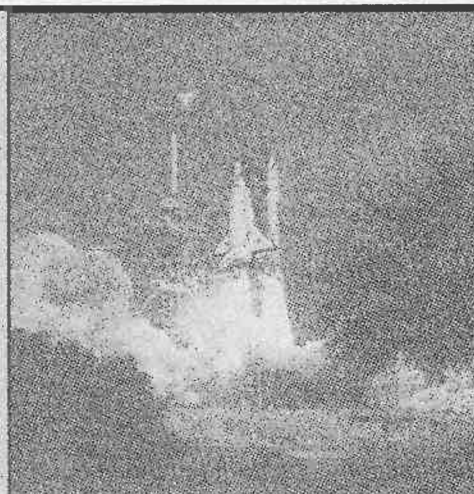

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PREFACE

The overwhelming response given to my book "AIEEE Physics" from students & teaching faculties has given me synergistic energy to bring forth 'Second Edition' of this book.

"AIEEE Physics" second edition is divided into 34 chapters, constituting increased number of questions- Objective questions, divided into level 1 and level 2, with star marked questions which are mainly subjective in nature. At the end of the book we have given AIEEE Solved Papers (2002,03,04 and 2005)

My teaching experience has polished my skills in presenting this book, eliminating all doubts in the mind of young students giving them a clear approach on the subject, preparing them more confidently without the examination phobia.

So, students all the very best for your forthcoming examinations.

D.B. Singh

CONTENTS

NOTE: * *In objective questions * (star) marked questions are subjective in nature. These questions are for practice purpose, to understand the theoretical concept.*

1

Units and Measurements

Syllabus: Units for measurement, system of units—SI, fundamental and derived units, dimensions and their applications.

Review of Concepts

1. Grammar of units:

(a) The unit is always written in singular form. *e.g.*, foot not feet.

(b) No punctuation marks are used after unit. *e.g.*, sec not secs.

(c) If a unit is named after a person, the unit is not written with capital initial letter. *e.g.*, newton not Newton.

(d) If a unit is named after a person, the symbol used is a capital letter. The symbols of other units are not written in capital letters. *e.g.*, N for newton (not n).

(e) More than one unit is not used at a time.

e.g., 1 poise = 1 g/s cm (and not 1 gm/s/cm)

2. Representation of physical quantity:

(a) Physical quantity $= nu$

Here n = numerical value of physical quantity in a proper unit u.

(b) $n_1u_1 = n_2u_2$

Here, n_1 = numerical value of physical quantity in proper unit u_1

n_2 = numerical value of physical quantity in proper unit u_2.

(c) As the unit will change, numerical value will also change. *e.g.*, acceleration due to gravity,

$$g = 32 \text{ ft/s}^2 = 9.8 \text{ m/s}^2$$

(d) **Addition and subtraction rule:** Two or more physical quantities are added or subtracted when their units and dimensions are same.

(e) If $A + B = C - D$

Then unit of A = unit of B = unit of C = unit of D

Also, dimensions of

$$A = \text{dimensions of } B = \text{dimensions of } C$$
$$= \text{dimensions of } D$$

(f) After multiplication or division, the resultant quantity may have different unit.

3. **Unit**

Unit → Fundamental unit | Derived unit | Supplementary unit | Practical unit

(I) Fundamental unit: It is independent unit. Fundamental units in any system of measurements are independent to each other. In other words, one fundamental unit cannot be expressed in the form of other fundamental unit.

Fundamental Units in Different System of Measurement:

A. MKS System (Mass, Kilogram, Second System)

	Quantity	Unit	Abbreviation
(i)	Mass	kilogram	kg
(ii)	Length or Distance	metre	m
(iii)	Time	second	s

B. CGS System or Gaussion System (Centimetre, Gram, Second System)

	Quantity	Unit	Abbreviation
(i)	Mass	gram	g
(ii)	Length or Distance	centimetre	cm
(iii)	Time	second	s

C. FPS System (Foot, Pound, Second System)

	Quantity	Unit	Abbreviation
(i)	Mass	slug	...
(ii)	Length or Distance	foot	ft
(iii)	Time	second	s

D. MKSA System

	Quantity	Unit	Abbreviation
(i)	Mass	kilogram	kg
(ii)	Length	metre	m
(iii)	Time	second	s
(iv)	Electric current	ampere	A

E. MKSQ System

	Quantity	Unit	Abbreviation
(i)	Mass	kilogram	kg
(ii)	Length	metre	m
(iii)	Time	second	s
(iv)	Electric charge	coulomb	C

F. SI System (International System of Units)

This system is result of CGPM meeting in 1971. Now-a-days this system is popular throughout the world.

	Quantity	Unit	Abbreviation
(i)	Mass	kilogram	kg
(ii)	Length	metre	m
(iii)	Time	second	s
(iv)	Electric current	ampere	A
(v)	Temperature	kelvin	k
(vi)	Amount of substance	mole	mol
(vii)	Luminous intensity	candela	cd

Definition of Fundamental Units :

(i) Kilogram : The standard of mass was established in 1887 in France. One kilogram is defined as the mass of a cylinder made of platinum-iridium placed at the international Bureau of weights and measures in Sevres, France.

(ii) Metre : The SI unit of length was defined with most precision in 1983, at the seventeenth general conference on weights and measures. According to this, one metre is defined as the distance travelled by light in vacuum during a time interval of $\frac{1}{299792458}$ second.

(iii) Second : One second is defined as the time required for 9192631770 periods of the light wave emitted by caesium-133 atoms making a particular atomic transition.

(II) Supplementary unit : The unit having no dimensions is supplementary unit.

e.g., Plane angle $\longrightarrow$ Radian

Solid angle $\longrightarrow$ Steradian

(III) Practical units : A larger number of units are used in general life for measurement of different quantities in comfortable manner. But they are neither fundamental units nor derived units.

Generally, the length of a road is measured in mile. This is the practical unit of length. Some practical units are given below :

(a) 1 fermi = 1 fm = 10^{-15} m

(b) 1 X-ray unit = $1 \times u = 10^{-13}$ m

(c) 1 angstrom = 1 Å – 10^{-10} m

(d) 1 micron = 1 μm = 10^{-6} m

(e) 1 astronomical unit = 1 Au = 1.49×10^{11} m
[Average distance between sun and earth, *i.e.*, radius of earth's orbit]

(f) 1 light year = 1 ly = 9.46×10^{15} m
[Distance that light travels in 1 year in vacuum]

(g) 1 parsec = 1 pc = 3.08×10^{16} m = 3.26 light year
[The distance at which a star subtends an angle of parallex of 1 s at an arc of 1 Au].

(h) One shake = 10^{-8} second.

(i) One slug = 14.59 kg

(j) One pound = 453.6 gram weight

(k) One metric ton = 1000 kg

(l) 1 barn = 10^{-28} m^2

(m) 1 atmospheric pressure = 1.013×10^5 N/m^2
= 760 mm of Hg

(n) 1 bar = 10^5 N/m^2 or pascal

(o) 1 torr = 1 mm of Hg = 133.3 N/m^2

(p) 1 mile = 1760 yard = 1.6 kilometre

(q) 1 yard = 3 ft

(r) 1 ft = 12 inch

(s) 1 inch = 2.54 cm

(t) 1 poiseuille = 10 poise

(u) One chandra shekhar limit = 1.4 × mass of Sun

(IV) Derived units : Derived unit is dependent unit. It is derived from fundamental units. Derived unit contains one or more than one fundamental unit.

Method for Finding Derived Unit :

Step I : Write the formula of the derived quantity.

Step II : Convert the formula in fundamental physical quantities.

Step III : Write the corresponding units in proper system.

Step IV : Make proper algebraic combination and get the result.

Example : Find the SI unit of force.

Solution : Step I $\rightarrow F = ma$

$$\text{Step II} \rightarrow F = m\frac{\Delta v}{\Delta t} = \frac{m}{\Delta t}\frac{\Delta s}{\Delta t}$$

$$\text{Step III} \rightarrow F = \frac{\text{kilogram} \times \text{metre}}{\text{second} \times \text{second}}$$

Step IV $\rightarrow$ The unit of force

= kilogram metre per second^2

4. Abbreviations for multiples and submultiples:

Factor	Prefix	Symbol
10^{24}	yotta	Y
10^{21}	zetta	Z
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10^{1}	deka	da
10^{-1}	deci	d
10^{-2}	centi	cm
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f

Factor	Prefix	Symbol
10^{-18}	atto	a
10^{-21}	zepto	z
10^{-24}	yocto	y
10^{6}	million	
10^{9}	billion	
10^{12}	trillion	

5. Some approximate lengths:

Measurement	Length in metres
Distance to the first galaxies formed	2×10^{26}
Distance to the Andromeda galaxy	2×10^{22}
Distance to the nearest star. (Proxima Centauri)	4×10^{16}
Distance of Pluto	6×10^{12}
Radius of Earth	6×10^{6}
Height of Mount Everest	9×10^{3}
Thickness of this page	1×10^{-4}
Length of a typical virus	1×10^{-8}
Radius of a hydrogen atom	5×10^{-11}
Radius of a proton	1×10^{-15}

6. Some approximate time intervals:

Measurement	Time interval in second
Life time of a proton (predicted)	1×10^{39}
Age of the universe	5×10^{17}
Age of the pyramid of cheops	1×10^{11}
Human life expectancy	2×10^{9}
Length of a day	9×10^{4}
Time between human heart beats	8×10^{-1}
Life time of the Muon	2×10^{-6}
Shortest lab light pulse	6×10^{-15}
Life time of the most unstable particle	1×10^{-23}
The Plank time	1×10^{-43}

7. Some approximate masses:

Object	Mass in kilogram
Known universe	1×10^{53}
Our galaxy	2×10^{41}
Sun	2×10^{30}
Moon	7×10^{22}
Asteroid Eros	5×10^{15}
Small mountain	1×10^{12}
Ocean liner	7×10^{7}
Elephant	5×10^{3}
Grape	3×10^{-3}
Speck of dust	7×10^{-10}
Penicillin molecule	5×10^{-17}
Uranium atom	4×10^{-25}
Proton	2×10^{-27}
Electron	9×10^{-31}

8. Dimensions and Dimensional Formulae: The dimensions of a physical quantity are powers raised to fundamental units to get the derived unit of that physical quantity. The corresponding expression is known as dimensional formula.

In the representation of dimensional formulae, fundamental quantities are represented by one letter symbols.

Fundamental Quantity	Symbol
Mass	M
Length or Distance	L
Time	T
Electric current	I
Temperature	K
Amount of substance	mol
Luminous intensity	cd

Method for finding dimensional formulae :

Step I : Write the formula of physical quantity.

Step II : Convert the formula in fundamental physical quantity.

Step III : Write the corresponding symbol for fundamental quantities.

Step IV : Make proper algebraic combination and get the result.

Example : Find the dimensions of momentum.

Solution : Step I $\rightarrow$ Momentum $=$ Mass $\times$ Velocity

Step II $\rightarrow$ Momentum $= \text{Mass} \times \dfrac{\text{Displacement}}{\text{Time}}$

Step III $\rightarrow$ Momentum $= \dfrac{[ML]}{[T]}$

Dimensional formula of momentum

$$= [\text{Momentum}] = [MLT^{-1}]$$

The dimensions of momentum are 1 in mass, 1 in length and -1 in time.

Example : The unit of gravitational constant is Nm^2/kg^2. Find dimensions of gravitational constant.

Solution : Step I $\rightarrow$ Write physical quantities of corresponding units.

Here, $$\frac{Nm^2}{kg^2} = \frac{\text{Force (Length)}^2}{(\text{Mass})^2}$$

Step II $\rightarrow$ Convert derived physical quantities in fundamental quantities.

$$\text{Gravitational constant} = \frac{\text{Force} \times (\text{Length})^2}{(\text{Mass})^2}$$

$$= \frac{(\text{Mass} \times \text{Acceleration}) \times (\text{Length})^2}{(\text{Mass})^2}$$

$$= \frac{\text{Mass}}{(\text{Mass})^2} \times \left(\frac{\text{Change in velocity}}{\text{Time}}\right)(\text{Length})^2$$

$$= \frac{(\text{Length})^2}{\text{Mass} \times \text{Time}}\left(\frac{\text{Distance}}{\text{Time}}\right)$$

Step III → Use proper symbols of fundamental quantities.

$$\text{Gravitational constant} = \frac{[L^2]}{[MT]} \cdot \frac{[L]}{[T]}$$

∴ The dimensional formula of gravitational constant

$$= [\text{Gravitational constant}] = \left[\frac{L^2}{MT}\frac{L}{T}\right] = [M^{-1}L^3T^{-2}]$$

9. Unit and Dimensions of some Physical Quantities

S. No.	Physical Quantity	Formula	Name of SI Unit	SI Units	Dimensional Formula
1.	Displacement or distance or length	length	metre	m	$M^0L^1T^0$
2.	Mass	—	kilogram	kg	$M^1L^0T^0$
3.	Time	—	second	s	$M^0L^0T^1$
4.	Electric current	—	ampere	A	$M^0L^0T^0I^1$
5.	Thermodynamic temperature	—	kelvin	K	—
6.	Amount of substance	—	mole	mol	—
7.	Luminous intensity	—	candela	cd	—
8.	Area	length × breadth	square metre	m^2	$M^0L^2T^0$
9.	Volume	length × breadth × height	cubic metre	m^3	$M^0L^3T^0$
10.	Density	$\left(\frac{\text{mass}}{\text{volume}}\right)$	kilogram per cubic metre	kg/m^3	$M^1L^{-3}T^0$
11.	Relative density or specific gravity	$\frac{\text{density of substance}}{\text{density of water at 4°C}}$	—	$\frac{kg/m^3}{kg/m^3}$ = no unit	$M^0L^0T^0$ or dimensionless
12.	Velocity or speed	$\frac{\text{distance}}{\text{time}}$	metre per second	m/s	$M^0L^1T^{-1}$
13.	Acceleration or retardation or g	$\frac{\text{change in velocity}}{\text{time}}$	metre per square second	m/s^2	$M^0L^1T^{-2}$
14.	Force (F)	mass × acceleration	newton or kilogram metre per square second	N or kg m/s^2	$M^1L^1T^{-2}$
15.	Linear momentum (p)	mass × velocity	kilogram metre per second	kg m/s	$M^1L^1T^{-1}$
16.	Impulse	force × time interval	newton-sec	Ns	$M^1L^1T^{-1}$
17.	Pressure	$\frac{\text{force}}{\text{area}}$	pascal or newton per square metre	N/m^2 or Pa	$M^1L^{-1}T^{-2}$
18.	Work	force × distance	kilogram-square metre per square second or joule	kg-m^2/s^2 or J	$M^1L^2T^{-2}$
19.	Energy	equivalent to work	kilogram square metre per square second or joule	kg m^2/s^2 or J	$M^1L^2T^{-2}$
20.	Power (P)	$\frac{\text{work}}{\text{time}}$	watt (W) or joule per second or kilogram square metre per cubic second	kg m^2/s^3 or J/s or watt (W)	$M^1L^2T^{-3}$
21.	Gravitational constant (G)	$G = \frac{Fr^2}{m_1m_2}$	newton-square metre per square kilogram	Nm^2/kg^2	$M^{-1}L^3T^{-2}$
22.	Angle (θ)	$\frac{\text{arc}}{\text{radius}}$	radian	rad	$M^0L^0T^0$ or dimensionless
23.	Angular velocity (ω)	$\frac{\text{angle}(\theta)}{\text{time}}$	radian per second	rad/s	$M^0L^0T^{-1}$

S. No.	Physical Quantity	Formula	Name of SI Unit	SI Units	Dimensional Formula
24.	Angular acceleration (α)	$\frac{\text{change in angular velocity}}{\text{time taken}}$	radian per square second	rad/s^2	$M^0L^0T^{-2}$
25.	Moment of inertia (I)	mass $\times$ (distance)^2	kilogram square metre	kg m^2	$M^1L^2T^0$
26.	Radius of gyration (K)	distance	metre	m	$M^0L^1T^0$
27.	Angular momentum ($\bar{L}$)	$I\vec{\omega}$	kilogram square metre per second	kg m^2/s	$M^1L^2T^{-1}$
28.	Torque ($\vec{\tau}$)	$I\vec{\alpha}$	newton metre or kilogram-square metre per square second	N-m or kg m^2/s^2	$M^1L^2T^{-2}$
29.	(Spring) force constant (k)	$\frac{\text{force}}{\text{displacement}}$	newton per metre or kilogram per square second	N/m or kg/s^2	$M^1L^0T^{-2}$
30.	Surface tension	$\frac{\text{force}}{\text{length}}$	newton per metre	N/m	$M^1L^0T^{-2}$
31.	Surface energy	$\frac{\text{energy}}{\text{area}}$	joule per metre square	J/m^2	$M^1L^0T^{-2}$
32.	Stress	$\frac{\text{force}}{\text{area}}$	newton per square metre	N/m^2	$M^1L^{-1}T^{-2}$
33.	Strain	$\frac{\text{change in dimenson}}{\text{original dimension}}$ or $\frac{\Delta L}{L}$	No unit	—	$M^0L^0T^0$
34.	Young's modulus (Y)	$\frac{\text{logitudinal stress}}{\text{logitudinal strain}}$	newton per square metre	N/m^2	$M^1L^{-1}T^{-2}$
35.	Bulk modulus (B)	$\frac{\text{volume stress}}{\text{volume strain}}$ or $\left(\frac{\text{normal stress}}{\text{volume strain}}\right)$	newton per square metre	N/m^2	$M^1L^{-1}T^{-2}$
36.	Compressibility	$\frac{1}{\text{Bulk modulus}}$	square metre per newton	N^{-1} m^2	$M^{-1}L^1T^2$
37.	Modulus of rigidity or shear modulus	$\frac{\text{shearing stress}}{\text{shearing strain}}$	newton per square metre	N/m^2	$M^1L^{-1}T^{-2}$
38.	Coefficient of viscosity (η)	$\eta = \frac{F}{A\left(\frac{\Delta v}{\Delta x}\right)}$	poise or kilogram per metre per second	kg m^{-1}s^{-1} or poise	$M^1L^{-1}T^{-1}$
39.	Coefficient of elasticity	$\frac{\text{stress}}{\text{strain}}$	newton per square metre	N/m^2	$M^1L^{-1}T^{-2}$
40.	Reynold's number (R)	$R = \frac{\rho r V_c}{\eta}$	no unit	—	$M^0L^0T^0$
41.	Wavelength (λ)	distance	metre	m	$M^0L^1T^0$
42.	Frequency (ν)	$\frac{\text{number of vibrations}}{\text{second}}$	per second or hertz	s^{-1} or Hz	$M^0L^0T^{-1}$
43.	Angular frequency (ω)	$\omega = 2\pi\nu$	radian per second	rad/s	$M^0L^0T^{-1}$
44.	Time period	T	second	s	$M^0L^0T^1$
45.	Intensity of wave (I)	$I = 2\pi^2 n^2 a^2 \rho v$ or energy transported per unit area per second	watt per square metre	W/m^2	$M^1L^0T^{-3}$
46.	Gas constant (R)	$\frac{PV}{nT}$	joule per mole kelvin	J mol^{-1} K^{-1}	$M^1L^2T^{-2}K^{-1}$
47.	Velocity gradient	$\frac{\text{velocity change}}{\text{distance}}$	per second	s^{-1}	$M^0L^0T^{-1}$

S. No.	Physical Quantity	Formula	Name of SI Unit	SI Units	Dimensional Formula
48.	Rate of flow	$\frac{\text{volume flow}}{\text{time}}$	cubic metre per second	$m^3 s^{-1}$	$M^0L^3T^{-1}$
49.	Thermal conductivity (K)	$K=\frac{Q}{At\left(\frac{\Delta\theta}{\Delta x}\right)}$	kilocalory per metre per degree celsius per second	kcal $m^{-1} {}^\circ C^{-1} s^{-1}$	$M^1L^1T^{-3}\theta^{-1}$
50.	Specific heat (c)	$c=\frac{Q}{m\,\Delta t}$	joule per kilogram per kelvin	$J\,kg^{-1}\,K^{-1}$	$M^0L^2T^{-2}K^{-1}$
51.	Latent heat (L)	$\frac{Q}{m}$	joule per kilogram	J/kg	$M^0L^2T^{-2}$
52.	Planck's constant (h)	$\frac{\text{energy}}{\text{frequency}}$	joule-second	J-s	$M^1L^2T^{-1}$
53.	Boltzmann constant (k_B)	$\frac{PV}{TN_A}$	joule per kelvin	J/K	$M^1L^2T^{-2}K^{-1}$
54.	Stefan's Boltzmann constant (σ)	$\sigma=\frac{E}{AtT^4}$	watt per square metre per (kelvin)^4	$Wm^{-2}K^{-4}$	$M^1L^0T^{-3}K^{-4}$
55.	Charge	$q=It$	ampere-second or coulomb	A-s or C	$M^0L^0T^1I^1$
56.	Dielectric constant	K	no unit	Unit less	dimensionless
57.	Electric field	$E=\frac{F}{q}$ or $E=\frac{\Delta V}{a}$	newton per coulomb or volt per metre	N/C or V/m	$M^1L^1T^{-3}I^{-1}$
58.	Potential (electric)	$V=\frac{W}{q}$	volt or joule per coulomb	J/C or volt	$M^1L^2T^{-3}I^{-1}$
59.	Electric dipole moment	$p=2qL$	coulomb-metre	C-m	$M^0L^1T^1I^1$
60.	Resistance (R)	$R=\frac{V}{I}$	ohm	Ω	$M^1L^2T^{-3}I^{-2}$
61.	Electric flux (ϕ or ϕ_E)	$\phi_E=\oint \vec{\mathbf{E}}\cdot\vec{\mathbf{dA}}$	volt-metre	V-m	$M^1L^3T^{-3}I^{-2}$
62.	Permittivity of free space (ε_0)	$\varepsilon_0=\frac{1}{4\pi F}\frac{q_1q_2}{r^2}$	square coulomb per newton per square metre	$C^2N^{-1}m^{-2}$	$M^{-1}L^{-3}T^4I^{-2}$
63.	Capacitance	$C=\frac{q}{V}$	farad	F	$M^{-1}L^{-2}T^4I^2$
64.	Specific resistance or electrical resistivity	$\rho=\frac{RA}{l}$	ohm-metre	Ω-m	$M^1L^3T^{-3}I^{-2}$
65.	Conductance	$G=\frac{I}{V}=\frac{1}{R}$	ohm^{-1} or mho or seimen or ampere per volt	AV^{-1} or S or mho	$M^{-1}L^{-2}T^3I^2$
66.	Current density	$j=\frac{I}{A}$	ampere per square metre	Am^{-2}	$M^0L^{-2}T^0I^1$
67.	EMF (E)		volt	V	$M^1L^2T^{-3}I^{-1}$
68.	Magnetic field (B)	$B=\frac{F}{qv}$	tesla or newton per ampere per metre	T or $NA^{-1}m^{-1}$	$M^1L^0T^{-2}I^{-1}$
69.	Permeability of free space (μ_0)	$\mu_0=\frac{4\pi r^2 dB}{Idl\sin\theta}$	tesla-m per ampere	TmA^{-1}	$M^1L^1T^{-2}I^{-2}$
70.	Magnetic dipole moment (M)	$M=IA$ or $M=NIA$	newton-metre per tesla	N–m–T^{-1}	$M^0L^2T^0I^1$
71.	Magnetic flux	$\phi_B=B\cdot A$	weber	Wb	$M^1L^2T^{-2}I^{-1}$
72.	Inductance (L or M)	$\frac{\phi_B}{I}$	weber per ampere or henry	$Wb\,A^{-1}$ or H	$M^1L^2T^{-2}I^{-2}$
73.	Time constant $\frac{L}{R}$ or CR	$I=I_0e^{-\frac{R}{L}t}$ or $I=I_0e^{-t/CR}$	second	s	$M^0L^0T^1$

10. Homogeneity principle: If the dimensions of left hand side of an equation are equal to the dimensions of right hand side of the equation, then the equation is dimensionally correct. This is known as homogeneity principle.

Mathematically, [LHS] = [RHS]

11. Uses of dimensions :

(a) To check the correctness of a given physical equation: According to homogeneity principle; if the dimensions of left hand side of an equation is same as that of right hand side of the equation, then the equation of physical quantity is dimensionally correct. Generally, physical equation contains one or more than one dimensionless constant. But homogeneity principle becomes failure to give information about dimensionless constant. Due to this reason, a dimensionally correct equation may or may not be physically correct.

Example : Show that the expression of velocity of sound given by $v = \sqrt{\left(\frac{E}{\rho}\right)}$ is dimensionally correct.

Here, E = coefficient of elasticity

ρ = density of medium

Solution : $[\text{L.H.S.}] = [v] = [\text{LT}^{-1}]$

$$[\text{R.H.S.}] = \left[\left(\frac{\text{E}}{\rho}\right)^{1/2}\right]$$

$$= \left[\left(\frac{\text{ML}^{-1}\,\text{T}^{-2}}{\text{ML}^{-3}}\right)^{1/2}\right] = [\text{LT}^{-1}]$$

$\because$ [L.H.S.] = [R.H.S.]

Hence, equation is dimensionally correct.

(b) To derive new relation among physical quantities : Homogeneity principle of dimensions is powerful tool to establish the relation among various physical quantities.

Example : The time period T of simple pendulum depends upon length l of the pendulum and gravitational acceleration. Derive the formula for time period of simple pendulum.

Solution : $T = f(l, g)$

Let, $T \propto l^a$

$T \propto g^b$

where, a and b are dimensionless constant.

$\therefore$ $T = kl^a g^b$

where, k is dimensionless constant.

$\therefore$ $[\text{L.H.S.}] = [\text{T}] = [\text{M}^0\text{L}^0\text{T}]$

and $[\text{R.H.S.}] = (l^a g^b)$

$$= [\text{L}^a (\text{LT}^{-2})^b]$$

$$= [\text{L}^{a+b}\,\text{T}^{-2b}]$$

$$= [\text{M}^0\text{L}^{a+b}\,\text{T}^{-2b}]$$

According to homogeneity principle,

[L.H.S.] = [R.H.S.]

or $[\text{M}^0\text{L}^0\,\text{T}] = [\text{M}^0\text{L}^{a+b}\,\text{T}^{-2b}]$

For dimensional balance, dimensions on both sides should be same.

$\therefore$ $a + b = 0$ and $-2b = 1$

$\therefore$ $b = -\frac{1}{2}$

$\therefore$ $a = \frac{1}{2}$

$\therefore$ $T = 2\pi\sqrt{\frac{l}{g}}$

[since, numerical value of k in case of simple pendulum is 2π.]

(c) To convert a physical quantity from one system to the other : Dimensional formula is useful to convert the value of a physical quantity from one system to the other. Physical quantity is expressed as a product of numerical value and unit.

In any system of measurement, this product remains constant. By using this fact, we can convert the value of a physical quantity from one system to the other.

Example : Convert one joule into erg.

Solution : Joule is SI unit of work. The dimensions of work in SI = $[W_1] = [\text{M}_1\text{L}_1^2\,\text{T}_1^{-2}]$ in SI.

But erg is CGS unit of work. The dimension of work is CGS = $[W_2] = [\text{M}_2\text{L}_2^2\,\text{T}_2^{-2}]$

$\therefore$ $n_1\,[u_1] = n_2\,[u_2]$

or $n_1\,[\text{M}_1\text{L}_1^2\,\text{T}_1^{-2}] = n_2\,[\text{M}_2\text{L}_2^2\,\text{T}_2^{-2}]$

Here, M_1 = kg

L_1 = metre

T_1 = second

M_2 = gram

L_2 = cm

T_2 = second

$\therefore$ $M_1 = 1000M_2$

$L_1 = 100L_2$

and $T_1 = T_2$

$n_1 = 1$

$$\therefore\quad n_2 = n_1\left[\frac{M_1}{M_2}\right]\left[\frac{L_1}{L_2}\right]^2\left[\frac{T_1}{T_2}\right]^{-2}$$

$$= (1)\left[\frac{1000M_2}{M_2}\right]\left[\frac{100L_2}{L_2}\right]^2\left[\frac{T_1}{T_2}\right]^{-2} = 10^7$$

$\therefore$ 1 joule = 10^7 erg

12. Limitations of dimensions:

(a) Numerical constant has no dimensions *e.g.*, $\frac{1}{2}$, 2π etc.

(b) Trigonometrical ratios have no dimensions *e.g.*, $\sin\theta$, $\cos\theta$, $\tan\theta$ etc.

(c) Exponents have no dimensions, *e.g.*, e^x

In this case, e^x and x both have no dimensions.

(d) Logrithms have no dimensions, *e.g.*, In x
Here In x and x both have no dimensions.

(e) This method gives no information about dimensional constants. Such as the universal constant of gravitation (G) or Planck's constant (h) and where they have to be introduced.

(f) This technique is useful only for deducing and verifying power relations. Relationship involving exponential, trigonometric functions, etc. cannot be obtained or studied by this technique.

(g) In this method, we compare the powers of the fundamental quantities (Like M, L, T etc.) to obtain a number of independent equations for finding the unknown powers. Since, the total number of such equations cannot exceed the number of fundamental quantities, we cannot use this method to obtain the required relation if the quantity of interest depends upon more parameters than the number of fundamental quantities used.

(h) In many problems, it is difficult to guess the parameters on which the quantity of interest may depend. This requires a trained, subtle and intuitive mind.

13. Significant figure :

(a) The significant figures are those number of digits in a quantity, that are known reliably plus one digit that is uncertain.

(b) All the non-zero digits are significant. 1325 has significant figures = 4.

(c) All zeros between two non-zero digits are significant. 1304 has four significant figures.

(d) The zeros of the right of decimal point and to the left of a non-zero digit are significant. 0.0012 has significant figures as two whereas 6400 has of two.

Measured Values	Number of Significant Figures
1234	4
86.234	5
0.0013	2
3100	2
23.100	5
1.80×10^{15}	3

14. Round off a digit : The rules for rounding off a measurement are given below :

(a) If the digit right to the one rounded is more than 5, the digit to be rounded is increased by one.

(b) If the digit right to the one rounded is less than 5, the digit to be rounded remains the same.

(c) If the digit right to the one rounded is equal to 5, the digit to be rounded is increased by one, if it is odd.

(d) If the digit right to the one rounded is equal to 5, the digit to be rounded remains the same, if it is even.

Example : Round of the following numbers to four significant digits.

(a) 7.36489
(b) 8.465438
(c) 1567589
(d) 1.562576

Solution : (a) Here the fourth digit is 4 and next one is 8 which is greater than 5. So, 7.36489 becomes 7.365.

(b) Here, the fourth digit is 5 and next one is 4 which is less than 5. So, 8.465438 becomes 8.465.

(c) $1567589 = 1.567589 \times 10^6$
Here, the fourth digit is 7 and next one is 5. But digit 7 is odd. So, 1.567589×10^6 becomes 1.568×10^6.

(d) Here the fourth digit is 2 and next one is 5.
But digit 2 is even.
So, 1.562576 becomes 1.562.

Addition and subtraction rule : Before addition and subtraction, all measured values are rounded off to smallest number of decimal places.

Example : Evaluate $1.368 + 2.3 + 0.0653$.

Solution : Here least number of significant figures after decimal is one.

$$\therefore \quad 1.368 = 1.4$$
$$2.3 = 2.3$$
$$0.0653 = 0.1$$
$$\therefore \quad 1.4 + 2.3 + 0.1 = \mathbf{3.8} \qquad \textbf{Ans.}$$

Example : Evaluate $5.835 - 2.3$.

Solution : $5.835 - 2.3$

After application of subtraction rule,

$$5.8 - 2.3 = 3.5$$

Multiplication and division rule : In the case of multiplication and division, answer should be in the form of least number of significant figures.

15. Error in measruement : There are many causes of errors in measurement. Errors may be due to instrumental defects, ignoring certain facts, carelessness of experimenter, random change in temperature, pressure, humidity etc. When an experimenter tries to reach accurate value of measurement by doing large number of experiments, the mean of a large number of the results of repeated experiments is close to the true value.

Let $y_1, y_2, ..., y_n$ are results of an experiment repeated n times.

Then the true value of measurement is

$$y_{\text{mean}} = \frac{y_1 + y_2 + \dots + y_n}{n}$$

The order of error is $\pm\sigma$.

where, $$\sigma = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (x_i - \bar{x})^2}$$

The value of quantity is $y_{\text{mean}} \pm \sigma$.

Example : The gravitational acceleration at the surface of earth is measured by simple pendulum method by an experimenter in repeated experiments. The results of repeated experiments are given below :

Number of Observations	Gravitational acceleration (m/s²)
1	9.90
2	9.79
3	9.82
4	9.85
5	9.86
6	9.78
7	9.76
8	9.92
9	9.94
10	9.45

The standard value of gravitational acceleration is 9.8 m/s^2 but as shown in 10 experiments the value differ from standard value. This shows that errors in the measurements are done by air resistance, instrumental defects or any other circumstances.

16. Calculation of Magnitude of Error :

(a) Absolute error : It is defined as difference of the true value and the measured value of a quantity.

$$y_{\text{mean}} = \frac{y_1 + y_2 + \ldots + y_n}{n}$$

The absolute error in first observation is

$$\Delta y_1 = y_m - y_1$$

The absolute error in second observation is

$$\Delta y_2 = y_m - y_2$$

$$\vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots$$

The absolute error in nth observation is

$$\Delta y_n = y_m - y_n$$

The mean absolute error is

$$\overline{\Delta y} = \frac{|\Delta y_1| + |\Delta y_2| + \ldots + |\Delta y_n|}{n}$$

(b) Relative error or fractional error $= \pm \dfrac{\overline{\Delta y}}{y_{\text{mean}}}$

(c) Percentage error $= \pm \dfrac{\overline{\Delta y}}{y_{\text{mean}}} \times 100$

Example : The average speed of a train is measured by 5 students. The results of measurements are given below :

Number of Students	Speed (m/s)
1	10.2 m/s
2	10.4 m/s
3	9.8 m/s
4	10.6 m/s
5	10.8 m/s

Calculate :
(a) mean value
(b) absolute error in each result
(c) mean absolute error
(d) relative error
(e) percentage error
(f) express the result in terms of percentage error.

Solution :

(a) $v_{\text{mean}} = \dfrac{10.2 + 10.4 + 9.8 + 10.6 + 10.8}{5}$

$$= \frac{51.8}{5} = 10.4 \text{ m/s}$$

(b) $\Delta y_1 = y_{\text{mean}} = 10.4 - 10.2 = 0.2$

$\Delta y_2 = y_{\text{mean}} - y_2 = 10.4 - 10.4 = 0.0$

$\Delta y_3 = y_{\text{mean}} - y_3 = 10.4 - 9.8 = 0.6$

$\Delta y_4 = y_{\text{mean}} - y_4 = 10.4 - 10.6 = -0.2$

$\Delta y_5 = y_{\text{mean}} - y_5 = 10.4 - 10.8 = -0.4$

(c) $\overline{\Delta y} = \dfrac{|\Delta y_1| + |\Delta y_2| + |\Delta y_3| + |\Delta y_4| + |\Delta y_5|}{5}$

$$= \frac{0.2 + 0.0 + 0.6 + 0.2 + 0.4}{5} = \frac{1.4}{5} = 0.28$$

(d) Relative error $= \pm \dfrac{\overline{\Delta y}}{y_{\text{mean}}} = \pm \dfrac{0.28}{10.4}$

(e) Percentage error $= \pm \dfrac{\overline{\Delta y}}{y_{\text{mean}}} \times 100 = \pm \dfrac{0.28}{10.4} \times 100$

(f) Result $= y_{\text{mean}} \pm \ldots \%$

Objective Questions

Level-1

1. Which of the following quantities is not dimensionless ?
(a) Reynold's number (b) Strain
(c) Angle (d) Radius of gyration

2. Which of the following pairs have same dimensions ?
(a) Torque and work
(b) Angular momentum and work
(c) Energy and Young's modulus
(d) Light year and wavelength

3. Which of the following physical quantities has neither dimensions nor unit ?
(a) Angle (b) Luminous intensity
(c) Coefficient of friction (d) Current

4. Which of the following is dimensionally correct ?
(a) Specific heat = joule per kilogram kelvin
(b) Specific heat = newton per kilogram kelvin
(c) Specific heat = joule per kelvin
(d) None of the above

5. If $v = \dfrac{A}{t} + Bt^2 + Ct^3$ where v is velocity, t is time and A, B and C are constant then the dimensional formula of B is :
(a) $[M^0LT^0]$ (b) $[ML^0T^0]$
(c) $[M^0L^0T]$ (d) $[M^0LT^{-3}]$

6. Which of the following is not correct for dimensionless quantity ?
(a) It does not exist (b) It always has a unit
(c) It never has a unit (d) It may have a unit

7. Taking density (ρ), velocity (v) and area (a) to be fundamental unit then the dimensions of force are :
(a) $[av^2\rho]$ (b) $[a^2v\rho]$
(c) $[av\rho^2]$ (d) $[a^0v\rho]$

8. The dimensions of radian per second are :
(a) $[M^0L^0T^0]$ (b) $[M^0L^0T]$
(c) $[M^0L^0T^{-1}]$ (d) none of these

9. The dimensional representation of gravitational potential is identical to that of :
(a) internal energy (b) angular momentum
(c) latent heat (d) electric potential

10. The volume of cube is equal to surface area of the cube. The volume of cube is :
(a) 216 unit (b) 512 unit
(c) 64 unit (d) none of these

11. The dimensional formula of compressibility is :
(a) $[M^0L^{-1}T^{-1}]$ (b) $[M^{-1}LT^2]$
(c) $[MLT^{-2}]$ (d) none of these

12. Velocity gradient has same dimensional formula as :
(a) angular frequency (b) angular momentum
(c) velocity (d) none of these

13. An atmosphere :
(a) is a unit of pressure
(b) is a unit of force
(c) gives an idea of the composition of air
(d) is the height above which there is no atmosphere

14. The dimensional formula of Reynold's number is :
(a) [MLT] (b) $[M^0L^0T]$
(c) $[M^0L^0T^0]$ (d) none of these

15. The dimensions of time constant are :
(a) $[M^0L^0T^0]$ (b) $[M^0L^0T]$
(c) [MLT] (d) none of these

16. The dimensions of self-inductance are :
(a) $[MLT^{-2}A^{-2}]$ (b) $[ML^2T^{-1}A^{-2}]$
(c) $[ML^2T^{-2}A^{-2}]$ (d) $[ML^2T^{-2}A^2]$

17. State which of the following is correct ?
(a) joule = coulomb × volt
(b) joule = coulomb/volt
(c) joule = volt + coulomb
(d) joule = volt/coulomb

18. The dimensional formula of electrical conductivity is :
(a) $[M^{-1}L^{-3}T^3A^2]$ (b) $[ML^3T^3A^2]$
(c) $[M^2L^3T^{-3}A^2]$ (d) $[ML^3T^{-3}A^{-2}]$

19. Which of the following pair has same dimensions ?
(a) Current density and charge density
(b) Angular momentum and momentum
(c) Spring constant and surface energy
(d) Force and torque

20. The dimensional formula of the Hall coefficient is :
(a) $[M^0L^0A^{-2}T^{-1}]$ (b) $[M^0L^3AJ]$
(c) $[M^0L^0AT]$ (d) $[M^0L^3A^{-1}T]$

21. The equation of alternating current $I = I_0 e^{-t/CR}$, where t is time, C is capacitance and R is resistance of coil, then the dimensions of CR is :
(a) $[MLT^{-1}]$ (b) $[M^0LT]$
(c) $[M^0L^0T]$ (d) none of these

22. The dimensional formula of radius of gyration is :
(a) $[M^0L^0T^0]$ (b) $[M^0L^0T]$
(c) $[M^0LT^0]$ (d) none of these

23. Universal time is based on :
(a) rotation of earth on its axis
(b) oscillation of quartz crystal
(c) vibration of caesium atom
(d) earth's orbital motion around the sun

24. In the equation $y = a\sin(\omega t + kx)$, the dimensional formula of ω is :
(a) $[M^0L^0T^{-1}]$ (b) $[M^0LT^{-1}]$
(c) $[ML^0T^0]$ (d) $[M^0L^{-1}T^0]$

25. Farad is not equivalent to :
(a) $\dfrac{q}{V}$ (b) qV^2
(c) $\dfrac{q^2}{J}$ (d) $\dfrac{J}{V^2}$
(q = coulomb, V = volt, J = joule)

26. If P represents radiation pressure, C represents speed of light and Q represents radiation energy striking a unit area per second then non zero integers a, b and c such that $P^aQ^bC^c$ is dimensionless, are :
(a) $a = 1, b = 1, c = -1$ (b) $a = 1, b = -1, c = 1$
(c) $a = -1, b = 1, c = 1$ (d) $a = 1, b = 1, c = 1$

27. Taking frequency f, velocity v and density ρ to be the fundamental quantities then the dimensional formula for momentum will be :
(a) $\rho v^4 f^{-3}$ (b) $\rho v^3 f^{-1}$
(c) $\rho v f^2$ (d) $\rho^2 v^2 f^2$

Level-2

1. The amount of water in slug containing by a cylindrical vessel of length 10 cm and cross-sectional radius 5 cm is (The density of water is $1000\ kg/m^3$) :
(a) 157×10^{-3} slug (b) 53.76×10^{-3} slug
(c) 10.7 slug (d) 14.6 slug

2. The capacity of a vessel is $5700\ m^3$. The vessel is filled with water. Suppose that it takes 12 hours to drain the vessel. What is the mass flow rate of water from the vessel ? [The density of water is $1\ g/cm^3$]
(a) 132 kg/s (b) 100 kg/s
(c) 32 kg/s (d) 152 kg/s
3. The height of the building is 50 ft. The same in millimetre is :
(a) 560 mm (b) 285 mm
(c) 1786.8 mm (d) 15240 mm
4. The name of the nearest star is proxima centauri. The distance of this star from Earth is 4×10^{16} m. The distance of this star from Earth in mile is :
(a) 3.5×10^{13} mile (b) 2.5×10^{13} mile
(c) 5.3×10^{13} mile (d) 1.5×10^{13} mile
5. The radius of hydrogen atom in ground state is 5×10^{-11} m. The radius of hydrogen atom in fermi metre is ($1\ fm = 10^{-15}$ m) :
(a) 5×10^4 fm (b) 2×10^4 fm
(c) 5×10^2 fm (d) 5×10^6 fm
6. One nautical mile is 6080 ft. The same in kilometre is :
(a) 0.9 km (b) 0.8 km
(c) 1.85 km (d) none of these
7. The area of a room is $10\ m^2$. The same in ft^2 is :
(a) 107.6 $feet^2$ (b) 77 $feet^2$
(c) 77.6 $feet^2$ (d) none of these
8. The density of iron is $7.87\ g/cm^3$. If the atoms are spherical and closely packed. The mass of iron atom is 9.27×10^{-26} kg. What is the volume of an iron atom ?
(a) $1.18 \times 10^{-29}\ m^3$ (b) $2.63 \times 10^{-29}\ m^3$
(c) $1.73 \times 10^{-28}\ m^3$ (d) $0.53 \times 10^{-29}\ m^3$
9. In the previous question, what is the distance between the centres of adjacent atoms ?
(a) 2.82×10^{-9} m (b) 0.282×10^{-9} m
(c) 0.63×10^{-9} m (d) 6.33×10^{-9} m
10. The world's largest cut diamond is the first star of Africa (mounted in the British Royal Sculpture and kept in the tower of London). Its volume is 1.84 cubic inch. What is its volume in cubic metre ?
(a) $30.2 \times 10^{-6}\ m^3$ (b) $33.28\ m^3$
(c) $4.8\ m^3$ (d) None of these
11. Crane is British unit of volume. (one crane = 170. 474 litre). Convert crane into SI unit :
(a) $0.170474\ m^3$ (b) $17.0474\ m^3$
(c) $0.0017474\ m^3$ (d) $1704.74\ m^3$
12. Generally, sugar cubes are added to coffee. A typical sugar cube has an edge of length of 1 cm. Minimum edge length of a cubical box containing one mole of the sugar cubes is :
(a) 840 km (b) 970 km
(c) 780 km (d) 750 km
13. The concorde is the fastest airlines used for commercial service. It can cruise at 1450 mile per hour (about two times the speed of sound or in other words, mach 2). What is it in m/s ?
(a) 644.4 m/s (b) 80 m/s
(c) 40 m/s (d) None of these
* 14. When pheiridippides run from Marathon to Athans in 490 B.C. to bring word of the Greek victory over the persians on the basis of approximate measurement, he ran at a speed of 23 ride per hour. The ride is an ancient Greek unit for distance, as are the stadium and the pletheron. One ride was defined to be 4 stadium, one stadium was defined to be 6 pletheran and in terms of SI unit, one pletheron is 30.8 m. How fast did pheiridippides run in m/s ?
(a) 5.25 m/s (approx) (b) 4.7 m/s (approx)
(c) 11.2 m/s (approx) (d) 51.75 m/s (approx)
15. One light year is defined as the distance travelled by light in one year. The speed of light is 3×10^8 m/s. The same in metre is :
(a) 3×10^{12} m (b) 9.461×10^{15} m
(c) 3×10^{15} m (d) none of these
16. The acceleration of a car is 10 mile per hour second. The same in ft/s^2 is :
(a) 1.467 ft/s^2 (b) 14.67 ft/s^2
(c) 40 ft/s^2 (d) none of these
17. One slug is equivalent to 14.6 kg. A force of 10 pound is applied on a body of one kg. The acceleration of the body is :
(a) 44.5 m/s^2 (b) 4.448 m/s^2
(c) 44.4 ft/s^2 (d) none of these
18. The speed of light in vacuum is 3×10^8 m/s. How many nano second does it take to travel one metre in a vacuum ?
(a) 8 ns (b) $\frac{10}{3}$ ns
(c) 3.34 ns (d) none of these
19. The time taken by an electron to go from ground state to excited state is one shake (one shake = 10^{-8} s). This time in nanosecond will be :
(a) 10 ns (b) 4 ns
(c) 2 ns (d) 25 ns
20. The time between human heart beat is 8×10^{-1} second. How many heart beats are measured in one minute ?
(a) 75 (b) 60 (c) 82 (d) 64
21. The age of the universe is 5×10^{17} second. The age of universe in year is :
(a) 158×10^5 (b) 158×10^9
(c) 158×10^6 (d) 158×10^{11}
22. Assuming the length of the day uniformly increases by 0.001 second per century. The net effect on the measure of time over 20 centuries is :
(a) 3.2 hour (b) 2.1 hour
(c) 2.4 hour (d) 5 hour

23. The number of molecules of H_2O in 90 g of water is :
(a) 35.6×10^{23} (b) 41.22×10^{23}
(c) 27.2×10^{23} (d) 30.11×10^{23}

24. The mass of earth is 5.98×10^{24} kg. The average atomic weight of atoms that make up Earth is 40 u. How many atoms are there in Earth ?
(a) 9×10^{51} (b) 9×10^{49}
(c) 9×10^{46} (d) 9×10^{55}

25. One amu is equivalent to 931 MeV energy. The rest mass of electron is 9.1×10^{-31} kg. The mass equivalent energy is (Here 1 amu = 1.67×10^{-27} kg)
(a) 0.5073 MeV (b) 0.693 MeV
(c) 4.0093 MeV (d) none of these

26. One atomic mass unit in amu $= 1.66 \times 10^{-27}$ kg. The atomic weight of oxygen is 16. The mass of one atom of oxygen is :
(a) 26.56×10^{-27} kg (b) 10.53×10^{-27} kg
(c) 74×10^{-27} kg (d) 2.73×10^{-27} kg

27. One horse power is equal to :
(a) 746 watt (b) 756 watt
(c) 736 watt (d) 766 watt

28. If $E = mc^2$
where, m = mass of the body
c = speed of light
Guess the name of physical quantity E :
(a) Energy (b) Power
(c) Momentum (d) None of these

29. One calorie of heat is equivalent to 4.2 J. One BTU (British thermal unit) is equivalent to 1055 J. The value of one BTU in calorie is :
(a) 251.2 cal (b) 200 cal
(c) 263 cal (d) none of these

30. The value of universal gas constant is $R = 8.3$ J/kcal/mol. The value of R in atmosphere litre per kelvin/mol is :
(a) 8.12 atm litre/K mol (b) 0.00812 atm litre/K mol
(c) 81.2 atm litre/K mol (d) 0.0812 atm litre/K mol

31. Refer the data from above question. The value of R in calorie per °C mol is :
(a) 2 cal/mol °C (b) 4 cal/mol °C
(c) 6 cal/mol °C (d) 8.21 cal/mol °C

32. Electron volt is the unit of energy (1 eV = 1.6×10^{-19}J). In H-atom, the binding energy of electron in first orbit is 13.6 eV. The same in joule (J) is :
(a) 10×10^{-19} J (b) 21.76×10^{-19} J
(c) 13.6×10^{-19} J (d) none of these

33. 1 mm of Hg pressure is equivalent to one torr and one torr is equivalent to 133.3 N/m^2. The atmospheric pressure in mm of Hg pressure is :
(a) 70 mm (b) 760 mm
(c) 3.76 mm (d) none of these

34. One bar is equivalent to 10^5 N/m^2. The atmosphere pressure is 1.013×10^5 N/m^2. The same in bar is :
(a) 1.88 bar (b) 1.013 bar
(c) 2.013 bar (d) none of these

35. 1 revolution is equivalent to 360°. The value of 1 revolution per minute is :
(a) 2π rad/s (b) 0.1047 rad/s
(c) 3.14 rad/s (d) none of these

36. If v = velocity of a body
c = speed of light
Then the dimensions of $\frac{v}{c}$ is :
(a) $[M^0L^0T^0]$ (b) $[MLT^{-1}]$
(c) $[ML^2T^{-2}]$ (d) none of these

* 37. The expression for centripetal force depends upon mass of body, speed of the body and the radius of circular path. Find the expression for centripetal force :
(a) $F = \frac{mv^2}{2r^3}$ (b) $F = \frac{mv^2}{r}$
(c) $F = \frac{mv^2}{r^2}$ (d) $F = \frac{m^2v^2}{2r}$

38. The maximum static friction on a body is $F = \mu N$.
Here, N = normal reaction force on the body
μ = coefficient of static friction
The dimensions of μ is :
(a) $[MLT^{-2}]$ (b) $[M^0L^0T^0\theta^{-1}]$
(c) dimensionless (d) none of these

39. What are dimensions of Young's modulus of elasticity ?
(a) $[ML^{-1}T^{-2}]$ (b) $[MLT^{-2}]$
(c) $[MLT^{-1}]$ (d) None of these

* 40. If $F = 6\pi\eta^a r^b v^c$,
where, F = viscous force
η = coefficient of viscosity
r = radius of spherical body
v = terminal velocity of the body
Find the values of a, b and c :
(a) $a = 1, b = 2, c = 1$ (b) $a = 1, b = 1, c = 1$
(c) $a = 2, b = 1, c = 1$ (d) $a = 2, b = 1, c = 2$

41. The surface tension is $T = \frac{F}{l}$, then the dimensions of surface tension is :
(a) $[MLT^{-2}]$ (b) $[MT^{-2}]$
(c) $[M^0L^0T^0]$ (d) none of these

* 42. A gas bubble from an explosion under water oscillates with a time period T, depends upon static pressure P, density of water 'ρ' and the total energy of explosion E. Find the expression for the time period T (where, k is a dimensionless constant.) :
(a) $T = kP^{-5/6}\rho^{1/2}E^{1/3}$ (b) $T = kP^{-4/7}\rho^{1/2}E^{1/3}$
(c) $T = kP^{-5/6}\rho^{1/2}E^{1/2}$ (d) $T = kP^{-4/7}\rho^{1/3}E^{1/2}$

43. The dimensions of heat capacity is :
(a) $[L^2T^{-2}\theta^{-1}]$ (b) $[ML^2T^{-2}\theta^{-1}]$
(c) $[M^{-1}L^2T^{-2}\theta^{-1}]$ (d) none of these

44. If $\Delta H = mL$,
where 'm' is mass of body
ΔH = total thermal energy supplied to the body
L = latent heat of fusion
The dimensions of latent heat of fusion is :
(a) $[ML^2T^{-2}]$ (b) $[L^2T^{-2}]$
(c) $[M^0L^0T^{-2}]$ (d) $[M^1L^0T^{-1}]$

45. Solar constant is defined as energy received by earth per cm^2 per minute. The dimensions of solar constant is :
(a) $[ML^2T^{-3}]$ (b) $[M^2L^0T^{-1}]$
(c) $[MT^{-3}]$ (d) $[ML^1T^{-2}]$

46. The unit of electric permittivity is C^2/Nm^2. The dimensions of electric permittivity is :
(a) $[M^{-1}L^{-3}T^4A^2]$ (b) $[M^{-1}L^{-3}T^4A]$
(c) $[M^{-1}L^{-3}T^0A^2]$ (d) $[M^0L^{-3}T^4A^2]$

47. A physical relation is $\varepsilon = \varepsilon_0\varepsilon_r$
where, ε = electric permittivity of a medium
ε_0 = electric permittivity of vacuum
ε_r = relative permittivity of medium
What are dimensions of relative permittivity ?
(a) $[M^1L^2T^{-2}]$ (b) $[M^0L^2T^{-3}]$
(c) $[M^0L^0T^0]$ (d) $[M^0L^0T^{-1}]$

48. The dimensions of $1/2\,\varepsilon E^2$ are same as :
(a) energy density (energy per unit volume)
(b) energy
(c) power
(d) none of the above

49. The electric flux is given by scalar product of electric field strength and area. What are dimensions of electric flux ?
(a) $[ML^3T^{-2}A^{-2}]$ (b) $[ML^3T^{-2}A^{-1}]$
(c) $[ML^3T^{-3}A^{-1}]$ (d) $[M^2LT^{-1}A^0]$

50. Electric displacement is given by $D = \varepsilon E$
Here, ε = electric permittivity
E = electric field strength
The dimensions of electric displacement is :
(a) $[ML^{-2}TA]$ (b) $[L^{-2}T^{-1}A]$
(c) $[L^{-2}TA]$ (d) none of these

51. The energy stored in an electric device known as capacitor is given by $U = q^2/2C$.
where, U = energy stored in capacitor
C = capacity of capacitor
q = charge on capacitor
The dimensions of capacity of the capacitor is :
(a) $[M^{-1}L^{-2}T^4A^2]$ (b) $[M^{-1}L^{-2}T^4A]$
(c) $[M^{-2}L^{-2}T^4A^2]$ (d) $[M^0L^{-2}T^4A^0]$

52. The workdone by a battery is $W = \varepsilon\,\Delta q$, where Δq = charge transferred by battery, ε = emf of the battery. What are dimensions of emf of battery?
(a) $[M^0L^0T^{-2}A^{-2}]$ (b) $[ML^2T^{-3}A^{-2}]$
(c) $[M^2T^{-3}A^0]$ (d) $[ML^2T^{-3}A^{-1}]$

53. The expression for drift speed is $v_d = J/ne$
Here, J = current density,
n = number of electrons per unit volume,
$e = 1.6 \times 10^{-19}$ unit
The unit and dimensions of e are :
(a) coulomb and [AT]
(b) ampere per second and $[AT^{-1}]$
(c) no sufficient informations
(d) none of the above

54. The unit of current element is ampere metre. The dimensions of current element is :
(a) [MLA] (b) $[ML^2TA]$
(c) $[M^1LT^2]$ (d) [LA]

55. The magnetic force on a point moving charge is $\vec{F} = q(\vec{v} \times \vec{B})$
Here, q = electric charge
$\vec{v}$ = velocity of the point charge
$\vec{B}$ = magnetic field
The dimensions of $\vec{B}$ is :
(a) $[MLT^{-1}A]$ (b) $[MLT^{-2}A^{-1}]$
(c) $[MT^{-2}A^{-1}]$ (d) none of these

56. What are dimensions of E/B ?
(a) $[LT^{-1}]$ (b) $[LT^{-2}]$
(c) $[M^1L^1T^{-1}]$ (d) $[ML^2T^{-1}]$

57. What are the dimensions of $\mu_0\varepsilon_0$?
Here, μ_0 = magnetic permeability in vacuum
ε_0 = electric permittivity in vacuum
(a) $[ML^{-2}T^{-2}]$ (b) $[L^{-2}T^{-2}]$
(c) $[L^{-2}T^2]$ (d) none of these

58. In the formula, $a = 3bc^2$ 'a' and 'c' have dimensions of electric capacitance and magnetic induction respectively. What are dimensions of 'b' in MKS system :
(a) $[M^{-3}L^{-2}T^4Q^4]$ (b) $[M^{-3}T^4Q^4]$
(c) $[M^{-3}T^3Q]$ (d) $[M^{-3}L^2T^4Q^{-4}]$

59. If $X = \varepsilon_0 L \dfrac{\Delta V}{\Delta t}$
Here, ε_0 = electric permittivity of free space
L = length
ΔV = potential difference
Δt = time interval
What are the dimensions of X? Guess the physical quantity :
(a) Electric current, $[A^0M^0L^0T^0]$
(b) Electric potential, $[AM^0L^0T^0]$
(c) Electric current, $[AM^0L^0T^0]$
(d) None of the above

60. The dimensions of $\frac{R}{L}$ is :
Here, R = electric resistance
L = self inductance
(a) $[T^{-2}]$ (b) $[T^{-1}]$
(c) $[ML^{-1}]$ (d) $[T]$

*61. The magnetic energy stored in an inductor is given by $E = \frac{1}{2} L^a I^b$. Find the value of 'a' and 'b' :
Here, L = self inductance,
I = electric current
(a) $a = 3, b = 0$ (b) $a = 2, b = 1$
(c) $a = 0, b = 2$ (d) $a = 1, b = 2$

62. In L-R circuit, $I = I_0 [1 - e^{-t/\lambda}]$
Here, I = electric current in the circuit. Then
(a) the dimensions of I_0 and λ are same.
(b) the dimensions of t and λ are same.
(c) the dimensions of I and I_0 are not same.
(d) all of the above

63. A physical quantity u is given by the relation $u = \frac{B^2}{2\mu_0}$
Here, B = magnetic field strength
μ_0 = magnetic permeability of vacuum
The name of physical quantity u is
(a) energy (b) energy density
(c) pressure (d) none of these

64. The energy of a photon depends upon Planck's constant and frequency of light. The expression for photon energy is :
(a) $E = h\nu$ (b) $E = \frac{h}{\nu}$
(c) $E = \frac{\nu}{h}$ (d) $E = h\nu^2$

*65. If energy of photon is $E \propto h^a c^b \lambda^d$
Here, h = Planck's constant
c = speed of light
λ = wavelength of photon
Then the value of a, b and d are
(a) 1, 1, 1 (b) 1, – 1, 1
(c) 1, 1, – 1 (d) none of these

66. The radius of nucleus is $r = r_0 A^{1/3}$, where A is mass number. The dimensions of r_0 is
(a) $[MLT^{-2}]$ (b) $[M^0L^0T^{-1}]$
(c) $[M^0LT^0]$ (d) none of these

67. The power of lens is $P = \frac{1}{f}$, where 'f' is focal length of the lens. The dimensions of power of lens is :
(a) $[LT^{-2}]$
(b) $[M^0L^{-1}T^0]$
(c) $[M^0L^0T^0]$
(d) none of these

68. The dimensions of frequency is :
(a) $[T^{-1}]$ (b) $[M^0L^0T]$
(c) $[M^0L^0T^{-2}]$ (d) none of these

69. The dimensions of wavelength is :
(a) $[M^0L^0T^0]$ (b) $[M^0LT^0]$
(c) $[M^0L^{-1}T^0]$ (d) none of these

70. The optical path difference is defined as $\Delta x = \frac{2\pi}{\lambda}$. What are dimensions of optical path difference ?
(a) $[M^0L^{-1}T^0]$ (b) $[MLT^0]$
(c) $[ML^0T]$ (d) $[ML^{-2}T]$

71. The unit of intensity of a wave is W/m^2? What are dimensions of intensity of wave ?
(a) $[MT^{-3}]$ (b) $[AML^0T^{-2}]$
(c) $[M^0L^{-1}T^{-2}]$ (d) None of these

72. If $A = B + \frac{C}{D+E}$, the dimensions of 'B' and 'C' are $[LT^{-1}]$ and $[M^0LT^0]$, respectively. Find the dimensions of A, D and E :
(a) $A = [M^0L^0T^{-1}]$, $D = [T]$, $E = [LT]$
(b) $A = [MLT^0]$, $D = [T^2]$, $E = [T^2]$
(c) $A = [LT^{-1}]$, $D = [MT]$, $E = [MT]$
(d) $A = [LT^{-1}]$, $D = [T]$, $E = [T]$

*73. If $x = \frac{a \sin\theta + b\cos\theta}{a+b}$, then :
(a) the dimensions of x and a are same
(b) the dimensions of a and b are not same
(c) x is dimensionless
(d) none of the above

74. $\int \frac{dv}{\sqrt{2av - v^2}} = a^n \sin^{-1}\left[\frac{x}{a} - 1\right]$ on the basis of dimensional analysis, the value of n is :
(a) 0 (b) – 2
(c) 3 (d) none of these

Find the value of following on the basis of significant figure rule :

75. The height of a man is 5.87532 ft. But measurement is correct upto three significant figures. The correct height is :
(a) 5.86 ft (b) 5.87 ft
(c) 5.88 ft (d) 5.80 ft

76. 4.32×2.0 is equal to :
(a) 8.64 (b) 8.6
(c) 8.60 (d) 8.640

77. $4.338 + 4.835 \times 3.88 \div 3.0$ is equal to :
(a) 10.6 (b) 10.59
(c) 10.5912 (d) 10.591267

78. 1.0×2.88 is equal to :
(a) 2.88
(b) 2.880
(c) 2.9
(d) none of these

79. 1.00×2.88 is equal to :

(a) 2.88 (b) 2.880

(c) 2.9 (d) none of these

80. The velocity of the body within the error limits, if a body travels uniformly a distance of (13.8 ± 0.2) m in a time (4.0 ± 0.3), is :

(a) (3.45 ± 0.2) m/s (b) (3.45 ± 0.4) m/s

(c) (3.45 ± 0.3) m/s (d) (3.45 ± 0.5) m/s

81. The fractional error $\left(\frac{\Delta x}{x}\right)$, if $x = a^n$ is :

(a) $\pm\left(\frac{\Delta a}{a}\right)^n$ (b) $\pm n\left(\frac{\Delta a}{a}\right)$

(c) $\pm n \log_e \frac{\Delta a}{a}$ (d) $\pm n \log \frac{\Delta a}{a}$

82. The relation gives the value of 'x'

$$x = \frac{a^3 b^3}{c\sqrt{d}}$$

The percentage error in 'x', if the percentage error in a, b, c, d are 2%, 1%, 3% and 4% respectively, is :

(a) $\pm 8\%$ (b) $\pm 10\%$

(c) $\pm 12\%$ (d) $\pm 14\%$

83. While measuring the diameter of a wire by screw gauge, three readings were taken are 1.002 cm, 1.004 cm and 1.006 cm. The absolute error in the third reading is :

(a) 0.002 cm

(b) 0.004 cm

(c) zero

(d) 1.002 cm

Answers

Level-1

1. (d)	2. (a)	3. (c)	4. (a)	5. (d)	6. (b)	7. (a)	8. (c)	9. (c)	10. (a)
11. (b)	12. (a)	13. (a)	14. (c)	15. (b)	16. (c)	17. (a)	18. (a)	19. (c)	20. (d)
21. (c)	22. (c)	23. (a)	24. (a)	25. (b)	26. (b)	27. (a)			

Level-2

1. (b)	2. (a)	3. (d)	4. (b)	5. (a)	6. (c)	7. (a)	8. (a)	9. (b)	10. (a)
11. (a)	12. (a)	13. (a)	14. (b)	15. (b)	16. (a)	17. (a)	18. (b)	19. (a)	20. (a)
21. (c)	22. (b)	23. (d)	24. (b)	25. (a)	26. (a)	27. (a)	28. (a)	29. (a)	30. (d)
31. (a)	32. (b)	33. (b)	34. (b)	35. (b)	36. (a)	37. (b)	38. (c)	39. (a)	40. (b)
41. (b)	42. (a)	43. (b)	44. (b)	45. (c)	46. (a)	47. (c)	48. (a)	49. (c)	50. (c)
51. (a)	52. (d)	53. (a)	54. (d)	55. (c)	56. (a)	57. (c)	58. (a)	59. (c)	60. (b)
61. (d)	62. (b)	63. (b)	64. (a)	65. (c)	66. (c)	67. (b)	68. (a)	69. (b)	70. (a)
71. (a)	72. (d)	73. (c)	74. (a)	75. (c)	76. (b)	77. (a)	78. (c)	79. (a)	80. (c)
81. (b)	82. (d)	83. (a)							

Solutions

Level-1

3. Coefficient of friction $= \frac{\text{Applied force}}{\text{Normal reaction}}$

$$= \frac{[MLT^{-2}]}{[MLT^{-2}]} = \text{No dimensions}$$

$$\text{Unit} = \frac{N}{N} = \text{No unit}$$

5.

$$v = Bt^2$$

$$\therefore \quad B = \frac{v}{t^2} = \frac{[LT^{-1}]}{[T^2]} = [LT^{-3}]$$

10. Let us take side of cube $= a$

then $a^3 = 6a^2$

$\therefore$ $a = 6$

$$a^3 = (6)^3 = 216$$

11. Compressibility $= \frac{1}{\text{Bulk modulus}}$

$$= [M^{-1}LT^2]$$

19. Spring constant $= \frac{F}{l} = [ML^0T^{-2}]$

Surface energy $= \frac{\text{Energy}}{\text{Area}}$

$$= [ML^0T^{-2}]$$

21. CR is known as time constant

$$CR = [M^{-1}L^{-2}T^4I^2][ML^2T^{-3}I^{-2}]$$

$$= [M^0L^0T]$$

25.

$$C = \frac{\text{Charge}}{\text{Potential}} = \frac{q}{V}$$

Also potential $= \frac{\text{Work}}{\text{Charge}}$ $\left(\because V = \frac{W}{q}\right)$

$$C = \frac{q^2}{J} \text{ as well as } C = \frac{J}{V^2}$$

Thus (a), (c), (d) are equivalent to farad but (b) is not equivalent to farad.

2

Vector Operations

Syllabus: Scalars and vectors, vector addition, multiplication of a vector by a real number, zero vector and its properties, resolution of vectors, scalar and vector products.

Review of Concepts

1. Physical Quantity: Physical quantity is that which can be measured by available apparatus.

Observation + Measurement = Physics

Physical Quantity

(a) Scalar quantity (b) Vector quantity (c) Tensor quantity

(a) Scalar Quantity: The quantity which does not change due to variation of direction is known as scalar quantity. *e.g.*, mass, distance, time, electric current, potential, pressure etc.

Some Important Points:

(i) It obeys simple laws of algebra.

(ii) The scalar quantity, which is found by modulus of a vector quantity is always positive. *e.g.*, distance, speed etc.

(iii) The scalar quantity which is found by dot product of two vectors may be negative. *e.g.*, work, power etc.

(iv) The tensor rank of scalar quantity is zero.

(b) Vector Quantity: The quantity which changes due to variation of direction is known as vector quantity. *e.g.*, displacement, velocity, electric field etc.

Some Important Points:

(i) Vector does not obey the laws of simple algebra.

(ii) Vector obeys the laws of vector algebra.

(iii) Vector does not obey division law. *e.g.*, $\dfrac{\vec{a}}{\vec{b}}$ is meaningless.

(iv) The tensor rank of vector quantity is one.

(v) Division of a vector by a positive scalar quantity gives a new vector whose direction is same as initial vector but magnitude changes.

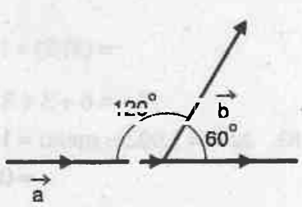
e.g., $$\vec{b}=\frac{\vec{a}}{n}$$

Here n is a positive scalar.

In this case, the directions of $\vec{a}$ and $\vec{b}$ are same to each other.

(vi) A scalar quantity never be divided by a vector quantity.

(vii) The angle between two vectors is measured tail to tail. *e.g.*, in the fig, the angle between $\vec{a}$ and $\vec{b}$ is 60° not 120°.



(viii) The angle between two vectors is always lesser or equal to 180°. (*i.e.*, $0 \le \theta \le 180°$)

(ix) A vector never be equal to scalar quantity.

(x) The magnitude or modulus of a vector quantity is always a scalar quantity.

(xi) Two vectors are compared with respect to magnitude.

(xii) The minimum value of a vector quantity is always greater than or equal to zero.

(xiii) The magnitude of unit vector is one.

(xiv) The direction of zero vector is in indeterminate form.

(xv) The gradient of a scalar quantity is always a vector quantity.

e.g., $$\vec{F}=-\frac{\partial U}{\partial x}\hat{i}-\frac{\partial U}{\partial y}\hat{j}-\frac{\partial U}{\partial z}\hat{k}$$

Here, $\vec{F}$ = conservative force

and U = potential energy

(xvi) If a vector is displaced parallel to itself, it does not change.

(c) Tensor Quantity: The physical quantity which is not completely specified by magnitude and direction is known as tensor quantity. *e.g.*, moment of inertia, stress etc.

2. Types of Vector:

(a) Zero or empty or null vector: The vector whose magnitude is zero and direction is indeterminate is known as zero vector ($\vec{0}$).

Properties of zero vector:

(i) $\vec{a}+\vec{0}=\vec{a}$

(ii) $\vec{a}+\vec{b}+\vec{0}=\vec{a}+\vec{b}$

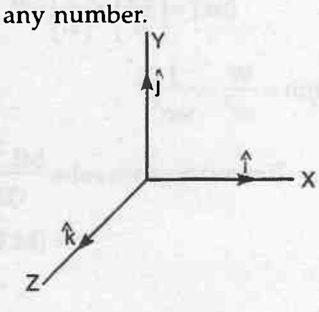
(iii) $\vec{a}-\vec{a}=\vec{0}$

(iv) The cross-product of two parallel vectors is always a zero vector.

(v) $n\vec{0}=\vec{0}$, where n is any number.

(b) Unit vector: A vector of unit magnitude is known as unit vector. If $\hat{n}$ is a unit vector, then $|\hat{n}|=1$.

The unit vectors along X-axis, Y-axis and Z-axis are denoted by $\hat{i}$, $\hat{j}$ and $\hat{k}$.



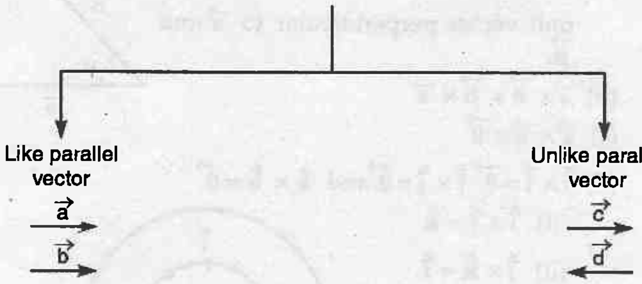
Some important points :

(i) $\hat{i} \neq \hat{j} \neq \hat{k}$

(ii) $|\hat{i}| = |\hat{j}| = |\hat{k}| = 1$

(iii) The unit vector along a vector $\vec{a}$ is $\hat{n} = \frac{\vec{a}}{|\vec{a}|}$

(c) Parallel vectors



Some important points :

(i) If vectors are parallel, then their unit vectors are same to each other. Suppose $\vec{a}$ and $\vec{b}$ are parallel vectors, then

$$\frac{\vec{a}}{|\vec{a}|} = \frac{\vec{b}}{|\vec{b}|}$$

(ii) The angle between like parallel vectors is zero.

(iii) The angle between unlike parallel vectors is 180°.

(iv) The magnitude of parallel vectors may or may not be same.

(v) If the magnitude of like parallel vectors are same, then the vectors are known as equal vectors. Suppose $\vec{a}$ and $\vec{b}$ are equal vectors, then

$$|\vec{a}| = |\vec{b}|$$

(d) **Polar vectors :** The vectors related to translatory motion of a body are known as polar vectors. *e.g.*, linear velocity, linear momentum etc.

(e) **Axial or pseudo vectors :** The vectors which are rotatory to rotatory motion of a body are known as axial vectors. *e.g.*, torque, angular velocity etc.

3. Multiplication of a vector by a number : Let a vector $\vec{b}$ which is result of multiplication of a number k and $\vec{a}$ be

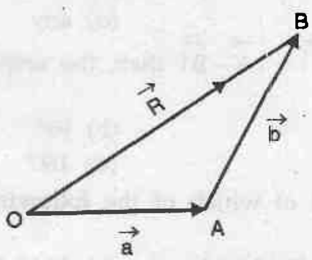
$$\vec{b} = k\vec{a}$$

i.e., the magnitude of $\vec{b}$ is k times that of $\vec{a}$.

If k is positive, then the direction of $\vec{b}$ is same as that of $\vec{a}$. If k is a negative, then the direction of $\vec{b}$ is opposite as that of $\vec{a}$.

4. Addition law of vectors :

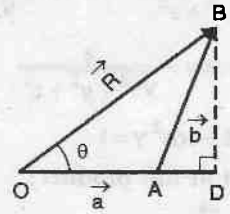
(a) **According to addition law of vector :**



$$\vec{OA} + \vec{AB} = \vec{OB}$$

i.e., $$\vec{a} + \vec{b} = \vec{R}$$

(b) **Magnitude of $\vec{R}$:** Let α = angle between $\vec{a}$ and $\vec{b}$, then,



$$|\vec{R}| = \sqrt{a^2 + b^2 + 2ab\cos\alpha}$$

(c) **Direction of $\vec{R}$:** Let resultant $\vec{R}$ makes an angle θ with $\vec{a}$.

Then, $\tan\theta = \dfrac{b\sin\alpha}{a + b\cos\alpha}$

(d) $|\vec{R}|_{max} = a + b$

(e) $|\vec{R}|_{min} = a - b$

(f) $a + b > R > a - b$

(g) Vector addition obeys commutative law. *i.e.*,

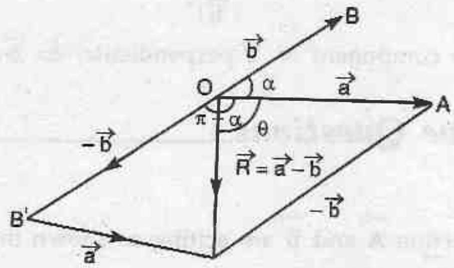
$$\vec{a} + \vec{b} = \vec{b} + \vec{a}$$

(h) Vector addition obeys associative law. *i.e.*,

$$\vec{a} + (\vec{b} + \vec{c}) = (\vec{a} + \vec{b}) + \vec{c}$$

5. Subtraction of vectors : Let two vectors $\vec{a}$ and $\vec{b}$ make an angle α with each other. We define

$$\vec{R} = \vec{a} - \vec{b}$$



Then, $\vec{R}$ is resultant of $\vec{a}$ and $(-\vec{b})$.

The angle between $\vec{a}$ and $(-\vec{b})$ is $\pi - \alpha$.

According to parallelogram law of vectors, the magnitude of $\vec{R}$

$$= |\vec{R}| = \sqrt{a^2 + b^2 + 2ab\cos(\pi - \alpha)}$$
$$= \sqrt{a^2 + b^2 - 2ab\cos\alpha}$$

and $$\tan\alpha = \frac{b\sin(\pi - \alpha)}{a + b\cos(\pi - \alpha)} = \frac{b\sin\alpha}{a - b\cos\alpha}$$

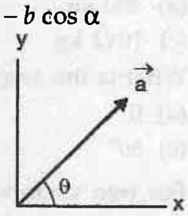
6. Components of a vector :

Here, x-component $= a\cos\theta$

and y-component $= a\sin\theta$

and $\vec{a} = a\cos\theta\,\hat{i} + a\sin\theta\,\hat{j}$

Also, $\tan\theta = \dfrac{y\text{-component}}{x\text{-component}}$



7. Vector in three dimension : If $\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$

(a) $|\vec{r}| = \sqrt{x^2 + y^2 + z^2}$

(b) Let $\vec{r}$ makes α, β and γ angles with x-axis, y-axis and z-axis respectively, then

$$\cos\alpha = \frac{x}{\sqrt{x^2+y^2+z^2}}; \qquad \cos\beta = \frac{y}{\sqrt{x^2+y^2+z^2}}$$

and $$\cos\gamma = \frac{z}{\sqrt{x^2+y^2+z^2}}$$

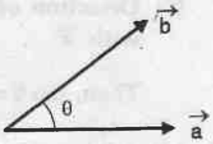
(c) $\cos^2\alpha + \cos^2\beta + \cos^2\gamma = 1$

8. **Scalar product or dot product :**

(a) $\vec{a}\cdot\vec{b} = |\vec{a}|\,|\vec{b}|\cos\theta$

(b) Dot product of two vectors may be negative.

(c) $\vec{a}\cdot\vec{b} = \vec{b}\cdot\vec{a}$



(d) $\vec{a}\cdot(\vec{b}+\vec{c}) = \vec{a}\cdot\vec{b} + \vec{a}\cdot\vec{c}$

(e) $\vec{a}\cdot\vec{a} = a^2$

(f) $\hat{i}\cdot\hat{i} = 1,\ \hat{j}\cdot\hat{j} = 1$ and $\hat{k}\cdot\hat{k} = 1$

(g) $\hat{i}\cdot\hat{j} = 0,\ \hat{j}\cdot\hat{k} = 0,\ \hat{i}\cdot\hat{k} = 0$

(h) If $\vec{a} = a_x\hat{i} + a_y\hat{j} + a_z\hat{k}$ and $\vec{b} = b_x\hat{i} + b_y\hat{j} + b_z\hat{k}$

$\therefore$ $$\vec{a}\cdot\vec{b} = a_x b_x + a_y b_y + a_z b_z$$

(i) The angle between vectors $\vec{a}$ and $\vec{b}$ is

$$\theta = \cos^{-1}\left[\frac{\vec{a}\cdot\vec{b}}{|\vec{a}|\,|\vec{b}|}\right]$$

(j) The component of $\vec{a}$ parallel to $\vec{b}$ in vector form is

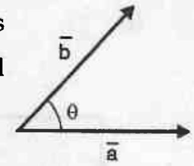
$$\vec{c} = \frac{(\vec{a}\cdot\vec{b})\,\vec{b}}{|\vec{b}|^2}$$

(k) The component of $\vec{a}$ perpendicular to $\vec{b}$ in vector form is

$$\vec{d} = \vec{a} - \left(\frac{\vec{a}\cdot\vec{b}}{|\vec{b}|^2}\right)\vec{b}$$

9. **Vector product or Cross product of two vectors :**

(a) $\vec{a}\times\vec{b} = |\vec{a}|\,|\vec{b}|\sin\theta\,\hat{n}$, where $\hat{n}$ is unit vector perpendicular to $\vec{a}$ and $\vec{b}$.



(b) $\vec{a}\times\vec{b} \neq \vec{b}\times\vec{a}$

(c) $\vec{a}\times\vec{a} = \vec{0}$

(d) $\hat{i}\times\hat{i} = \vec{0},\ \hat{j}\times\hat{j} = \vec{0}$ and $\hat{k}\times\hat{k} = \vec{0}$

(i) $\hat{i}\times\hat{j} = \hat{k}$

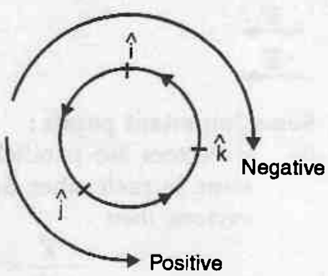
(ii) $\hat{j}\times\hat{k} = \hat{i}$

(iii) $\hat{k}\times\hat{i} = \hat{j}$

(iv) $\hat{i}\times\hat{k} = -\hat{j}$

(v) $\hat{k}\times\hat{j} = -\hat{i}$

(vi) $\hat{j}\times\hat{i} = -\hat{k}$



(e) The unit vector normal to $\vec{a}$ and $\vec{b}$ is

$$\hat{e} = \pm\frac{(\vec{a}\times\vec{b})}{|\vec{a}\times\vec{b}|}$$

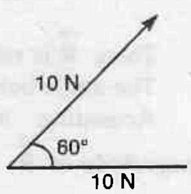
(f) If $\vec{a} = a_x\hat{i} + a_y\hat{j} + a_z\hat{k}$ and $\vec{b} = b_x\hat{i} + b_y\hat{j} + b_z\hat{k}$

then $$\vec{a}\times\vec{b} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ a_x & a_y & a_z \\ b_x & b_y & b_z \end{vmatrix}$$

Objective Questions

Level-1

1. Two vectors $\vec{A}$ and $\vec{B}$ are aciting as shown in figure. If $|\vec{A}| = |\vec{B}| = 10\,\text{N}$ then the resultant is :



(a) $10\sqrt{2}$ N
(b) 10 N
(c) $5\sqrt{3}$ N
(d) none of the above

2. A force $F = (6\hat{i} - 8\hat{j} + 10\hat{k})$ N produces an acceleration of 1 m/s² in a body. The mass of body would be :

(a) 200 kg (b) 20 kg
(c) $10\sqrt{2}$ kg (d) $6\sqrt{2}$ kg

3. What is the angle between $\hat{i} + \hat{i} + \hat{k}$ and $\hat{j}$?

(a) 0 (b) 45°
(c) 60° (d) None of these

4. For two vectors $\vec{A}$ and $\vec{B}$, which of following relations are not commutative ?

(a) $\vec{P} + \vec{Q}$ (b) $\mathbf{P}\times\mathbf{Q}$
(c) $\vec{P}\cdot\vec{Q}$ (d) None of these

5. If $\vec{P} + \vec{Q} = \vec{R}$ and $|\vec{P}| = |\vec{Q}| = \sqrt{3}$ and $|\vec{C}| = 3$, then the angle between $\vec{P}$ and $\vec{Q}$ is :

(a) 0 (b) $\pi/6$
(c) $\pi/3$ (d) $\pi/2$

6. The angle between $\vec{A}\times\vec{B}$ and $\vec{A}+\vec{B}$ is :

(a) 90° (b) 180°
(c) 60° (d) none of these

7. Minimum number of unequal coplanar forces whose vector sum can be equal to zero is :

(a) two (b) three
(c) four (d) any

8. If $|\vec{A}+\vec{B}| = |\vec{A}-\vec{B}|$ then, the angle between $\vec{A}$ and $\vec{B}$ is :

(a) 0° (b) 90°
(c) 60° (d) 180°

9. Resultant of which of the following may be equal to zero ?

(a) 10 N, 10 N, 10 N (b) 10 N, 10 N, 25 N
(c) 10 N, 10 N, 35 N (d) None of these

10. The maximum resultant of two vectors is 26 unit and minimum resultant is 16 unit, then the magnitude of each vector is :

(a) 21, 5 (b) 13, 13
(c) 20, 6 (d) none of these

11. If $\vec{P} \times \vec{Q} = \vec{0}$ and $\vec{Q} \times \vec{R} = \vec{0}$, then the value of $\vec{P} \times \vec{R}$ is :

(a) zero (b) $AC \sin \theta\, \hat{n}$
(c) $AC \cos \theta$ (d) $AB \tan \theta$

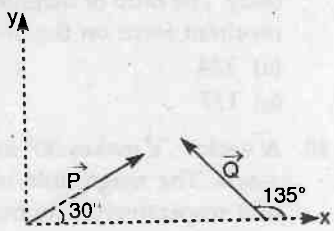
12. Two vectors $\vec{P}$ and $\vec{Q}$ are such that $\vec{P} + \vec{Q} = \vec{R}$ and $|\vec{P}|^2 + |\vec{Q}|^2 = |\vec{R}|^2$. Which of the following is correct ?

(a) $\vec{P}$ is parallel to $\vec{Q}$
(b) $\vec{P}$ is anti-parallel to $\vec{Q}$
(c) $\vec{P}$ is perpendicular to $\vec{Q}$
(d) $\vec{P}$ and $\vec{Q}$ are equal in magnitude

13. What is the property of two vectors $\vec{P}$ and $\vec{Q}$ if $\vec{P} + \vec{Q} = \vec{P} - \vec{Q}$?

(a) P is null vector (b) Q is null vector
(c) P is proper vector (d) Q is proper vector

14. Two vectors $\vec{P}$ and $\vec{Q}$ have equal magnitude of 10 unit. They are oriented as shown in figure. The resultant of these vector is :



(a) 10 unit
(b) $10\sqrt{2}$ unit
(c) 12 unit
(d) none of the above

15. If $\vec{P} = \vec{Q} + \vec{R}$ and $\vec{Q} = \vec{R} + \vec{P}$ then the vector $\vec{R}$ is :

(a) $\vec{P} + \vec{Q}$ (b) $\vec{Q} - \vec{P}$
(c) $\vec{P} - \vec{Q}$ (d) null vector

16. If $\vec{A} = a_1 \hat{i} + b_1 \hat{i}$ and $\vec{B} = a_2 \hat{i} + b_2 \hat{j}$, the condition that they are parallel to each other is :

(a) $\dfrac{a_1}{b_1} = -\dfrac{b_2}{a_2}$ (b) $a_1 b_1 = a_2 b_2$
(c) $\dfrac{a_1}{a_2} = \dfrac{b_1}{b_2}$ (d) none of these

17. A vector $\vec{P}$ makes an angle of 10° and $\vec{Q}$ makes an angle of 100° with x-axis. The magnitude of these vectors are 6 m and 8 m. The resultant of these vectors is :

(a) 10 m (b) 14 m
(c) 2 m (d) none of these

18. The algebraic sum of modulus of two vectors acting at a point is 20 N. The resultant of these vectors is perpendicular to the smaller vector and has a magnitude of 10 N. If the smaller vector is of magnitude b, then the value of b is :

(a) 5 N (b) 20 N
(c) 7.5 N (d) none of these

19. The modulus of the vector product of two vectors is $\dfrac{1}{\sqrt{3}}$ times their scalar product. The angle between vectors is :

(a) $\dfrac{\pi}{6}$ (b) $\dfrac{\pi}{2}$
(c) $\dfrac{\pi}{4}$ (d) $\dfrac{\pi}{3}$

20. The resultant of two vectors makes angle 30° and 60° with them and has magnitude of 40 unit. The magnitude of the two vectors are :

(a) 20 unit, 20 unit (b) 20 unit, 28 unit
(c) 20 unit, $20\sqrt{3}$ unit (d) 20 unit, 60 unit

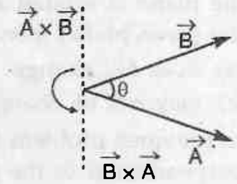
21. A child takes 8 steps towards east and 6 steps towards north. If each step is equal to 1 cm, then the magnitude of displacement is :

(a) 14 m (b) 0.1 m
(c) 10 m (d) none of these

22. A cyclist is moving on a circular path with constant speed. What is the change in its velocity after it has described an angle of 30° ?

(a) $v\sqrt{2}$ (b) $v\,(0.3\sqrt{3})$
(c) $v\sqrt{3}$ (d) None of these

23. Angle between $\vec{A} \times \vec{B}$ and $\vec{B} \times \vec{A}$ is :



(a) π
(b) $\dfrac{\pi}{2}$
(c) $\dfrac{\pi}{6}$
(d) none of the above

24. Given $\vec{P} = P \cos \theta \hat{i} + P \sin \theta \hat{j}$. The vector $\vec{P}$ which is perpendicular to $\vec{Q}$ is given by :

(a) $Q \cos \theta \hat{i} - Q \sin \theta \hat{j}$ (b) $Q \sin \theta \hat{i} - Q \cos \theta \hat{j}$
(c) $Q \cos \theta \hat{i} + Q \sin \theta \hat{j}$ (d) $Q \sin \theta \hat{i} + Q \cos \theta \hat{j}$

25. The resultant $\vec{R}$ of vectors $\vec{P}$ and $\vec{Q}$ is perpendicular to $\vec{P}$ also $|\vec{P}| = |\vec{R}|$, the angle between $\vec{P}$ and $\vec{Q}$ is :

(a) 45° (b) 135°
(c) 225° (d) none of these

26. A force $\vec{F} = 3\hat{i} - 2\hat{j} + 4\hat{k}$ displaces an object from a point P (1, 1, 1) to another point of co-ordinates (2, 0, 3). The work done by force is :

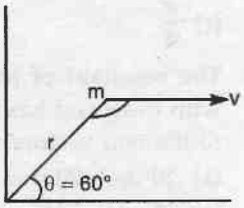
(a) 10 J (b) 12 J
(c) 13 J (d) none of these

27. The arbitrary number '–2' is multiplied with vector $\vec{A}$ then :

(a) the magnitude of vector will be doubled and direction will be same
(b) the magnitude of vector will be doubled and direction will be opposite
(c) the magnitude of vector and its direction remain constant
(d) none of the above

28. A man first moves 3 m due east, then 6 m due north and finally 7 m due west, then the magnitude of the resultant displacement is :
(a) $\sqrt{16}$ (b) $\sqrt{24}$
(c) $\sqrt{40}$ (d) $\sqrt{94}$

29. A particle of mass m is moving with constant velocity v along x-axis in x-y plane as shown in figure. Its angular momentum with respect to origin at any time 't', if position vector $\vec{r}$, is :



(a) $3mv\,\vec{\mathbf{k}}$ (b) $\frac{\sqrt{3}}{2}mv\,\vec{\mathbf{k}}$
(c) $\frac{1}{2}mv\,\vec{\mathbf{k}}$ (d) $mv\,\vec{\mathbf{k}}$

30. The maximum and minimum resultant of two forces are in ratio 5 : 3, then ratio of the forces is :
(a) 10 : 6
(b) 3 : 5
(c) 4 : 1
(d) none of the above

Level-2

1. Pressure is :
(a) a scalar quantity (b) a vector quantity
(c) a tensor quantity (d) either scalar or vector

2. If electric current is assumed as vector quantity, then :
(a) charge conservation principle fails
(b) charge conservation principle does not fail
(c) Coulomb's law fails
(d) none of the above

3. The direction of area vector is perpendicular to plane. If the plane is rotated about an axis lying in the plane of the given plane, then the direction of area vector :
(a) does not change (b) remains the same
(c) may not be changed (d) none of the above

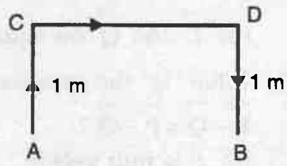
4. In previous problem if the plane is rotated about an axis perpendicular to the plane of the given plane, then area vector :
(a) must be changed (b) may not be changed
(c) must not be changed (d) none of the above

5. An insect moves on a circular path of radius 7m. The maximum magnitude of displacement of the insect is :
(a) 7 m (b) 14π m
(c) 7π m (d) 14 m

6. In previous problem, if the insect moves with constant speed 10 m/s, the minimum time to achieve maximum magnitude of displacement is :
(a) 10 s (b) 2 s
(c) 1.4 s (d) 2.2 s

* 7. The IIT lecture theatre is 50 ft wide and has a door at the corner. A teacher enters at 7.30 AM through the door and makes 20 rounds along the 50 ft wall back and fourth during period and finally leaves the class-room at 9 AM through the same door. If he walks with constant speed of 10 ft/min, find the distance and the magnitude of displacement travelled by the teacher during the period :
(a) 2000 ft and 0 ft (b) 100 ft and 0 ft
(c) 2000 ft and 50 ft (d) none of these

8. A man walks from A to C , C to D and D to B (as shown in figure). The magnitude of displacement of man is 10 m. The total distance travelled by the man is :



(a) 10 m
(b) 2 m
(c) 12 m
(d) 7 m

9. Two forces of magnitudes 3N and 4N are acted on a body. The ratio of magnitude of minimum and maximum resultant force on the body is :
(a) 3/4 (b) 4/3
(c) 1/7 (d) none of these

10. A vector $\vec{a}$ makes 30° and $\vec{b}$ makes 120° angle with the x-axis. The magnitude of these vectors are 3 unit and 4 unit respectively. The magnitude of resultant vector is :
(a) 3 unit (b) 4 unit
(c) 5 unit (d) 1 unit

11. If two forces of equal magnitude 4 units acting at a point and the angle between them is 120° then the magnitude and direction of the sum of the two vectors are :
(a) $4, \theta = \tan^{-1}(1.73)$ (b) $4, \theta = \tan^{-1}(0.73)$
(c) $2, \theta = \tan^{-1}(1.73)$ (d) $6, \theta = \tan^{-1}(0.73)$

12. If $\frac{|\vec{a}+\vec{b}|}{|\vec{a}-\vec{b}|} = 1$, then the angle between $\vec{a}$ and $\vec{b}$ is :
(a) 0° (b) 45°
(c) 90° (d) 60°

13. The angle between $\vec{A}$ and the resultant of $(\vec{A}+\vec{B})$ and $(\vec{A}-\vec{B})$ will be :
(a) 0° (b) $\tan^{-1}\left(\frac{A}{B}\right)$
(c) $\tan^{-1}\left(\frac{B}{A}\right)$ (d) $\tan^{-1}\left(\frac{A-B}{A+B}\right)$

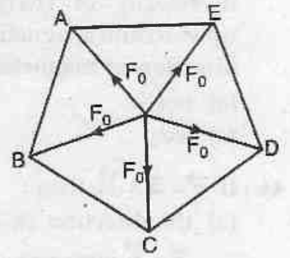
14. Mark correct option :
(a) $|\vec{a}-\vec{b}| = |\vec{a}| - |\vec{b}|$
(b) $|\vec{a}-\vec{b}| < |\vec{a}| - |\vec{b}|$
(c) $|\vec{a}-\vec{b}| > |\vec{a}| - |\vec{b}|$
(d) $|\vec{a}-\vec{b}| > |\vec{a}| - |\vec{b}|$

15. How many minimum number of vector of equal magnitude are required to produce zero resultant ?
(a) 2 (b) 3
(c) 4 (d) More than 4

16. Three forces are acted on a body. Their magnitudes are 3 N, 4 N and 5 N. Then
(a) the acceleration of body must be zero
(b) the acceleration of body may be zero
(c) the acceleration of the body must not be zero
(d) none of the above

17. In previous problem, the minimum magnitude of resultant force is :
(a) $= 0$ (b) > 0
(c) < 0 (d) ≤ 0

18. In the given figure, O is the centre of regular pentagon $ABCDE$. Five forces each of magnitude F_0 are acted as shown in figure. The resultant force is :

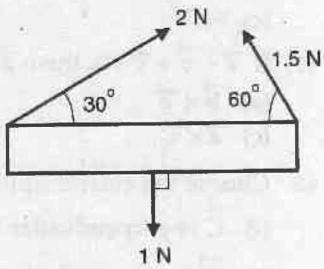


(a) $5F_0$
(b) $5F_0 \cos 72°$
(c) $5F_0 \sin 72°$
(d) zero

19. $ABCD$ is a parallelogram, and $\vec{a}, \vec{b}, \vec{c}$ and $\vec{d}$ are the position vectors of vertices A, B, C and D of a parallelogram. The correct option is :
(a) $\vec{c} + \vec{b} = \vec{d} - \vec{a}$ (b) $\vec{c} - \vec{b} = \vec{d} - \vec{a}$
(c) $\vec{b} - \vec{c} = \vec{d} - \vec{a}$ (d) none of these

20. A man walks 4 km due west, 500 m due south finally 750 m in south west direction. The distance and magnitude of displacement travelled by the man are :
(a) 4646.01 m and 5250 m
(b) 5250 m and 4646.01 m
(c) 4550.01 m and 2300 m
(d) none of the above

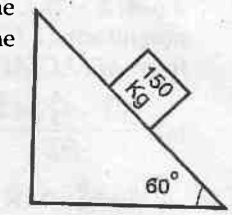
21. From Newton's law of motion, $\vec{F} = m\vec{a}$, three forces (shown in figure) are acted on the body of mass 0.8 kg. The magnitude of acceleration of the body is :



(a) 1 m/s^2
(b) 2 m/s^2
(c) 1.6 m/s^2
(d) none of the above

22. Calculate the resultant force, when four forces of 30 N due east, 20N due north, 50N due west and 40 N due south, are acted upon a body :
(a) $20\sqrt{2}$ N, 60°, south-west
(b) $20\sqrt{2}$ N, 45°, south-west
(c) $20\sqrt{2}$ N, 45° north-east
(d) $20\sqrt{2}$ N, 45° south-east

23. A block of 150 kg is placed on an inclined plane with an angle of 60°. The component of the weight parallel to the inclined plane is :



(a) 1300 N
(b) 1400 N
(c) 1100 N
(d) 1600 N

24. In the previous problem, the component of weight perpendicular to the inclined plane is :
(a) 980 N (b) 1500 N
(c) 1000 N (d) 750 N

25. If three forces $\vec{F_1} = 3\hat{i} - 4\hat{j} + 5\hat{k}$
$$\vec{F_2} = -3\hat{i} + 4\hat{j} \text{ and } \vec{F_3} = -5\hat{k}$$
are acted on a body, then the direction of resultant force on the body is :
(a) along x-axis (b) along y-axis
(c) along z-axis (d) in indeterminate form

26. A cat is situated at point A (0, 3, 4) and a rat is situated at point B (5, 3, – 8). The cat is free to move but the rat is always at rest. The minimum distance travelled by cat to catch the rat is :
(a) 5 unit (b) 12 unit
(c) 13 unit (d) 17 unit

27. An insect started flying from one corner of a cubical room and reaches at diagonally opposite corner. The magnitude of displacement of the insect is $40\sqrt{3}$ ft. The volume of cube is :
(a) $64\sqrt{3}$ ft^3 (b) 1600 ft^3
(c) 64000 ft^3 (d) none of these

28. In previous problem, if the insect does not fly but crawls, what is the minimum distance travelled by the insect ?
(a) 89.44 ft (b) 95.44 ft
(c) 40 ft (d) 80 ft

29. The position vector of a moving particle at time t is $\vec{r} = 3\hat{i} + 4t^2\hat{j} - t^3\hat{k}$. Its displacement during the time interval $t = 1$ s to $t = 3$ s is :
(a) $\hat{j} - \hat{k}$ (b) $3\hat{i} + 4\hat{j} - \hat{k}$
(c) $9\hat{i} + 36\hat{j} - 27\hat{k}$ (d) $32\hat{j} - 26\hat{k}$

***30.** If a rigid body is rotating about an axis passing through the point $2\hat{i} - \hat{j} - \hat{k}$ and parallel to $\hat{i} - 2\hat{j} + 2\hat{k}$ with an angular velocity 3 radians/sec, then find the velocity of the point of the rigid body whose position vector is $2\hat{i} + 3\hat{j} - 4\hat{k}$:
(a) $-2\hat{i} + 3\hat{j} + 4\hat{k}$ (b) $2\hat{i} - 3\hat{j} + 4\hat{k}$
(c) $-2\hat{i} + 3\hat{j} - 4\hat{k}$ (d) $-2\hat{i} - 3\hat{j} - 4\hat{k}$

***31.** Obtain the magnitude and direction cosines of vector $(\vec{A} - \vec{B})$, if $\vec{A} = 2\hat{i} + 3\hat{j} + \hat{k}$, $\vec{B} = 2\hat{i} + 2\hat{j} + 3\hat{k}$:
(a) $0, \frac{1}{\sqrt{5}}, \frac{-2}{\sqrt{5}}$ (b) $0, \frac{2}{\sqrt{5}}, \frac{1}{\sqrt{5}}$
(c) $0, 0, \frac{1}{\sqrt{5}}$ (d) none of these

32. The vertices of a quadrilateral are $A(1, 2, -1)$, $B(-4, 2, -2)$, $C(4, 1, -5)$ and $D(2, -1, 3)$. Forces of magnitudes 2 N, 3 N, 2 N are acting at point A along the lines AB, AC, AD respectively. Their resultant is :

(a) $\dfrac{10\hat{i}-9\hat{j}+6\hat{k}}{\sqrt{26}}$ (b) $\left(\dfrac{\hat{i}-9\hat{j}-6\hat{k}}{\sqrt{26}}\right)$

(c) $\dfrac{\hat{i}+9\hat{j}+16\hat{k}}{\sqrt{26}}$ (d) $\dfrac{\hat{i}-19\hat{j}+6\hat{k}}{\sqrt{26}}$

33. The position vectors of four points A, B, C and D are

$\vec{a}=2\hat{i}+3\hat{j}+4\hat{k}$, $\vec{b}=3\hat{i}+5\hat{j}+7\hat{k}$,

$\vec{c}=\hat{i}+2\hat{j}+3\hat{k}$ and $\vec{d}=3\hat{i}+6\hat{j}+9\hat{k}$

respectively. Then vectors $\overrightarrow{AB}$ and $\overrightarrow{CD}$ are :

(a) coplanar (b) collinear

(c) perpendicular (d) none of these

34. A force $\vec{F}=a\hat{i}+b\hat{j}+c\hat{k}$ is acted upon a body of mass 'm'. If the body starts from rest and was at the origin initially. Its new co-ordinates after time t are :

(a) $\dfrac{at^2}{2m}, \dfrac{bt^2}{2m}, \dfrac{ct^2}{2m}$ (b) $\dfrac{at^2}{2m}, \dfrac{2bt^2}{m}, \dfrac{ct^2}{2m}$

(c) $\dfrac{at^2}{m}, \dfrac{bt^2}{m}, \dfrac{ct^2}{2m}$ (d) none of these

35. The angle between vectors $\vec{a}=2\hat{i}+\hat{j}-2\hat{k}$ and $\vec{b}=3\hat{i}-4\hat{j}$ is equal to :

(a) $\cos^{-1}\left(\dfrac{3}{15}\right)$ (b) $\cos^{-1}\left(\dfrac{1}{15}\right)$

(c) zero (d) $\cos^{-1}\dfrac{2}{15}$

36. The angular relationship between the vectors $\vec{A}$ and $\vec{B}$ is :

$\vec{A}=3\hat{i}+2\hat{j}+4\hat{k}$, $\vec{B}=2\hat{i}+\hat{j}-2\hat{k}$

(a) 180° (b) 90° (c) 0° (d) 240°

*** 37.** The resultant of two vectors $\vec{P}$ and $\vec{Q}$ is $\vec{R}$. If the vector $\vec{Q}$ is reversed, then the resultant becomes $\vec{S}$, then choose the correct option

(a) $R^2+S^2=2(P^2-Q^2)$ (b) $R^2+S^2=2(P^2+Q^2)$

(c) $R^2+S^2=(P^2-Q^2)$ (d) $R^2-S^2=2(P^2+Q^2)$

38. The velocity of a particle is $\vec{v}=6\hat{i}+2\hat{j}-2\hat{k}$. The component of the velocity of a particle parallel to vector $\vec{a}=\hat{i}+\hat{j}+\hat{k}$ in vector form is :

(a) $6\hat{i}+2\hat{j}+2\hat{k}$ (b) $2\hat{i}+2\hat{j}+2\hat{k}$

(c) $\hat{i}+\hat{j}+\hat{k}$ (d) $6\hat{i}+2\hat{j}-2\hat{k}$

39. In previous problem, the component of $\vec{v}$ in perpendicular direction of $\vec{a}$ in vector form is ?

(a) $-2\hat{i}-2\hat{j}-2\hat{k}$ (b) $4\hat{i}-4\hat{k}$

(c) $6\hat{i}+2\hat{j}-2\hat{k}$ (d) $2\hat{i}+2\hat{j}+2\hat{k}$

40. For what value of x, will the two vectors $\vec{A}=2\hat{i}+2\hat{j}-x\hat{k}$ and $\vec{B}=2\hat{i}-\hat{j}-3\hat{k}$ are perpendicular to each other ?

(a) $x=-2/3$ (b) $x=3/2$

(c) $x=-4/3$ (d) $x=2/3$

41. A force $\vec{F}=2\hat{i}+3\hat{j}+\hat{k}$ acts on a body. The work done by the force for a displacement of $-2\hat{i}+\hat{j}-\hat{k}$ is :

(a) 2 unit (b) 4 unit

(c) − 2 unit (d) − 4 unit

42. The work done by a force $\vec{F}=(\hat{i}+2\hat{j}+3\hat{k})$ N, to displace a body from position A to position B is : [The position vector of A is $\vec{r}_1=(\hat{i}+3\hat{i}+\hat{k})$ m and the position vector of B is $\vec{r}_2=(2\hat{i}+2\hat{j}+3\hat{k})$ m]

(a) 5 J (b) 3 J

(c) 2 J (d) 10 J

43. Magnetic force on a moving positive charge is defined by $\vec{F}=q\vec{v}\times\vec{B}$

Here, $\vec{v}$ = velocity of the body

$\vec{B}$ = magnetic field

If velocity of charged particle is directed vertically upward and magnetic force is directed towards west, the direction of magnetic field is :

(a) north (b) east

(c) west (d) south

44. If $\vec{c}=\vec{a}\times\vec{b}$, then :

(a) the direction of $\vec{c}$ changes, when the angle between $\vec{a}\times\vec{b}$ increases up to θ ($\theta<180°$)

(b) the direction of $\vec{c}$ changes, when the angle between $\vec{a}$ and $\vec{b}$ decreases up to θ ($\theta>0°$)

(c) the direction of $\vec{c}$ does not change, when the angle between $\vec{a}$ and $\vec{b}$ increases

(d) none of the above

45. The unit vector perpendicular to vectors $\vec{a}=3\hat{i}+\hat{j}$ and $\vec{b}=2\hat{i}-\hat{j}-5\hat{k}$ is :

(a) $\pm\dfrac{(\hat{i}-3\hat{j}+\hat{k})}{\sqrt{11}}$ (b) $\pm\dfrac{3\hat{i}+\hat{j}}{\sqrt{11}}$

(c) $\pm\dfrac{(2\hat{i}-\hat{j}-5\hat{k})}{\sqrt{30}}$ (d) none of these

46. The value of $\hat{i}\times(\hat{i}\times\vec{a})+\hat{j}\times(\hat{j}\times\vec{a})+\hat{k}\times(\hat{k}\times\vec{a})$ is :

(a) $\vec{a}$ (b) $\vec{a}\times\hat{k}$

(c) $-2\vec{a}$ (d) $-\vec{a}$

47. If $\vec{a}+\vec{b}+\vec{c}=0$, then $\vec{a}\times\vec{b}$ is :

(a) $\vec{b}\times\vec{c}$ (b) $\vec{c}\times\vec{b}$

(c) $\vec{a}\times\vec{c}$ (d) none of these

48. Choose the correct option for $\vec{A}\times\vec{B}=\vec{C}$:

(i) $\vec{C}$ is perpendicular to $\vec{A}$

(ii) $\vec{C}$ is perpendicular to $\vec{B}$

(iii) $\vec{C}$ is perpendicular to $(\vec{A}+\vec{B})$

(iv) $\vec{C}$ is perpendicular to $(\vec{A}\times\vec{B})$

(a) Only (i) and (ii) are correct

(b) Only (ii) and (iv) are correct

(c) (i), (ii) and (iii) are correct.

(d) All are correct

49. The vector area of a triangle whose sides are $\vec{a}, \vec{b}, \vec{c}$, is :

(a) $\frac{1}{2}(\vec{b}\times\vec{c}+\vec{c}\times\vec{a}+\vec{a}\times\vec{b})$

(b) $\frac{1}{3}(\vec{b}\times\vec{c}+\vec{c}\times\vec{a}+\vec{a}\times\vec{b})$

(c) $\frac{1}{3}(-\vec{b}\times\vec{c}+\vec{a}\times\vec{c}+\vec{b}\times\vec{a})$

(d) none of the above

50. If three vectors $x\vec{a}-2\vec{b}+3\vec{c}$, $-2\vec{a}+y\vec{b}-4\vec{c}$ and $-z\vec{b}+2\vec{c}$ are coplanar, where $\vec{a}, \vec{b}, \vec{c}$ are unit (or any) vectors, then

(a) $xy+3zx-3z=4$ (b) $2xy-2zx-3z-4=0$
(c) $4xy-3zx+3z=4$ (d) $xy-2zx+3z-4=0$

51. A force $\vec{F}=(2\hat{i}+3\hat{j}-\hat{k})$ N is acting on a body at a position $\vec{r}=(6\hat{i}+3\hat{j}-2\hat{k})$. The torque about the origin is :

(a) $(3\hat{i}+2\hat{j}+12\hat{k})$ Nm (b) $(9\hat{i}+\hat{j}+7\hat{k})$ Nm
(c) $(\hat{i}+2\hat{j}+12\hat{k})$ Nm (d) $(3\hat{i}+12\hat{j}+\hat{k})$ Nm

52. The values of x and y for which vectors $\vec{A}=(6\hat{i}+x\hat{j}-2\hat{k})$ and $\vec{B}=(5\hat{i}-6\hat{j}-y\hat{k})$ may be parallel are :

(a) $x=0, y=\frac{2}{3}$ (b) $x=-\frac{36}{5}, y=\frac{5}{3}$
(c) $x=-\frac{15}{3}, y=\frac{23}{5}$ (d) $x=\frac{36}{5}, y=\frac{15}{4}$

53. The area of the parallelogram determined by $\vec{A}=2\hat{i}+\hat{j}-3\hat{k}$ and $\vec{B}=12\hat{j}-2\hat{k}$ is :

(a) 42 (b) 56
(c) 38 (d) 74

54. Choose the correct option :

(a) $\vec{a}\times(\vec{b}\times\vec{c})+\vec{b}\times(\vec{c}\times\vec{a})+\vec{c}\times(\vec{a}\times\vec{b})=0$
(b) $\vec{a}\times(\vec{c}\times\vec{b})+\vec{b}\times(\vec{c}\times\vec{a})+\vec{c}\times(\vec{a}\times\vec{b})=0$
(c) $\vec{a}\times(\vec{c}\times\vec{b})+\vec{b}\times(\vec{c}\times\vec{a})-\vec{c}\times(\vec{a}\times\vec{b})=0$
(d) none of the above

55. The three conterminous edges of a parallelopiped are

$$\vec{a}=2\hat{i}-6\hat{j}+3\hat{k}$$
$$\vec{b}=5\hat{j}$$
$$\vec{c}=-2\hat{i}+\hat{k}$$

The volume of parallelopiped is :

(a) 36 cubic unit (b) 45 cubic unit
(c) 40 cubic unit (d) 54 cubic unit

56. If the three vectors are coplanar, then value of 'x' is :

$$\vec{A}=\hat{i}-2\hat{j}+3\hat{k}$$
$$\vec{B}=x\hat{j}+3\hat{k}$$
$$\vec{C}=7\hat{i}+3\hat{j}-11\hat{k}$$

(a) 36/21 (b) –51/32
(c) 51/32 (d) –36/21

57. The position vectors of point charges q_1 and q_2 are $\vec{r}_1$ and $\vec{r}_2$ respectively. The electrostatic force of interaction between charges is $F=\frac{q_1q_2}{4\pi\varepsilon_0 r^2}$

where r = distance between charges

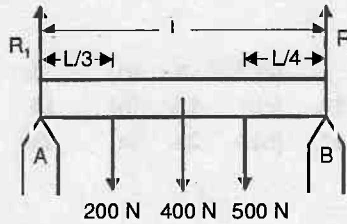
ε_0 = electric permittivity of vacuum.

If electric force on first point charge due to second point charge is directed along the line from q_2 to q_1. Electrostatic force on first point charge due to second point charge in vector form is :

(a) $\frac{q_1q_2(\vec{r}_1-\vec{r}_2)}{4\pi\varepsilon_0|\vec{r}_1-\vec{r}_2|^3}$ (b) $\frac{q_1q_2(\vec{r}_2-\vec{r}_1)}{4\pi\varepsilon_0|\vec{r}_2-\vec{r}_1|^3}$

(c) $\frac{q_1q_2\vec{r}_1}{4\pi\varepsilon_0|\vec{r}_1-\vec{r}_2|^3}$ (d) $\frac{q_1q_2\vec{r}_2}{4\pi\varepsilon_0|\vec{r}_2-\vec{r}_1|^3}$

* 58. The system is shown in the figure, consists of a uniform beam of 400 N weight on which objects of weight 200 N and 500 N are hanging. Calculate the magni- tude of forces R_1 and R_2 exerted in the supports :



(a) $R_1=590$ N, $R_2=840$ N
(b) $R_1=420$ N, $R_2=580$ N
(c) $R_1=458$ N, $R_2=642$ N
(d) $R_1=1390$ N, $R_2=375$ N

59. A particle is moving along a circular path with a constant speed 30 m/s. What is change in velocity of a particle, when it describes an angle of 90° at the centre of the circle ?

(a) Zero (b) $30\sqrt{2}$ m/s
(c) $60\sqrt{2}$ m/s (d) $\frac{30}{\sqrt{2}}$ m/s

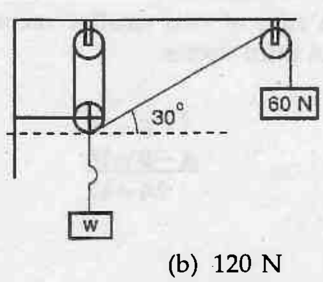
60. One day in still air, a motor-cyclist riding north at 30 m/s, suddenly the wind starts blowing westward with a velocity 50 m/s, then the apparent velocity with which the motor-cyclist will move, is :

(a) 58.3 m/s (b) 65.4 m/s
(c) 73.2 m/s (d) 53.8 m/s

61. A man walks 20 m at an angle of 60° north-east. How far towards east has he travelled ?

(a) 10 m (b) 20 m
(c) $20\sqrt{3}$ m (d) $\frac{10}{\sqrt{3}}$ m

* 62. If the system shown in the figure is in equilibrium then, calculate the value of weight w. Assume pulleys to be weightless and frictionless :



(a) 60 N (b) 120 N
(c) 150 N (d) 90 N

63. The distance travelled by the car, if a car travels 4 km towards north at an angle of 45° to the east and then travels a distance of 2 km towards north at an angle of 135° to the east, is :

(a) 6 km (b) 8 km
(c) 5 km (d) 2 km

64. On one rainy day a car starts moving with a constant acceleration of 1.2 m/s^2. If a toy monkey is suspended from the ceiling of the car by a string, then at what angle the string is inclined with the vertical ?

(a) $\tan^{-1}(0.25)$ (b) $\tan^{-1}(0.63)$
(c) $\tan^{-1}(0.12)$ (d) $\tan^{-1}(\sqrt{3})$

65. If a particle is moving on an elliptical path given by $\vec{r} = b\cos\omega t\,\hat{i} + a\sin\omega t\,\hat{j}$, then its radial acceleration along $\vec{r}$ is :

(a) $\omega\vec{r}$ (b) $\omega^2\vec{r}$
(c) $-\omega^2\vec{r}$ (d) none of these

66. What is the $\nabla\phi$ at the point (0, 1, 0) of a scalar function ϕ, if $\phi = 2x^2 + y^2 + 3z^2$?

(a) $2\hat{j}$
(b) $3\hat{j}$
(c) $4\hat{i} + 2\hat{j}$
(d) $3\hat{i} + 3\hat{j}$

Answers

Level-1

1. (b)	2. (c)	3. (d)	4. (b)	5. (c)	6. (a)	7. (b)	8. (b)	9. (a)	10. (a)
11. (a)	12. (c)	13. (b)	14. (c)	15. (d)	16. (a)	17. (a)	18. (c)	19. (a)	20. (c)
21. (b)	22. (b)	23. (a)	24. (b)	25. (b)	26. (c)	27. (b)	28. (c)	29. (b)	30. (c)

Level-2

1. (a)	2. (a)	3. (b)	4. (c)	5. (d)	6. (d)	7. (a)	8. (c)	9. (c)	10. (c)
11. (a)	12. (c)	13. (a)	14. (c)	15. (a)	16. (b)	17. (a)	18. (d)	19. (b)	20. (a)
21. (b)	22. (b)	23. (a)	24. (d)	25. (d)	26. (c)	27. (c)	28. (a)	29. (d)	30. (a)
31. (a)	32. (b)	33. (b)	34. (a)	35. (d)	36. (b)	37. (b)	38. (b)	39. (b)	40. (a)
41. (c)	42. (a)	43. (a)	44. (c)	45. (a)	46. (c)	47. (a)	48. (c)	49. (a)	50. (d)
51. (a)	52. (b)	53. (a)	54. (a)	55. (c)	56. (b)	57. (a)	58. (c)	59. (b)	60. (a)
61. (a)	62. (c)	63. (a)	64. (c)	65. (c)	66. (a)				

Solutions

Level-1

2. $m = \dfrac{|\vec{F}|}{a} = \dfrac{10\sqrt{2}}{1} = 10\sqrt{2}$ kg

3. $\cos\theta = \dfrac{(\hat{i}+\hat{j}+\hat{k})\cdot\hat{j}}{\sqrt{(1)^2+(1)^2+(1)^2}\,\sqrt{(1)^2}} = \dfrac{1}{\sqrt{3}}$

5.
$$|\vec{C}|^2 = |\vec{P}|^2 + |\vec{Q}|^2 + 2|\vec{P}|\,|\vec{Q}|\cos\theta$$
$$3^2 = 3 + 3 + 2(3)\cos 0$$
$$\frac{9}{6} = 1 + \cos\theta$$
$$\therefore \quad \cos\theta = \frac{1}{2}$$
$$\therefore \quad \theta = 60°$$

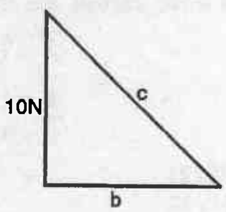
9. Hint : The resultant of three vectors will be zero if and only if the sum of two smaller vectors is equal to or greater than third vector.

10. Let
$$A + B = 26$$
$$\underline{A - B = 16}$$
$$2A = 42$$
$$\therefore \quad A - 21$$
$$B = 5$$

11.
$$\vec{P}\times\vec{Q} = 0 \Rightarrow \vec{P} \parallel \vec{Q};$$
$$\vec{Q}\times\vec{R} = 0 \Rightarrow \vec{Q} \parallel \vec{R}$$
$$\therefore \quad \vec{P}\times\vec{R} = 0 \text{ then } \vec{P} \parallel \vec{R}$$

16.
$$a_1a_2 + b_1b_2 = 0$$
$$a_1a_2 = -b_1b_2$$
$$\frac{a_1}{b_1} = -\frac{b_2}{a_2}$$

18.
$$b + c = 20 \quad \ldots(i)$$
and
$$c^2 = (10)^2 + b^2$$
$$(20-b)^2 = (10)^2 + b^2$$
$$400 - 40b + b^2 = 100 + b^2$$
$$400 - 100 = 40\,b$$
$$\frac{300}{40} = b \Rightarrow b = 7.5 \text{ N}$$



3

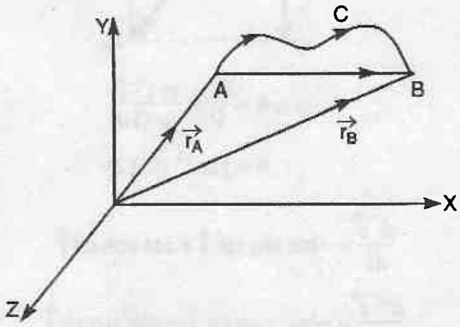
Kinematics

Syllabus: Motion in a straight line, uniform motion, its graphical representation, uniform accelerated motion and its applications, projectile motion.

Review of Concepts

1. Time : It is measure of succession of events. It is a scalar quantity. If any event is started at $t = 0$ then time will not be negative. But if the observation is started after the start of event then time may be negative.

2. Distance and Displacement : Suppose an insect is at a point $A(x_1, y_1, z_1)$ at $t = t_1$. It reaches at point $B(x_2, y_2, z_2)$ at $t = t_2$ through path ACB with respect to the frame shown in figure. The actual length of curved path ACB is the distance travelled by the insect in time $\Delta t = t_2 - t_1$.



If we connect point A (initial position) and point B (final position) by a straight line, then the length of straight line AB gives the magnitude of displacement of insect in time interval $\Delta t = t_2 - t_1$.

The direction of displacement is directed from A to B through the straight line AB. From the concept of vector, the position vector of $\vec{\mathbf{A}}$ is $\vec{\mathbf{r}}_A = x_1\hat{\mathbf{i}} + y_1\hat{\mathbf{j}} + z_1\hat{\mathbf{k}}$ and that of B is $\vec{\mathbf{r}}_B = x_2\hat{\mathbf{i}} + y_2\hat{\mathbf{j}} + z_2\hat{\mathbf{k}}$.

According to addition law of vectors,

$$\vec{\mathbf{r}}_A + \vec{\mathbf{AB}} = \vec{\mathbf{r}}_B$$

$$\therefore \quad \vec{\mathbf{AB}} = \vec{\mathbf{r}}_B - \vec{\mathbf{r}}_A$$

$$= (x_2 - x_1)\,\hat{\mathbf{i}} + (y_2 - y_1)\,\hat{\mathbf{j}} + (z_2 - z_1)\,\hat{\mathbf{k}}$$

The magnitude of displacement is

$$|\vec{\mathbf{AB}}| = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2}$$

Some Conceptual Points :

(i) Distance is a scalar quantity.

(ii) Distance never be negative.

(iii) For moving body, distance is always greater than zero.

(iv) Distance never be equal to displacement.

(v) Displacement is a vector quantity.

(vi) If a body is moving continuously in a given direction on a straight line, then the magnitude of displacement is equal to distance.

(vii) Generally, the magnitude of displacement is less or equal to distance.

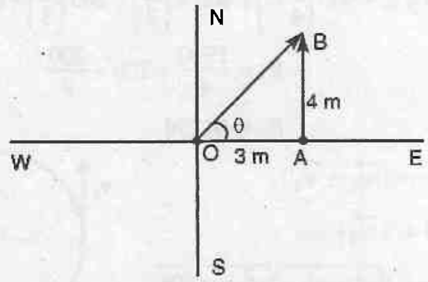
(viii) Many paths are possible between two points. For different paths between two points, distances are different but magnitudes of displacement are same.

(ix) The slope of distance-time graph is always greater or equal to zero.

(x) The slope of displacement-time graph may be negative.

Example : A man walks 3 m in east direction, then 4 m in north direction. Find distance covered and the displacement covered by man.

Solution : The distance covered by man is the length of path $= 3\text{ m} + 4\text{ m} = 7\text{ m}$.



Let the man starts from O and reaches finally at B (shown in figure). $\vec{\mathbf{OB}}$ represents the displacement of man. From figure,

$$|\vec{\mathbf{OB}}| = (OA)^2 + (AB)^2$$

$$= (3\text{ m})^2 + (4\text{ m})^2 = 5\text{ m}$$

and $\quad \tan\theta = \dfrac{4\text{ m}}{3\text{ m}} = \dfrac{4}{3}$

$$\therefore \quad \theta = \tan^{-1}\left(\frac{4}{3}\right)$$

The displacement is directed at an angle $\tan^{-1}\left(\frac{4}{3}\right)$ north of east.

3. Average Speed and Average Velocity : Suppose we wish to calculate the average speed and average velocity of the insect (in section 2) between $t = t_1$ and $t = t_2$. From the path (shown in figure) we see that at $t = t_1$, the position of the insect is $A(x_1, y_1, z_1)$ and at $t = t_2$, the position of the insect is $B(x_2, y_2, z_2)$.

The average speed is defined as total distance travelled by a body in a particular time interval divided by the time interval. Thus, the average speed of the insect is

$$v_{av} = \frac{\text{The length of curve } ACB}{t_2 - t_1}$$

The average velocity is defined as total displacement travelled by a body in a particular time interval divided by the time interval.

Thus, the average velocity of the insect in the time interval $t_2 - t_1$ is

$$\vec{v}_{av} = \frac{\vec{AB}}{t_2 - t_2}$$

$$= \frac{\vec{r}_B - \vec{r}_A}{t_2 - t_1}$$

$$= \frac{(x_2 - x_1)\,\hat{i} + (y_2 - y_1)\,\hat{j} + (z_2 - z_1)\,\hat{k}}{t_2 - t_1}$$

Some Important Points :

(i) Velocity is a vector quantity while speed is a scalar quantity.

(ii) If a particle travels equal distances at speeds $v_1, v_2, v_3, \ldots$ etc. respectively, then the average speed is harmonic mean of individual speeds.

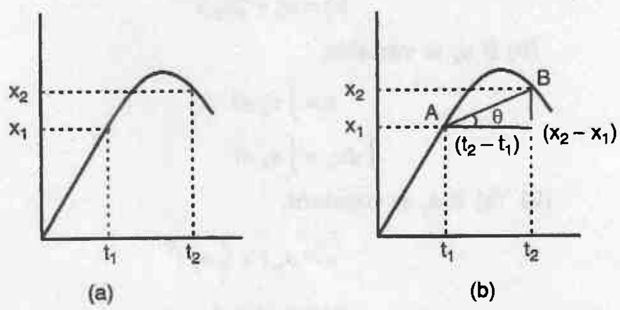
(iii) If a particle moves a distance at speed v_1 and comes back with speed v_2, then $v_{av} = \frac{2v_1v_2}{v_1 + v_2}$

But $\vec{v}_{av} = 0$

(iv) If a particle moves in two equal intervals of time at different speeds v_1 and v_2 respectively, then

$$v_{av} = \frac{v_1 + v_2}{2}$$

(v) The average velocity between two points in a time interval can be obtained from a position versus time graph by calculating the slope of the straight line joining the co-ordinates of the two points.



The graph [shown in fig. (a)], describes the motion of a particle moving along x-axis (along a straight line).

Suppose we wish to calculate the average velocity between $t = t_1$ and $t = t_2$. The slope of chord AB [shown in fig. (b)] gives the average velocity. Mathematically,

$$v_{av} = \tan\theta = \frac{x_2 - x_1}{t_2 - t_1}$$

(vi) The area of speed-time graph gives distance.

(vii) The area of velocity-time graph gives displacement.

(viii) Speed can never be negative.

4. Instantaneous Velocity : Instantaneous velocity is defined as the average velocity over smaller and smaller interval of time.

Suppose position of a particle at t is $\vec{r}$ and at $t + \Delta t$ is $\vec{r} + \Delta\vec{r}$. The average velocity of the particle for time interval Δt is $\vec{v}_{av} = \frac{\Delta\vec{r}}{\Delta t}$.

From our definition of instantaneous velocity, Δt should be smaller and smaller. Thus, instantaneous velocity is

$$\vec{v} = \lim_{\Delta t \to 0} \frac{\Delta\vec{r}}{\Delta t} = \frac{d\vec{r}}{dt}$$

If position of a particle at an instant t is $\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$, then

x-component of velocity is $v_x = \frac{dx}{dt}$

y-component of velocity is $v_y = \frac{dy}{dt}$

z-component of velocity is $v_z = \frac{dz}{dt}$

Thus, velocity of the particle is

$$\vec{v} = v_x\hat{i} + v_y\hat{j} + v_z\hat{k}$$

$$= \frac{dx}{dt}\hat{i} + \left(\frac{dy}{dt}\right)\hat{j} + \frac{dz}{dt}\hat{k}$$

Some Important Points :

(i) Average velocity may or may not be equal to instantaneous velocity.

(ii) If body moves with constant velocity, the instantaneous velocity is equal to average velocity.

(iii) The instantaneous speed is equal to modulus of instantaneous velocity.

(iv) Distance travelled by particle is

$$s = \int |\vec{v}|\, dt$$

(v) x-component of displacement is $\Delta x = \int v_x\, dt$

y-component of displacement is $\Delta y = \int v_y\, dt$

z-component of displacement is $\Delta z = \int v_z\, dt$

Thus, displacement of particle is

$$\Delta\vec{r} = \Delta x\hat{i} + \Delta y\hat{j} + \Delta z\hat{k}$$

(vi) If particle moves on a straight line, (along x-axis), then $v = \frac{dx}{dt}$

(vii) The area of velocity-time graph gives displacement.

(viii) The area of speed-time graph gives distance.

(ix) The slope of tangent at position-time graph at a particular instant gives instantaneous velocity at that instant.

5. Average Acceleration and Instantaneous Acceleration : In general, when a body is moving, its velocity is not always the same. A body whose velocity is increasing is said to be accelerated.

Average acceleration is defined as change in velocity divided by the time interval.

Let us consider the motion of a particle. Suppose that the particle has velocity $\vec{v}_1$ at $t = t_1$ and at a later time $t = t_2$ it has velocity $\vec{v}_2$. Thus, the average acceleration during time interval $\Delta t = t_2 - t_1$ is

$$a_{av} = \frac{\vec{v}_2 - \vec{v}_1}{t_2 - t_1} = \frac{\Delta \vec{v}}{\Delta t}$$

If the time interval approaches to zero, average acceleration is known as instantaneous acceleration. Mathematically,

$$a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt}$$

Some Important Points :

(i) Acceleration a vector quantity.

(ii) Its unit is m/s^2.

(iii) The slope of velocity-time graph gives acceleration.

(iv) The area of acceleration-time graph in a particular time interval gives change in velocity in that time interval.

6. Problem Solving Strategy :

Motion on a Straight Line (one dimensional motion)

Uniform velocity	**Motion with constant acceleration**	**Motion with variable acceleration**
(i) $s = vt$	(i) $s = \left(\frac{u+v}{2}\right)t$	(i) If $a = f(t)$, $a = \frac{dv}{dt}$
(ii) $a = 0$	(ii) $s = ut + \frac{1}{2}at^2$	(ii) If $a = f(s)$, $a = v\frac{dv}{ds}$
	(iii) $v^2 = u^2 + 2as$	(iii) If $a = f(v)$, $a = \frac{dv}{dt}$
	(iv) $v = u + at$	(iv) $v = \frac{ds}{dt}$
	(v) $s_{nth} = u + (2n-1)\frac{a}{2}$	(v) $s = \int v dt$
	(vi) For retardation, 'a' will be negative.	(vi) $v = \int a dt$

7. Motion in Two or Three Dimension : A body is free to move in space. In this case, the initial position of body is taken as origin.

Any convenient co-ordinate system is chosen. Let us suppose that at an instant t, the body is at point $P(x, y, z)$.

The position vector of the body is $\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$. Thus, velocity

$$\vec{v} = \frac{d\vec{r}}{dt} = \frac{dx}{dt}\hat{i} + \frac{dy}{dt}\hat{j} + \frac{dz}{dt}\hat{k}$$

In this way, $v_x = \frac{dx}{dt}$

and acceleration along x-axis is $a_x = \frac{dv_x}{dt}$.

The velocity along y-axis is $v_y = \frac{dy}{dt}$

and the acceleration along y-axis is $a_y = \frac{dv_y}{dt}$.

Similarly, $v_z = \frac{dz}{dt}$ and $a_z = \frac{dv_z}{dt}$

The acceleration of the body is $\vec{a} = a_x\hat{i} + a_y\hat{j} + a_z\hat{k}$.

Discussion :

(i) (a) If a_x is constant,

$$v_x = u_x + a_x t$$

$$x = u_x t + \frac{1}{2} a_x t^2$$

$$v_x^2 = u_x^2 + 2a_x x$$

(b) If a_x is variable,

$$x = \int v_x dt$$

$$\int dv_x = \int a_x dt$$

(ii) (a) If a_y is constant,

$$y = u_y t + \frac{1}{2} a_y t^2$$

$$v_y = u_y + a_y t$$

$$v_y^2 = u_y^2 + 2a_y y$$

(b) If a_y is variable,

$$y = \int v_y dt$$

$$\int dv_y = \int a_y dt$$

(iii) (a) If a_z is constant,

$$v_z = u_z + a_z t$$

$$z = u_z t + \frac{1}{2} a_z t^2$$

$$v_z^2 = u_z^2 + 2a_z z$$

(b) If a_z is variable,

$$z = \int v_z \, dt$$

$$\int dv_z = \int a_z \, dt$$

If the motion of the body takes place in x-y plane, then

$$a_z = 0, \quad v_z = 0, \quad u_z = 0$$

Example : A car moves in the x-y plane with acceleration $(3 \text{ m/s}^2 \hat{i} + 4 \text{ m/s}^2 \hat{j})$

(a) Assuming that the car is at rest at the origin at $t = 0$, derive expressions for the velocity and position vectors as function of time.

(b) Find the equation of path of car.

Solution : Here, $u_x = 0, \quad u_y = 0, \quad u_z = 0$

$$a_x = 3 \text{ m/s}^2, \quad a_y = 4 \text{ m/s}^2$$

(a) $\quad v_x = u_x + a_x t$

or $\quad v_x = 3t$

and $\quad v_y = u_y + a_y t$

or $\quad v_y = 4t$

$\therefore \quad \vec{v} = v_x \hat{i} + v_y \hat{j}$

$\quad = (3t\hat{i} + 4t\hat{j})$

(ii) $\quad x = u_x t + \frac{1}{2} a_x t^2$

or $\quad x = \frac{1}{2} \times 3t^2 = \frac{3}{2} t^2$

and $\quad y = u_y t + \frac{1}{2} a_y t^2$

or $\quad y = \frac{1}{2} (4) t^2 = 2t^2$

$\therefore \quad y = 2 \times \frac{2}{3} x = \frac{4}{3} x \qquad \left(\because x = \frac{3}{2} t^2 \right)$

$\therefore \quad y = \frac{4}{3} x$

Hence, the path is straight line.

(b) The position of car is

$$\vec{r} = x\hat{i} + y\hat{j} = \frac{3}{2} t^2 \hat{i} + 2t^2 \hat{j}$$

Example : A bird flies in the x-y plane with a velocity $\vec{v} = t^2 \hat{i} + 3t\hat{j}$. At $t = 0$, bird is at origin.

Calculate position and acceleration of bird as function of time.

Solution : $\because \quad \vec{v} = t^2 \hat{i} + 3t\hat{j}$

Here, $\quad v_x = t^2, \; v_y = 3t$ and $v_z = 0$

$\because \quad v_x = t^2$

or $\quad \frac{dx}{dt} = t^2$

or $\quad \int_0^x dx = \int_0^t t^2 dt$

or $\quad x = \frac{t^3}{3}$

Also, $\quad v_y = 3t$

or $\quad \frac{dy}{dt} = 3t$

or $\quad \int_0^y dy = \int_0^t 3t \, dt$

$\therefore \quad y = \frac{3t^2}{2}$

$\therefore$ Position of particle is $\vec{r} = x\hat{i} + y\hat{j}$

$$= \frac{t^3}{3} \hat{i} + \frac{3t^2}{2} \hat{j}$$

$\because \quad v_x = t^2$

$\therefore \quad a_x = \frac{dv_x}{dt} = \frac{d(t^2)}{dt} = 2t$

and $\quad v_y = 3t$

or $\quad \frac{dv_y}{dt} = 3 \frac{dt}{dt}$

$\therefore \quad a_y = 3$ unit

$\therefore \quad \vec{a} = a_x \hat{i} + a_y \hat{j}$

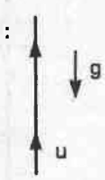
$\quad = 2t\hat{i} + 3\hat{j}$

8. Motion Under Gravity : The most familiar example of motion with constant acceleration on a straight line is motion in a vertical direction near the surface of earth. If air resistance is neglected, the acceleration of such type of particle is gravitational acceleration which is nearly constant for a height negligible with respect to the radius of earth. The magnitude of gravitational acceleration near surface of earth is $g = 9.8 \text{ m/s}^2 = 32 \text{ ft/s}^2$.

Discussion :

Case I : If particle is moving upwards :

In this case applicable kinematics relations are :



(i) $\quad v = u - gt$

(ii) $\quad h = ut - \frac{1}{2} gt^2$

(iii) $\quad v^2 = u^2 - 2gh$

(iv) Here h is the vertical height of the particle in upward direction. For maximum height attained by projectile

$$h = h_{max}, \quad v = 0$$

i.e., $\quad (0)^2 = u^2 - 2gh_{max}$

$\therefore \quad h_{max} = \frac{u^2}{2g}$

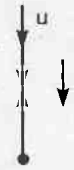
Case II : If particle is moving vertically downwards :

In this case,

(i) $v = u + gt$

(ii) $v^2 = u^2 + 2gh$

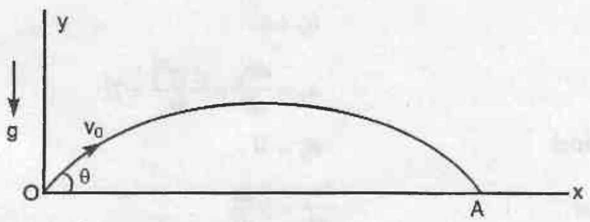
(iii) $h = ut + \frac{1}{2}gt^2$



Here, h is the vertical height of particle in downward direction.

9. Projectile Motion : A familiar example of two dimensional motion is projectile motion. If a stone is thrown from ground obliquily, it moves under the force of gravity (in the absence of air resistance) near the surface of earth. Such type of motion is known as projectile motion. We refer to such object as projectile. To analyse this type of motion, we will start with its acceleration. The motion of stone is under gravitational acceleration which is constant in magnitude as well as in direction.

Now let us consider a projectile launched so that its initial velocity v_0 makes an angle θ with the horizontal (shown in figure). For discussion of motion, we take origin



at the point of projection. Horizontal direction as x-axis and vertical direction as y-axis is taken.

The initial velocity of projectile along x-axis is $u_x = v_0 \cos\theta$.

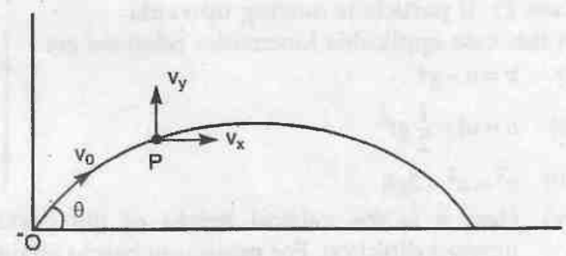
The component of gravitational acceleration along x-axis is $a_x = g\cos 90° = 0$.

The component of initial velocity along y-axis is $u_y = v_0 \sin\theta$.

The acceleration along y-axis is $a_y = -g$.

Discussion :

(i) **The instantaneous velocity of the projectile as function of time :** Let projectile reaches at point (x, y) after time t (shown in figure).



$\therefore$ $v_x = u_x = v_0 \cos\theta$

and $v_y = u_y - gt = v_0 \sin\theta - gt$

$\therefore$ $\vec{v} = v_x\hat{i} + v_y\hat{j}$

$\therefore$ $\vec{v} = v_0\cos\theta\,\hat{i} + (v_0\sin\theta - gt)\,\hat{j}$

The instantaneous speed

$$= |\vec{v}| = \sqrt{(v_0\cos\theta)^2 + (v_0\sin\theta - gt)^2}$$

Also, $x = u_x t - (v_0\cos\theta)t = v_0 t\cos\theta$

$$y = u_y t - \frac{1}{2}gt^2$$

or $y = (v_0\sin\theta)t - \frac{1}{2}gt^2$

The position of the projectile is

$$\vec{r} = x\hat{i} + y\hat{j}$$

$$= v_0 t\cos\theta\,\hat{i} + \left(v_0 t\sin\theta - \frac{1}{2}gt^2\right)\hat{j}$$

(ii) **Trajectory of projectile :** The y-x graph gives the path or trajectory of the projectile.

From discussion of instantaneous velocity of projectile.

$x = v_0 t\cos\theta$ ...(1) and $y = v_0 t\sin\theta - \frac{1}{2}gt^2$ ...(2)

$\therefore$ $t = \frac{x}{v_0\cos\theta}$ ...(3)

Putting the value of t from (3) in the equation (2),

$$y = v_0\sin\theta\left(\frac{x}{v_0\cos\theta}\right) - \frac{1}{2}g\left(\frac{x}{v_0\cos\theta}\right)^2$$

or $y = x\tan\theta - \frac{gx^2}{2v_0^2\cos^2\theta}$ ...(4)

This is the required path of projectile.

Multiplying the equation (4) by $-\frac{2v_0^2\cos^2\theta}{g}$ to both sides, we get

$$x^2 - \frac{2v^2\sin\theta\cos\theta}{g}x = \left(-\frac{2v^2\cos^2\theta}{g}\right)y$$

Adding $\left(\frac{v_0^2\sin\theta\cos\theta}{g}\right)^2$ to both sides, we get

$$\left(x - \frac{v_0^2\sin\theta\cos\theta}{g}\right)^2 = -\left(\frac{2v_0^2\cos^2\theta}{g}\right)\left(y - \frac{v_0^2\sin^2\theta}{2g}\right)$$

This is of the form,

$$(x-a)^2 = -c(y-b)$$

which is the equation of a parabola. Hence, the equation of the path of the projectile is a parabola.

(iii) **Time of flight :** The time taken by projectile to reach at point A from point O is known as time of flight.

Here, $OA = v_x T$, where T is time of flight. The total displacement along y-axis during motion of projectile from O to A is zero so, $y = 0$,

But $y = u_y T - \frac{1}{2}gT^2$

or $0 = (v_0\sin\theta)T - \frac{1}{2}gT^2$

$\therefore$ $T = \frac{2v_0\sin\theta}{g}$

(iv) **Range of projectile :** Distance OA is known as range.

The time taken to reach to point A from point O is $T = \frac{2v_0 \sin\theta}{g}$.

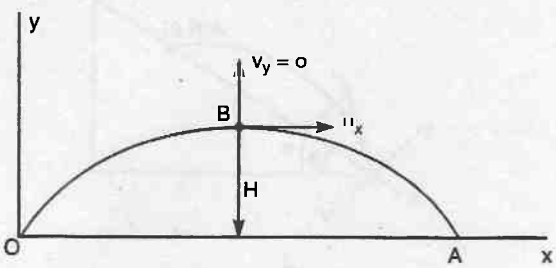
The range $R = u_x T = (v_0 \cos\theta)\left(\frac{2v_0 \sin\theta}{g}\right)$

$$= v_0^2 \frac{(2 \sin\theta \cos\theta)}{g}$$

$$= \frac{v_0^2 \sin 2\theta}{g}$$

The time taken by projectile to reach from O to B is equal to the time taken by projectile to reach from B to $A = \frac{T}{2}$.

(v) **Height attained by projectile :** At the maximum height (at point B) the vertical component of velocity is zero.



$\because$ $$v_y^2 = u_y^2 - 2gH$$

or $$(0)^2 = (v \sin\theta)^2 - 2gH$$

$\therefore$ $$H = \frac{v_0^2 \sin^2\theta}{2g}$$

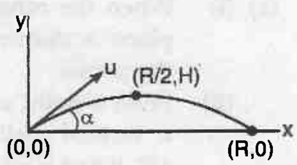
Alternative method : A particle is projected with a velocity u at an angle α to the horizontal, there being no force except gravity, which remains constant throughout its motion.

$\vec{u} = u \cos\alpha\,\hat{i} + u \sin\alpha\,\hat{j}$

$\vec{a} = -g\hat{j}$

$\vec{s} = x\hat{i} + y\hat{j}$

$\vec{s} = \vec{u}t + \frac{1}{2}\vec{a}\,t^2$



$$x\hat{i} + y\hat{j} = (u \cos\alpha\,\hat{i} + u \sin\alpha\,\hat{j})\,t - \frac{1}{2}gt^2\hat{j}$$

$$x = ut \cos\alpha, \quad y = ut \sin\alpha - \frac{1}{2}gt^2$$

For the maximum height,

$$t = \frac{T}{2}, \quad T = \frac{2u \sin\alpha}{g}, \quad x = \frac{R}{2}, \quad y = H$$

$\therefore$ $$H = \frac{u^2 \sin^2\alpha}{2g}$$

(a) For the range,

$$x = R, \quad y = 0, \quad t = T$$

$\therefore$ $$R = \frac{u^2 \sin 2\alpha}{g}$$

(b) (i) If for the two angles of projection α_1 and α_2, the speeds are same then ranges will be same. The condition is $\alpha_1 + \alpha_2 = 90°$.

(ii) If particles be projected from the same point in the same plane so as to describe equal parabolas, the vertices of their paths lie on a parabola.

(iii) The locus of the foci of all parabolas described by the particles projected simultaneously from the same point with equal velocity but in different directions is a circle.

(iv) The velocity acquired by a particle at any point of its path is the same as acquired by a particle in falling freely from the directrix to that point.

(v) A projectile will have maximum range when it is projected at an angle of 45° to the horizontal and the maximum range will be $\frac{u^2}{g}$.

At the maximum range, $H = \frac{R_{max}}{4}$

(vi) In the case of projectile motion, at the highest point, potential energy is maximum and is equal to $\frac{1}{2}mu^2 \sin^2\alpha$.

(vii) If the body is projected at an angle of 45° to the horizontal, at the highest point half of its mechanical energy is potential energy and rest is kinetic energy.

(viii) The weight of a body in projectile motion is zero as it is freely falling body.

(ix) If two projectiles A and B are projected under gravity, then the path of projectile A with respect to the projectile B is a straight line.

10. The equation of trajectory of projectile is

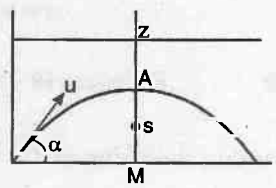
$$\left(x - \frac{u^2 \sin\alpha \cos\alpha}{g}\right)^2 = -\left(\frac{2u^2 \cos^2\alpha}{g}\right)\left(y - \frac{u^2 \sin^2\alpha}{2g}\right)$$

(a) Latus rectum $= \frac{2u^2 \cos^2\alpha}{g}$,

S be the focus, then

$$AS = \frac{1}{4}\text{(latus rectum)}$$

$$SM = -\frac{u^2 \cos^2\alpha}{2g}$$

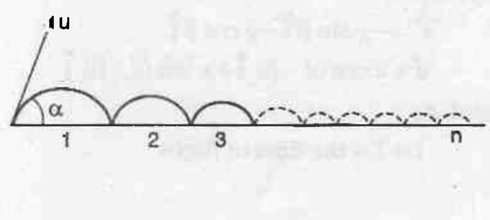


(b) The co-ordinates of the focus

$$= \left(\frac{u^2 \sin\alpha \cos\alpha}{g}, \frac{-u^2 \sin^2\alpha}{2g}\right)$$

(c) The equation of directrix, $y = \frac{u^2}{2g}$

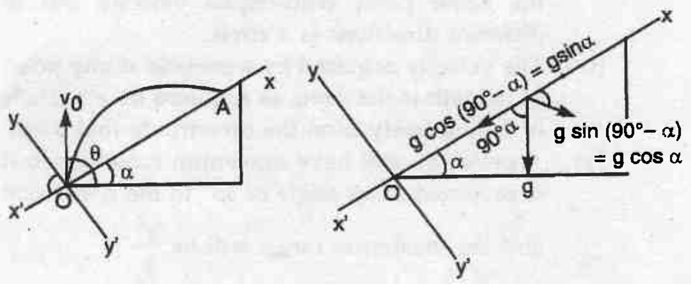
The range of nth trajectory



$$= \frac{e^{n-1} u^2 \sin 2\alpha}{g}$$

where e is the coefficient of restitution.

11. Projectile motion on an inclined plane: A projectile is projected up the inclined plane from the point O with an initial velocity v_0 at an angle θ with horizontal. The angle of inclination of the plane with horizontal is α (as shown in figure)



The acceleration along x-axis is

$$a_x = -g \sin \alpha \quad \text{and} \quad a_y = -g \cos \alpha.$$

The component of velocity along x-axis is

$$u_x = v_0 \cos(\theta - \alpha) \quad \text{and} \quad u_y = v_0 \sin(\theta - \alpha)$$

(a) Time of flight: During motion from point O to A, the displacement along y-axis is zero.

$\therefore$ $$y = 0 \quad \text{at} \quad t = T$$

$\because$ $$y = u_y t + \frac{1}{2} a_y t^2$$

or $$0 = v_0 \sin(\theta - \alpha) T - \frac{1}{2} g \cos \alpha T^2$$

$\therefore$ $$T = \frac{2v_0 \sin(\theta - \alpha)}{g \cos \alpha}$$

(b) Range of projectile: As shown in figure OA represents the range of projectile. For range,

$$x = R, \quad t = T$$

$$x = u_x t + \frac{1}{2} a_x t^2$$

or $$R = v_0 \cos(\theta - \alpha) T - \frac{1}{2} g \sin \alpha T^2 \qquad \ldots(1)$$

Putting the value of $T = \dfrac{2v_0 \sin(\theta - \alpha)}{g \cos \alpha}$ in eq. (1)

$$R = \frac{v_0^2}{g \cos^2 \alpha} [\sin(2\theta - \alpha) - \sin \alpha]$$

Alternative method:

Here, β = The angle of inclination of the inclined plane
α = The angle of projection
u = The velocity of projection

$\therefore$ In vector form,

$$\vec{a} = -g \sin \beta \hat{i} - g \cos \beta \hat{j}$$

$$\vec{u} = u \cos(\alpha - \beta) \hat{i} + u \sin(\alpha - \beta) \hat{j}$$

For the point A,

$$t = T = \text{the time of flight.}$$

$$\vec{s} = R\hat{i}$$

$$\vec{s} = \vec{u}t + \frac{1}{2} \vec{a} t^2$$

or $$R\hat{i} + 0\hat{j} = (u \cos(\alpha - \beta)\hat{i} + u \sin(\alpha - \beta)\hat{j})T - \frac{1}{2} g T^2 (\sin \beta \hat{i} + \cos \beta \hat{j})$$

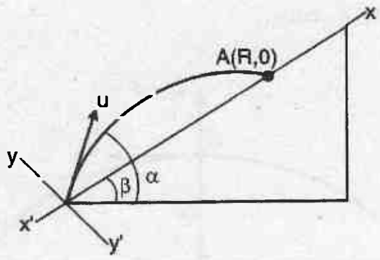
Equating the coefficients of $\hat{i}$ and $\hat{j}$ separately.

We get, $$R = uT \cos(\alpha - \beta) - \frac{1}{2} g T^2 \sin \beta$$

$$0 = uT \sin \alpha - \frac{1}{2} g T^2 \cos \beta$$

(a) $\therefore$ $$T = \frac{2u \sin(\alpha - \beta)}{g \cos \beta}$$

(b) Range is $R = \dfrac{2u^2 \cos \alpha \sin(\alpha + \beta)}{g \cos^2 \beta}$



$$= \frac{u^2}{g \cos^2 \beta} [\sin(2\alpha - \beta) - \sin \beta]$$

(c) For maximum range

$$2\alpha - \beta = \frac{\pi}{2}$$

$\therefore$ $$R_{max} = \frac{u^2 (1 - \sin \beta)}{g \cos^2 \beta} = \frac{u^2}{g(1 + \sin \beta)}$$

(d) $$T^2 g = 2R_{max}$$

(e) (i) When the range of a projectile on an inclined plane is maximum, the focus of the path is on the plane.

(ii) From a point on the ground at distance x from a vertical wall, a ball is thrown at an angle 45°, it just clears the wall and strikes the ground at a distance y on the other side. Then the height of the wall is $\dfrac{xy}{x+y}$.

(iii) If a body moves along a straight line by an engine delivering constant power, then $t \propto s^{2/3}$.

(iv) If a, b, c be distances moved by a particle travelling with uniform acceleration during xth, yth and zth second of its motion respectively, then $a(y - z) + b(z - x) + c(x - y) = 0$

12. Relative velocity:

$\vec{v}_{AB}$ = relative velocity of A with respect to B

$$\vec{v}_{AB} = \vec{v}_A - \vec{v}_B$$

$$\vec{v}_{BA} = \vec{v}_B - \vec{v}_A$$

$$\vec{a}_{AB} = \vec{a}_A - \vec{a}_B$$

(a) If a satellite is moving in equatorial plane with velocity $\vec{v}$ and a point on the surface of earth with velocity $\vec{u}$ relative to the centre of earth, the velocity of satellite relative to the surface of earth

$$\vec{v}_{SE} = \vec{v} - \vec{u}$$

(b) If a car is moving at equator on the earth's surface with a velocity v_{CE} relative to earth's surface and a point on the surface of earth with velocity v_E relative to its centre, then

$$\vec{v}_{CE} = \vec{v}_C - \vec{u}_E$$

(c) If the car moves from west to east (the direction of motion of earth)

$$v_C = v_{CE} + v_E$$

and if the car moves from east to west (opposite to the motion of earth)

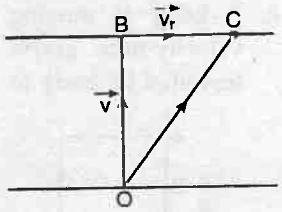
$$v_C = v_{CE} - v_E$$

(d) For crossing the river in shortest time, the boat should sail perpendicular to the flow.

If the width of river is d.

v = the velocity of boat in still water, then,

$$t = \frac{d}{v}$$



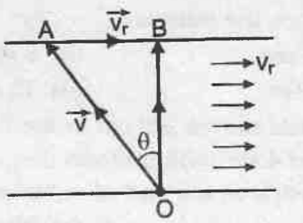
The position of boat at the other bank is C (not B).

The displacement of the boat $= \vec{OC} = \vec{OB} + \vec{BC}$

$$OC = \sqrt{(OB)^2 + (BC)^2}$$

$$= \sqrt{d^2 + (v_r t)^2} = \sqrt{d^2 + \left(v_r \frac{d}{v}\right)^2}$$

(e) For crossing the river in shortest distance, the boat moves as such its horizontal component of velocity balances the speed of flow.



OB = the shortest path $= d$

$$v_r = v \sin\theta \quad \therefore \quad \sin\theta = \frac{v_r}{v}$$

$$\cos\theta = \sqrt{1 - \sin^2\theta}$$

$$= \sqrt{\left[1 - \left(\frac{v_r}{v}\right)^2\right]} = \sqrt{\left(\frac{v^2 - v_r^2}{v^2}\right)}$$

$$\therefore \quad t = \frac{d}{v\cos\theta} = \frac{d}{v\,\frac{\sqrt{v^2 - v_r^2}}{v}}$$

$$\therefore \quad t = \frac{d}{\sqrt{v^2 - v_r^2}}$$

In this case, the magnitude of displacement $= d$.

(f) If boat crosses the river along the shortest path, then time is not least.

(g) If c is a space curve defined by the function $\vec{r}(t)$, then $\frac{d\vec{r}}{dt}$ is a vector in the direction of the tangent to c. If the scalar t is taken arc length s measured from some fixed point on c, then $\frac{d\vec{r}}{ds}$ is a unit tangent vector to c and the arc length is denoted by $\vec{R}$. Then $\frac{d\vec{R}}{ds} = k\,\vec{n}$ where $\vec{n}$ is a unit normal vector.

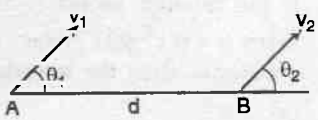
(h) The derivative of vector of constant magnitude is perpendicular to the vector itself.

(i) The derivative of a vector of constant direction is parallel to that vector.

(j) $y - x$ curve gives actual path of the particle. The tangent at a point on $y - x$ curve gives the direction of instantaneous velocity at that point.

(k) When n number of particles are located at the vertices of a regular polygon of n-sides having side length a and if they start moving heading to each other,
they must collide at the centre of polygon after the time $t = \dfrac{a}{v\left(1 - \cos\frac{2\pi}{n}\right)}$ where v is speed of each particle.

13. Velocity of approach: If two particles A and B separated by a distance d at a certain instant of time move with velocities v_1 and v_2 at angles θ_1 and θ_2 with the direction $\vec{AB}$, the velocity by which the particle A approaches $B = v_1\cos\theta_1 - v_2\cos\theta_2$.

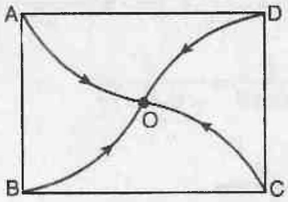


The angular velocity of B with respect to A

$$= \frac{v_2\sin\theta_2 - v_1\sin\theta_1}{d}$$

Example : Four particles are located at the corners of a square whose side equals a. They all start moving simultaneously with velocity v constant in magnitude, with the first particle heading continually for the second, the second for the third, third for the fourth and fourth for the first. How soon will the particles converge?

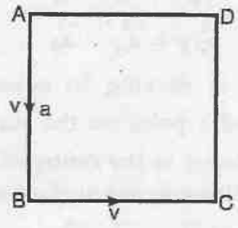
Solution :



The paths of particles are shown in figure.

The velocity of approach of A to B

$$= v - v\cos 90° = v - 0 = v$$



$$\therefore \quad t = \frac{v}{a}$$

Objective Questions

Level-1

1. The two ends of a train moving with uniform acceleration pass a certain point with velocities u and v. The velocity with which the middle point of the train passes the same point is :

   (a) $\frac{v+u}{2}$ (b) $\frac{u^2+v^2}{2}$
   (c) $\sqrt{\frac{u^2+v^2}{2}}$ (d) $\sqrt{v+u}$

2. A point particle starting from rest has a velocity that increases linearly with time such that $v = pt$ where $p = 4\ \text{m/s}^2$. The distance covered in the first 2 sec will be :

   (a) 6 m (b) 4 m
   (c) 8 m (d) 10 m

3. A body starts from rest, with uniform acceleration a. The acceleration of a body as function of time t is given by the equation $a = pt$ where p is constant, then the displacement of the particle in the time interval $t = 0$ to $t = t_1$ will be :

   (a) $\frac{1}{2}pt_1^3$ (b) $\frac{1}{3}pt_1^2$
   (c) $\frac{1}{4}pt_1^2$ (d) $\frac{1}{6}pt_1^3$

4. If the relation between distance x and time t is of the form $t = \alpha x^2 + \beta x$ here α and β being appropriate constants, then the retardation of the particle is :

   (a) $2\alpha v^3$ (b) $2\beta v^3$
   (c) $2\alpha\beta v^3$ (d) $2\beta^2 v^3$

5. A car starts from rest requires a velocity v with uniform acceleration $2\ \text{m/s}^2$ then it comes to stop with uniform retardation $4\ \text{m/s}^2$. If the total time for which it remains in motion is 3 sec, the total distance travelled is :

   (a) 2 m (b) 3 m
   (c) 4 m (d) 6 m

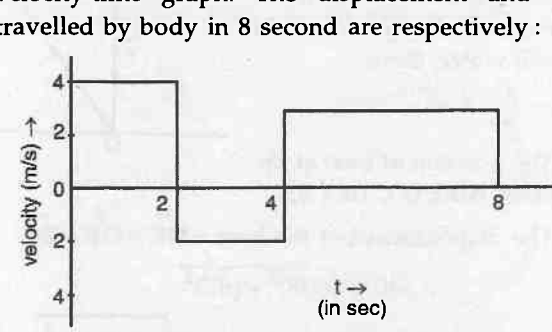
6. A beaker containing water is balanced on the pan of a common balance. A solid of specific gravity one and mass 5 g is tied on the arm of the balance and immersed in water contained in the beaker, the scale pan with the beaker :

   (a) goes up (b) goes down
   (c) remains unchanged (d) none of these

7. A particle starts from rest with constant acceleration for 20 sec. If it travels a distance y_1 in the first 10 sec and a distance y_2 in the next 10 sec then :

   (a) $y_2 = 2y_1$ (b) $y_2 = 3y_1$
   (c) $y_2 = 4y_1$ (d) $y_2 = 5y_1$

8. A body is moving in a straight line as shown in velocity-time graph. The displacement and distance travelled by body in 8 second are respectively :



   (a) 12 m, 20 m (b) 20 m, 12 m
   (c) 12 m, 12 m (d) 20 m, 20 m

9. A train starts from station with an acceleration $1\ \text{m/s}^2$. A boy who is 48 m behind the train with a constant velocity 10 m/s, the minimum time after which the boy will catch the train is :

   (a) 4.8 sec (b) 8 sec
   (c) 10 sec (d) 12 sec

10. A particle moves 200 cm in the first 2 sec and 220 cm in the next 4 sec with uniform deceleration. The velocity of the particle at the end of seven second is :

    (a) 15 cm/s (b) 20 cm/s
    (c) 10 cm/s (d) none of these

11. An aeroplane flying horizontally with speed 90 km/hr releases a bomb at a height of 78.4 m from the ground, when will the bomb strike the ground ?

    (a) 8 sec (b) 6 sec
    (c) 4 sec (d) 10 sec

12. The velocity of a particle at an instant is 10 m/s. After 3 sec its velocity will become 16 m/s. The velocity at 2 sec before the given instant, will be :
(a) 6 m/s (b) 4 m/s
(c) 2 m/s (d) 1 m/s

13. A stone is thrown vertically upwards from cliff with velocity 5 m/s. It strikes the pond near the base of cliff after 4 sec. The height of cliff is :
(a) 6 m (b) 60 m
(c) 40 m (d) 100 m

14. A stone is released from a hydrogen balloon, going upwards with velocity 12 m/s. When it is at height of 65 m from the ground, time the stone will take to reach the ground is :
(a) 5 sec (b) 6 sec
(c) 7 sec (d) 8 sec

15. A parachutist jumps from an aeroplane moving with a velocity of u. parachute opens and accelerates downwards with 2 m/s^2. He reaches the ground with velocity 4 m/s. How long is the parachutist remained in the air ?
(a) 1.5 m (b) 2.5 m
(c) 4 m (d) None ot these

16. A stone is projected upwards and it returns to ground on a parabolic path. Which of the following remains constant ?
(a) Speed of the ball
(b) Horizontal component of velocity
(c) Vertical component of velocity
(d) None of the above

17. A stone is released from the top of a tower. The total distance covered by it in the last second of its motion equals distance covered by it in the first three seconds of its motion. The stone remains in the air for :
(a) 5 sec (b) 8 sec
(c) 10 sec (d) 15 sec

18. A dust packet is dropped from 9th storey of a multi-storeyed building. In the first second of its free fall another dust packet is dropped from 7th storey 15 m below the 9th storey. If both packets reach the ground at same time, then height of the building is :
(a) 25 m (b) 15 m
(c) 20 m (d) 16 m

19. A stone is thrown vertically upwards in air, the time of upward motion is t_1 and time of down motion is t_2. When air resistance is taken into consideration then :
(a) $t_1 = t_2$ (b) $t_1 < t_2$
(c) $t_1 > t_2$ (d) $t_1 > = < t_2$

20. Two different masses m and $2m$ are fallen from height H_1 and H_2 respectively. First mass takes t second and another takes $2t$ second, then the ratio of H_1 and H_2 is :
(a) 2 : 1 (b) 4 : 1
(c) 0.25 : 1 (d) none of these

21. A car start from station and moves along the horizontal road by a machine delivering constant power. The distance covered by the car in time t is proportional to :
(a) t^2 (b) $t^{3/2}$
(c) $t^{2/3}$ (d) t^3

22. For a particle moving in a straight line, the velocity at any instant is given by $4t^3 - 2t$, where t is in second and velocity in m/s. The acceleration of the particle when it is 2 m from the starting point, will be :
(a) 20 m/s^2 (b) 22 m/s^2
(c) 14 m/s^2 (d) none ot these

23. A body initially at rest is moving with uniform acceleration a. Its velocity after n second is v. The displacement of the body in 2 sec is :
(a) $\dfrac{2v(n-1)}{n}$ (b) $\dfrac{v(n-1)}{n}$
(c) $\dfrac{v(n+1)}{n}$ (d) $\dfrac{2v(2n+1)}{n}$

24. A point moves with constant acceleration and v_1, v_2 and v_3 denote the average velocities in the three successive intervals t_1, t_2 and t_3 of time. Which of the following relations is correct ?
(a) $\dfrac{v_1 - v_2}{v_2 - v_3} = \dfrac{t_1 - t_2}{t_2 + t_3}$ (b) $\dfrac{v_1 - v_2}{v_2 - v_3} = \dfrac{t_1 - t_2}{t_1 - t_3}$
(c) $\dfrac{v_1 - v_2}{v_2 - v_3} = \dfrac{t_1 - t_2}{t_2 - t_3}$ (d) $\dfrac{v_1 - v_2}{v_2 - v_3} = \dfrac{t_1 + t_2}{t_2 + t_3}$

25. A large number of bullets are fired in all directions with the same speed v. The maximum area on the ground on which these bullets will spread is :
(a) $\dfrac{\pi v^2}{g}$ (b) $\dfrac{\pi v^4}{g^2}$
(c) $\dfrac{\pi^2 v^4}{g^2}$ (d) $\dfrac{\pi^2 v^2}{g^2}$

26. A piece of marble is projected from earth's surface with velocity of 50 m/s. 2 seconds later, it just clears a wall 5 m high. What is the angle of projection ?
(a) 45° (b) 30°
(c) 60° (d) None of these

27. Two stones having different masses m_1 and m_2 are projected at an angle α and $(90° - \alpha)$ with same velocity from same point. The ratio of their maximum heights is :
(a) 1 : 1 (b) 1 : $\tan\alpha$
(c) $\tan\alpha$: 1 (d) $\tan^2\alpha$: 1

28. A stone of mass 2 kg is projected with velocity 20 m/s at an angle 60° with the horizontal, its momentum at the highest point is :
(a) 20 kg ms^{-1} (b) $20\sqrt{3}$ kg ms^{-1}
(c) 40 kg ms^{-1} (d) none of these

29. A body is projected with speed v m/s at angle θ. The kinetic energy at the highest point is half of the initial kinetic energy. The value of θ is :
(a) 30° (b) 45°
(c) 60° (d) 90°

30. A body projected with velocity u at projection angle θ has horizontal displacement R. For the same velocity and projection angle, its range on the moon surface will be :
(a) $36R$ (b) $\frac{R}{36}$
(c) $\frac{R}{16}$ (d) $6R$

31. Three balls of same masses are projected with equal speeds at angle $15°, 45°, 75°$ and their ranges are respectively R_1, R_2 and R_3 then :
(a) $R_2 > R_2 > R_3$ (b) $R_1 < R_2 < R_3$
(c) $R_1 = R_2 = R_3$ (d) $R_1 = R_3 < R_2$

32. A projectile can have the same range R for two angles of projection θ and $(90° - \theta)$. If t_1 and t_2 are the times of flight in the two cases then :
(a) $R \propto \sqrt{t_1 t_2}$ (b) $\frac{1}{R} \propto \sqrt{t_1 t_2}$
(c) $R \propto t_1 t_2$ (d) none of these

33. Two stones are projected with same velocity v at an angle θ and $(90° - \theta)$. If H and H_1 are greatest heights in the two paths, what is the relation between R, H and H_1 ?
(a) $R - 4\sqrt{HH_1}$ (b) $R = \sqrt{HH_1}$
(c) $R = 4HH_1$ (d) None of these

34. A bullet fired from gun at sea level rises to a maximum height 10 m. When fired at a ship 40 m away, the muzzle velocity should be :
(a) 20 m/s (b) 15 m/s
(c) 16 m/s (d) none of these

35. A ball is projected with velocity u at an angle α with horizontal plane. Its speed when it makes an angle β with the horizontal is :
(a) $u \cos \alpha$ (b) $\frac{u}{\cos \beta}$
(c) $u \cos \alpha \cos \beta$ (d) $\frac{u \cos \alpha}{\cos \beta}$

36. An aeroplane is flying horizontally with velocity 150 m/s at a height 100 m from the ground. How long must the distance from the plane to target be, if a bomb is released from the plane to hit the target ?
(a) 671 m (b) 67 m
(c) 335 m (d) 1.34 km

37. A stone is projected with a velocity of 10 m/s at an angle of 30° with the horizontal. It will hit the ground after time :
(a) 3 sec (b) 2 sec
(c) 1.5 sec (d) 1 sec

38. For the same horizontal range, in how many projections can an object be projected ?
(a) 4 (b) 3
(c) 2 (d) 1

39. The range of projectile projected at an angle 15° is $10\sqrt{3}$ m. If it is fired with the same speed at angle of 30°, its range will be :
(a) 60 m (b) 45 m
(c) 30 m (d) 15 m

40. A body is projected with initial velocity of $(8\hat{i} + 6\hat{j})$ m/s. The horizontal range is :
(a) 9.6 m (b) 14 m
(c) 50 m (d) none of these

41. A ball of mass M is thrown vertically upwards. Another ball of mass $2M$ is thrown at an angle θ to vertical. Both of them stay in air for the same period of time, the heights attained by the two are in the ratio :
(a) 1 : 2 (b) 2 : 1
(c) 1 : 1 (d) $1 : \cos \theta$

42. A tennis ball rolls off the top of a stair case way with a horizontal velocity u m/s. If the steps are b metre wide and h metre high, the ball will hit the edge of the nth step, if :
(a) $n = \frac{2hu}{gb^2}$ (b) $n = \frac{2hu^2}{gb^2}$
(c) $n = \frac{2hu^2}{gb}$ (d) $n = \frac{hu^2}{gb^2}$

43. The co-ordinates of the initial point of a vectors (2, 1) and those of terminal point are (7, 9). The magnitude of vector is :
(a) 8 (b) $\sqrt{84}$
(c) $\sqrt{89}$ (d) 10

44. One of the rectangular components of a velocity of 60 m/s is 30 m/s, the other rectangular component is :
(a) 30 m/s (b) $30\sqrt{3}$ m/s
(c) $30\sqrt{2}$ m/s (d) none of these

45. A river is flowing from west to east at a speed 15 m/s . A boy on the south bank of the river, capable of swimming at 30 m/s in still water, wants to swim, cross the river in the shortest time. He should swim in direction ?
(a) due north (b) 30° east of north
(c) 30° west of north (d) 60° east of north

Level-2

Motion in One Dimension

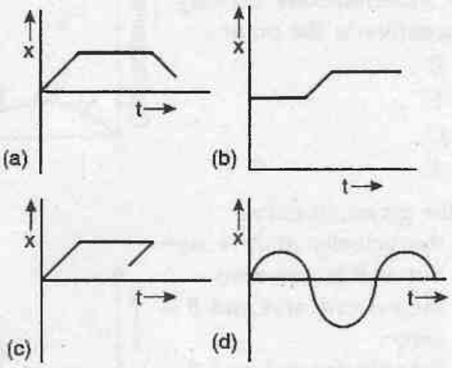
1. Mark correct option or options :
(a) displacement may be equal to the distance
(b) displacement must be in the direction of the acceleration of the body
(c) displacement must not be in the direction of velocity
(d) none of the above

2. In the two dimensional motions :
(a) x-t graph gives actual path of the particle
(b) y-t graph gives actual path of the particle
(c) $\sqrt{x^2 + y^2}$ versus t graph gives the actual path of the particle
(d) y-x graph gives actual path of particle

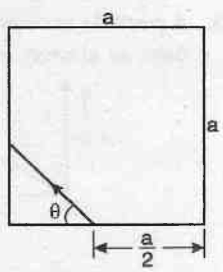
3. A cat wants to catch a rat. The cat follows the path whose equation is $x+y=0$. But rat follows the path whose equation is $x^2+y^2=4$. The co-ordinates of possible points of catching the rat are :
(a) $(\sqrt{2}, \sqrt{2})$ (b) $(-\sqrt{2}, \sqrt{2})$
(c) $(\sqrt{2}, \sqrt{3})$ (d) (0, 0)

4. A deer wants to save her life from a lion. The lion follows a path whose equation is $x^2+y^2=16$. For saving life, the deer moves on a path whose equation is/are :
(a) $x^2+y^2=4$
(b) $x^2+y^2=16$
(c) $x^2+y^2-64=0$
(d) both (a) and (c) are correct

5. Which of the following position-time graph does not exist in nature ?



* 6. There is a square caromboard of side a. A striker is projected in hole after two successive collisions. Assuming the collisions to be perfectly elastic and the surface to be smooth. The angle of projection of striker is :



(a) $\cot^{-1}\left(\frac{3}{4}\right)$
(b) $\cos^{-1}\left(\frac{3}{4}\right)$
(c) $\sin^{-1}\left(\frac{3}{4}\right)$
(d) none of these

7. Speed is to velocity as :
(a) centimetre is to metre
(b) force is to torque
(c) velocity is to acceleration
(d) distance is to displacement

8. A person travelling on a straight line moves with a uniform velocity v_1 for some time and with uniform velocity v_2 for the next the equal time. The average velocity v is given by :
(a) $v=\frac{v_1+v_2}{2}$ (b) $\frac{2}{v}=\frac{1}{v_1}+\frac{1}{v_2}$
(c) $v=\sqrt{v_1 v_2}$ (d) $\frac{1}{v}=\frac{1}{v_1}+\frac{1}{v_2}$

9. A car moves at 80 km/hr in the first half of total time of motion and at 40 km/h^{-1} in the later half. Its average speed is :
(a) 60 km/hr (b) 30 km/hr
(c) 120 km/hr (d) none of these

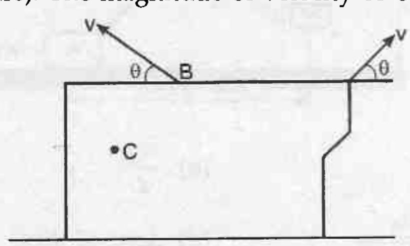
10. A particle moves with constant speed v along a regular hexagon $ABCDEF$ in same order. (*i.e.*, A to B, B to C, C to D, D to E, E to F and F to A) The magnitude of average velocity for its motion from A to C is :
(a) v (b) $\frac{v}{2}$
(c) $\frac{\sqrt{3}\,v}{2}$ (d) none of these

* 11. One rickshaw leaves Patna Junction for Gandhi Maidan at every 10 minute. The distance between Gandhi Maidan and Patna Junction is 6 km. The rickshaw travels at the speed of 6 km/hr. What is the number of rickshaw that a rickshaw puller driving from Gandhi Maidan to Patna Junction must be in the route if he starts from Gandhi Maidan simultaneously with one of the rickshaw leaving Patna Junction :
(a) 11 (b) 12
(c) 5 (d) 1

12. During the shooting of a super hit film 'MARD' Amitabh Bachchan was waiting for his beloved 'Amrita Singh' with his dog. When he saw her approaching, the dog was excited and dashed to her then back to master and so on, never stopping. How far would you estimate the dog ran if its speed is 30 km/hr and each of them walked at 4 km/hr, starting from a distance 400 m apart ?
(a) 400 m (b) 880 m
(c) 1500 m (d) 30 km

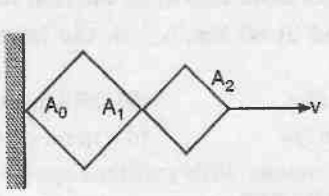
13. Two particles start from the same point with different speeds but one moves along $y=a\sin\omega x$ and other moves along curve $y=a\cos\omega x$:
(a) they must collide after some time
(b) they never collide with each other
(c) they may collide at a point $P\left(\frac{\pi}{4\omega}, \frac{a}{\sqrt{2}}\right)$
(d) they must collide at the point P

14. A sheet of wood moves over a smooth surface (shown in the figure). The magnitude of velocity of C is :



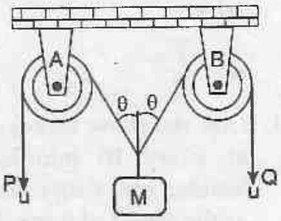
(a) v (b) $2v\cos\theta$
(c) $2v\sin\theta$ (d) $2v$

15. The given hing construction consists of two rhombus with the ratio 3 : 2. The vertex A_2 moves in the horizontal direction with a velocity v. The velocity of A_1 is :



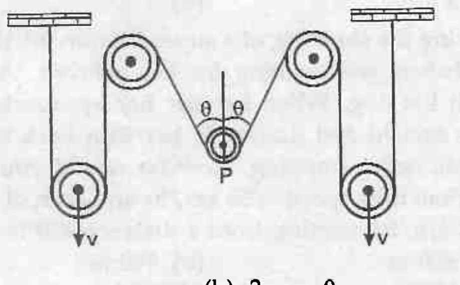
(a) $0.6v$ (b) $0.7v$
(c) $3v$ (d) $2v$

16. In the arrangement shown in figure, the ends P and Q of an inextensible string move downwards with uniform speed u. Pulleys A and B are fixed. The mass m moves upwards with a speed:



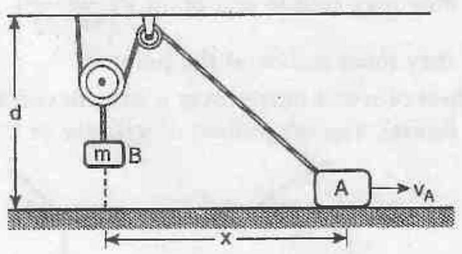
(a) $2u \cos \theta$ (b) $\frac{u}{\cos \theta}$
(c) $\frac{2u}{\cos \theta}$ (d) $u \cos \theta$

*17. In the given figure, find the speed of pulley P:



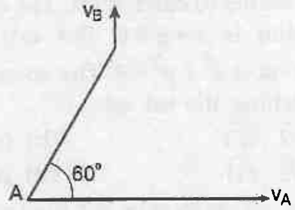
(a) $\frac{v}{2}$ (b) $2v \cos \theta$
(c) $\frac{2v}{\cos \theta}$ (d) $\frac{v}{2 \sin \theta}$

*18. A tractor A is used to hoist the body B with the pulley arrangement shown in fig. If A has a forward velocity v_A, find the velocity of the body B:



(a) $\frac{xv_A}{2}$ (b) $\frac{xv_A}{d}$
(c) $\frac{xv_A}{2\sqrt{x^2+d^2}}$ (d) none of these

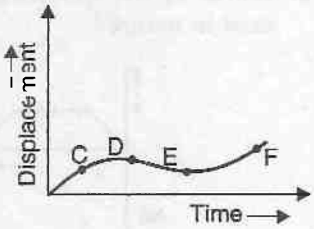
19. A link AB is moving in a vertical plane. At a certain instant when the link is inclined 60° to the horizontal, the point A is moving horizontally at 3 m/s, while B is moving in the vertical direction. What is the velocity of B?



(a) $\frac{1}{\sqrt{3}}$ m/s
(b) $2\sqrt{3}$ m/s
(c) $\sqrt{3}$ m/s
(d) $\frac{\sqrt{3}}{2}$ m/s

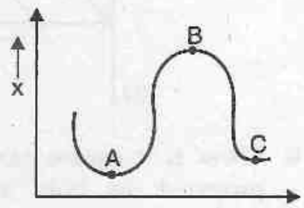
20. Two intersecting straight lines moves parallel to themselves with speeds 3 m/s and 4 m/s respectively. The speed of the point of intersection of the lines, if the angle between them is 90° will be:
(a) 5 m/s (b) 3 m/s
(c) 4 m/s (d) none of these

21. The displacement time graph is shown in figure. The instantaneous velocity is negative at the point:



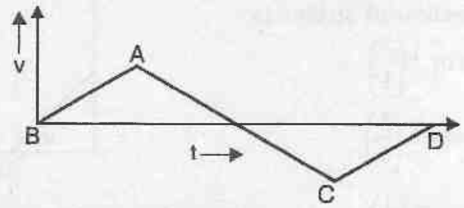
(a) D
(b) F
(c) C
(d) E

22. In the given x-t curve:

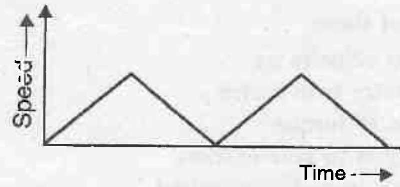


(a) the velocity at A is zero but at B is non-zero
(b) the velocity at A and B is zero
(c) the velocity at A and B is non-zero
(d) the directions of velocity at A and B are definite

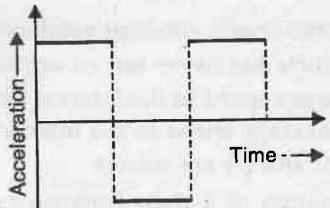
23. A particle moves along X-axis whose velocity varies with time as shown in the figure:



Then which of the following graphs is/are correct?

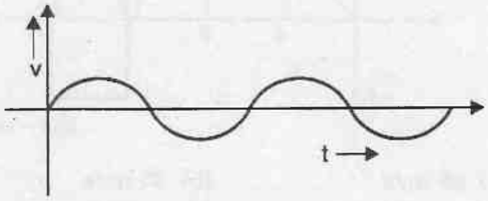
(a)


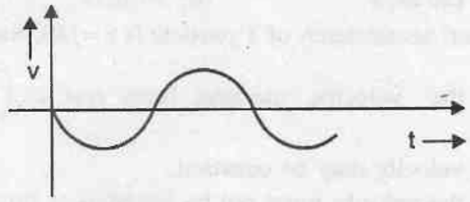
(b)

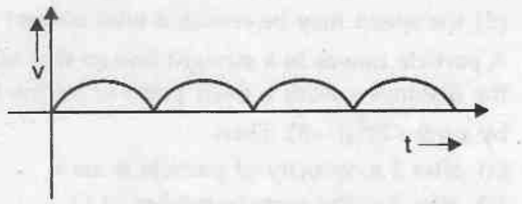

(c) 

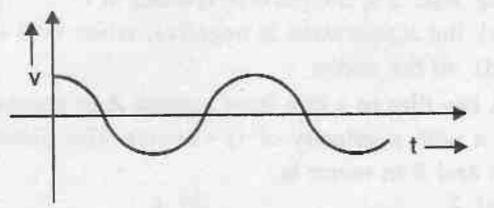
(d) All the above

24. The position of a particle at any instant t is given by $x = a\cos\omega t$. The speed-time graph of the particle is :

(a) 

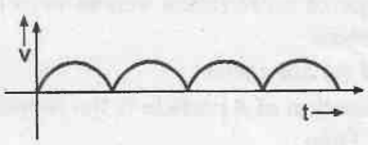
(b) 

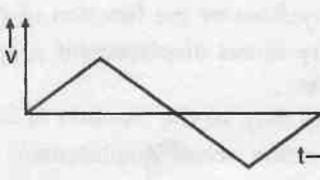
(c) 

(d) 

25. Which of the following speed-time graphs exists in the nature?

(a) 

(b) 

(c) 

(d) All the above

26. Two particles describe the same circle of radius a in the same sense with the same speed v. What is their relative angular velocity ?

(a) v/a (b) $2v/a$
(c) $v/2a$ (d) va

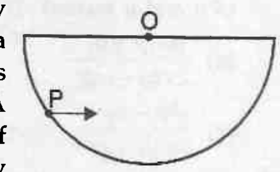
27. A particle is moving on a straight line path with constant acceleration directed along the direction of instantaneous velocity. Which of following statements are false about the motion of particle ?

(a) Particle may reverse the direction of motion
(b) Distance covered is not equal to magnitude of displacement
(c) The magnitude of average velocity is less than average speed
(d) All the above

28. Mark the correct statements for a particle going on a straight line :

(a) if the velocity and acceleration have opposite signs, the object is slowing down
(b) if the position and velocity have opposite signs, the particle is moving towards the origin
(c) if the velocity is zero at an instant, the acceleration should also be zero at that instant
(d) if the velocity is zero for a time interval, the acceleration is zero at any instant within the time interval
(e) (a), (b) and (d) are correct.

29. A particle of mass m is initially situated at the point P inside a hemispherical surface of radius r as shown in figure. A horizontal acceleration of magnitude a_0 is suddenly produced on the particle in the horizontal direction. If gravitational acceleration is neglected, the time taken by particle to touch the sphere again is :



(a) $\sqrt{\dfrac{4r\sin\alpha}{a_0}}$ (b) $\sqrt{\dfrac{4r\tan\alpha}{a_0}}$
(c) $\sqrt{\dfrac{4r\cos\alpha}{a_0}}$ (d) none of these

30. A particle starts with a velocity of 2 m/s and moves in a straight line with a retardation of 0.1 m/s^2. The time that it takes to describe 15 m is :

(a) 10 s in its backward journey
(b) 30 s in its forward journey
(c) 10 s in its forward journey
(d) 30 s in its backward journey
(e) both (b) and (c) are correct

31. A particle starts from rest with acceleration 2 m/s^2. The acceleration of the particle decreases down to zero uniformly during time-interval of 4 second. The velocity of particle after 2 second is :

(a) 3 m/s (b) 4 m/s
(c) zero (d) 8 m/s

32. In the previous problem, the distance travelled by the particle during the time interval of 4 s is :
(a) 10.66 m (b) 20 m
(c) 4 m (d) 2 m

33. If the greatest admissible acceleration or retardation of a train be 3 feet/sec^2, the least time taken from one station to another at a distance of 10 metre is [the maximum speed being 60 mile per hour] :
(a) 500 sec (b) 58.67 sec
(c) 400 sec (d) $314\frac{2}{3}$ sec

34. A person walks up a stalled escalator in 90 second. When standing on the same escalator, now moving, he is carried in 60 second. The time it would take him to walk up the moving escalator will be :
(a) 27 s (b) 72 s
(c) 18 s (d) 36 s

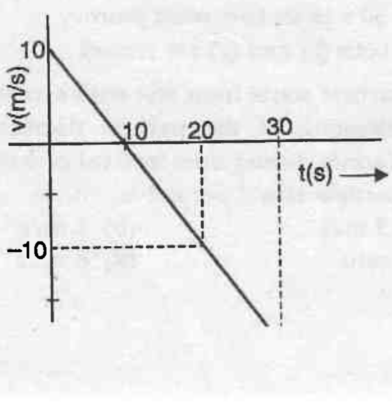
35. A body starts from rest and moves with a constant acceleration. The ratio of distance covered in the *n*th second to the distance covered in *n* second is :
(a) $\frac{2}{n} - \frac{1}{n^2}$ (b) $\frac{1}{n^2} - \frac{1}{n}$
(c) $\frac{2}{n^2} - \frac{1}{n}$ (d) $\frac{2}{n} + \frac{1}{n^2}$

36. A particle moving with a uniform acceleration along a straight line covers distances *a* and *b* in successive intervals of *p* and *q* second. The acceleration of the particle is :
(a) $\frac{pq(p+q)}{2(bp-aq)}$ (b) $\frac{2(aq-bp)}{pq(p-q)}$
(c) $\frac{bp-aq}{pq(p-q)}$ (d) $\frac{2(bp-aq)}{pq(p+q)}$

37. A body moves along *x*-axis with velocity *v*. If the plot *v*-*x* is an ellipse with major axis 2*A* and minor axis $2v_0$, the maximum acceleration has a modulus :
(a) $\frac{v_0^2}{A}$ (b) $\frac{A}{v_0^2}$
(c) $v_0 A$ (d) none of these

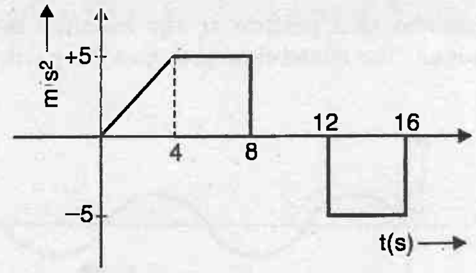
38. The distance time graph of a particle at time *t* makes angle 45° with respect to time axis. After one second, it makes angle 60° with respect to time axis. What is the acceleration of the particle ?
(a) $\sqrt{3} - 1$ unit (b) $\sqrt{3} + 1$ unit
(c) $\sqrt{3}$ unit (d) 1 unit

39. The velocity-time plot for a particle moving on a straight line is shown in the figure, then :



(a) the particle has a constant acceleration
(b) the particle has never turned around
(c) the average speed in the interval 0 to 10 s is the same as the average speed in the interval 10 s to 20 s
(d) both (a) and (c) are correct

40. The acceleration of a train between two stations 2 km apart is shown in the figure. The maximum speed of the train is :



(a) 60 m/s (b) 30 m/s
(c) 120 m/s (d) 90 m/s

41. When acceleration of a particle is $a = f(t)$, then :
(a) the velocity, starting from rest is $\int_0^t f(t)\,dt$
(b) velocity may be constant
(c) the velocity must not be function of time
(d) the speed may be constant with respect to time

42. A particle moves in a straight line so that after *t* second, the distance *x* from a fixed point *O* on the line is given by $x = (t-2)^2 (t-5)$. Then :
(a) after 2 s, velocity of particle is zero
(b) after 2 s, the particle reaches at *O*
(c) the acceleration is negative, when $t < 3$ s
(d) all the above

43. A bee flies in a line from a point *A* to another point *B* in 4 s with a velocity of $|t-2|$ m/s. The distance between *A* and *B* in metre is :
(a) 2 (b) 4
(c) 6 (d) 8

44. When acceleration be function of velocity as $a = f(v)$. Then :
(a) the displacement $(x) = \int \frac{v\,dv}{f(v)}$
(b) the acceleration may be constant
(c) the slope of acceleration versus velocity graph may be constant
(d) (a) and (c) are correct

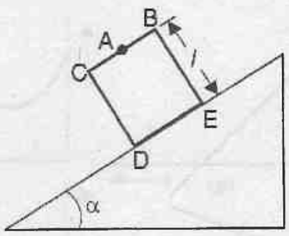
45. If the acceleration of a particle is the function of distance as $a = f(x)$. Then :
(a) the velocity must be the function of displacement
(b) the velocity *versus* displacement graph cannot be a straight line
(c) the velocity may be the function of displacement
(d) the acceleration *versus* displacement graph may be straight line

46. A particle moves as such whose acceleration is given by $a = 3\sin 4t$, then :
(a) the initial velocity of the particle must be zero
(b) the acceleration of the particle becomes zero after each interval of $\frac{\pi}{4}$ second
(c) the particle does not come at its initial position after some time
(d) the particle must move on a circular path

47. A particle moves along a straight line such that its position x at any time t is $x = 3t^2 - t^3$, where x is in metre and t in second, then :
(a) at $t = 0$ acceleration is 6 m/s^2
(b) x-t curve has maximum at 8 m
(c) x-t curve has maximum at 2 s
(d) both (a) and (c) are correct

48. The motion of a body falling from rest in a resisting medium is described by the equation $\frac{dv}{dt} = a - bv$, where a and b are constant. The velocity at any time t is :
(a) $a(1 - b^{2t})$ (b) $\frac{a}{b}(1 - e^{-bt})$
(c) abe^{-t} (d) $ab^2(1 - t)$

49. A rectangular box is sliding on a smooth inclined plane of inclination θ. At $t = 0$, the box starts to move on the inclined plane. A bolt starts to fall from point A. Find the time after which bolt strikes the bottom surface of the box :

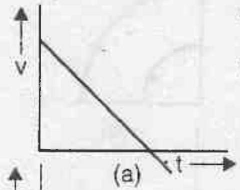


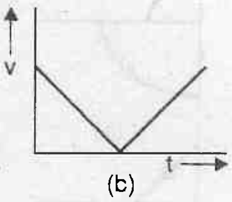
(a) $\sqrt{\left(\frac{2l}{g\cos\alpha}\right)}$ (b) $\sqrt{\left(\frac{2l}{g\sin\alpha}\right)}$
(c) $\sqrt{\left(\frac{2l}{g}\right)}$ (d) $\sqrt{\left(\frac{l}{g}\right)}$

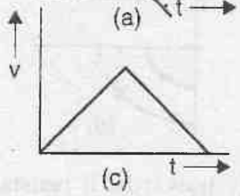
50. A point moves in a straight line under the retardation kv^2. If the initial velocity is u, the distance covered in t second is :
(a) kut (b) $\frac{1}{k}\log kut$
(c) $\frac{1}{k}\log(1 + kut)$ (d) $k\log kut$

51. An object moves, starting from rest through a resistive medium such that its acceleration is related to velocity as $a = 3 - 2v$. Then :
(a) the terminal velocity is 1.5 unit
(b) the terminal velocity is 3 unit
(c) the slope of a-v graph is not constant
(d) initial acceleration is 2 unit

52. A stone is released from a balloon moving upward with velocity v_0 at height h at $t = 0$. The speed-time graph is :







(d) none of these

53. If the velocity of a moving particle is $v \propto x^n$ where x is the displacement, then :
(a) when $x = 0$, the velocity and acceleration are zero
(b) $n > \frac{1}{2}$
(c) $n < \frac{1}{2}$
(d) (a) and (b) are correct

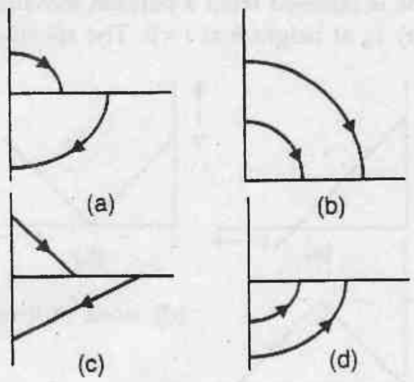
54. Which of the following statements is correct ?
(a) When air resistance is negligible, the time of ascent is less than the time of descent
(b) When air resistance is not negligible, time of ascent is less than the time of descent
(c) When air resistance is not negligible, the time ascent is greater than the time of descent
(d) When air resistance is not negligible, the time of ascent is lesser than the time of descent

55. A particle is projected veritically upward in vacuum with a speed 40 m/s then velocity of particle when it reaches at maximum height 2 s before, is : (Take $g = 10\ m/s^2$)
(a) 20 m/s (b) 4.2 m/s
(c) 9.8 m/s (d) none of these

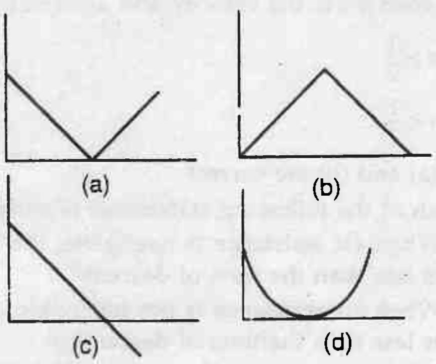
56. A juggler keeps on moving four balls in the air throws the balls in regular interval of time. When one ball leaves his hand (speed = 20 m/s), the position of other balls will be : (Take $g = 10\ m/s^2$)
(a) 10 m, 20 m, 10 m (b) 15 m, 20 m, 15 m
(c) 5 m, 15 m, 20 m (d) 5 m, 10 m, 20 m

57. Balls are thrown vertically upward in such a way that the next ball is thrown when the previous one is at the maximum height. If the maximum height is 5 m, the number of balls thrown per minute will be :
(Take $g = 10\ m/s^2$)
(a) 60 (b) 40
(c) 50 (d) 120

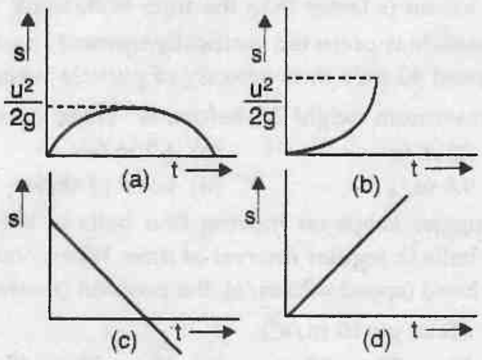
58. A ball is dropped vertically from a height d above the ground. It hits the ground and bounces up vertically to a height $d/2$. Neglecting subsequent motion and air resistance, its speed v varies with the height h above the ground as :



*** 59.** A ball is projected vertically upwards. If resistance due to air is ignored, then which of the following graphs represents the velocity-time graph of the ball during its flight ?



*** 60.** An object is thrown upward with a velocity u, then displacement-time graph is :



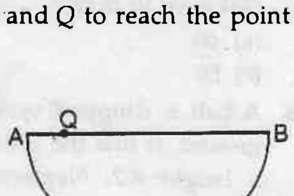
61. A particle P is sliding down a frictionless hemispherical bowl. It passes the point A at $t = 0$. At this instant of time, the horizontal component of its velocity is v. A bead Q of the same mass as P is ejected from A at $t = 0$ along the horizontal string AB, with the speed v. Friction between the bead and the string may be neglected. Let t_P and t_Q be the respective times by P and Q to reach the point B. Then :

(a) $t_P < t_Q$

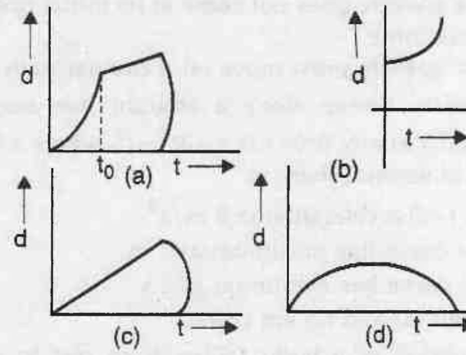
(b) $t_P = t_Q$

(c) $t_P > t_Q$

(d) $\frac{t_P}{t_Q} = \frac{\text{length of arc } ACB}{\text{length of chord } AB}$



*** 62.** Two stones A and B are dropped from a multistoried building with a time interval t_0, where t_0 is smaller than the time taken by A to reach the floor. At $t = t_0$, stone A is dropped. After striking the floor, stone comes to rest. The separation between stones plotted against the time lapse t is best represented by :

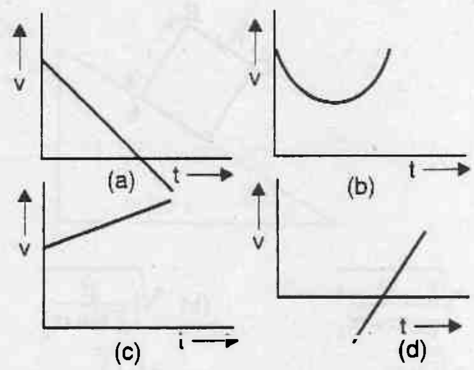


63. A balloon going upward with a velocity of 12 m/s is at a height of 65 m from the earth surface at any instant. Exactly at this instant a packet drops from it. How much time will the packet take in reaching the surface of earth ? ($g = 10$ m/s^2)

(a) 7.5 sec (b) 10 sec

(c) 5 sec (d) none of these

64. A stone is released from a balloon moving upward with velocity v_0 at height h at $t = 0$. Which of the following graphs is best representation of velocity-time graph for the motion of stone ?



Motion in Two and Three Dimensions

65. A particle is projected at angle 60° with the horizontal with speed 10 m/s then equation of directrix is : (Take $g = 10$ m/s^2)

(a) $y = 5$ (b) $x = 5$

(c) $x = 10$ (d) $x + y = 5$

66. Three particles of equal masses are located at the vertices of an equilateral triangle whose side equals a. They all strart moving simultaneously with constant speed v with the first point heading continuously for second, the second for third and third for first. Then :

(a) the distance travelled by each particle is $2a/3$

(b) at every instant before collision the momentum of the system is zero

(c) the force on each particle is perpendicular to velocity of the particle at any instant before collision

(d) all the above

67. Eight particles are situated at the vertices of a regular octagon having edge length 10 cm. They all start moving simultaneously with equal constant speed 1 cm/s heading towards each other all the time. Then :
(a) momentum of system does not remain constant
(b) kinetic energy of the system remains constant after collision
(c) they will collide after time $\left(\frac{10\sqrt{2}}{\sqrt{2}-1}\right)$ second
(d) every particle moves with constant acceleration

68. A particle P is at the origin starts with velocity $\vec{u} = (2\hat{i} - 4\hat{j})$ m/s with constant acceleration $(3\hat{i} + 5\hat{j})$ m/s^2. After travelling for 2 second, its distance from the origin is :
(a) 10 m (b) 10.2 m
(c) 9.8 m (d) 11.7 m

69. At an instant t, the co-ordinates of a particles are $x = at^2, y = bt^2$ and $z = 0$. The magnitude of velocity of particle at an instant t is :
(a) $t\sqrt{a^2 + b^2}$ (b) $\frac{v}{\sqrt{2}}$
(c) $\frac{V}{\sqrt{3}}$ (d) $2t\sqrt{a^2 + b^2}$

70. If $x = a(\cos\theta + \theta\sin\theta)$ and $y = a(\sin\theta - \theta\cos\theta)$ and θ increases at uniform rate ω. The velocity of particle is :
(a) $a\omega$ (b) $\frac{a^2\theta}{\omega}$
(c) $\frac{a\theta}{\omega}$ (d) $a\theta\omega$

71. If co-ordinates of a moving point at time t are given by $x = a(t + \sin t)$, and $y = a(1 - \cos t)$, then :
(a) the slope of acceleration time graph is zero
(b) the slope of velocity-time graph is constant
(c) the direction of motion makes an angle $t/2$ with x-axis
(d) all the above

72. A particle moves along the positive branch of the curve $y = \frac{x^2}{2}$ where $x = \frac{t^2}{2}$, where x and y are measured in metre and t in second. At $t = 2$ sec, the velocity of the particle is :
(a) $(2\hat{i} - 4\hat{j})$ m/sec (b) $(2\hat{i} + 4\hat{j})$ m/sec
(c) $(2\hat{i} + 2\hat{j})$ m/sec (d) $(4\hat{i} - 2\hat{j})$ m/sec

* **73.** The velocity of a particle moving in the x-y plane is given by

$$\frac{dx}{dt} = 8\pi\sin 2\pi t \quad \text{and} \quad \frac{dy}{dt} = 5\pi\cos 2\pi t$$

where $t = 0$, $x = 8$ and $y = 0$. The path of the particle is :
(a) a straight line (b) an ellipse
(c) a circle (d) a parabola

74. A light rigid rod is placed on a smooth horizontal surface. Initially the end A begins to move vertically upward with constant velocity v_0 and centre of the rod upward with a velocity $v_0/2$ having downward acceleration $a_0/2$, the other end moves downward with :
(a) zero initial velocity having zero acceleration
(b) zero initial velocity having a_0 downward acceleration
(c) non-zero initial velocity and zero acceleration
(d) none of the above

75. At the top of the trajectory of a projectile, the directions of its velocity and acceleration are :
(a) parallel to each other
(b) inclined to each other at an angle of 45°
(c) anti parallel to each other
(d) perpendicular to each other

76. A projectile is thrown at an angle of $\theta = 45°$ to the horizontal, reaches a maximum height of 16 m, then :
(a) its velocity at the highest point is zero
(b) its range is 64 m
(c) its range will decrease when it is thrown at an angle 30°
(d) (b) and (c) both are correct

77. A heavy stone is thrown from a cliff of height h in a given direction. The speed with which it hits the ground (air resistance may be neglected) :
(a) must depend on the speed of projection
(b) must be larger than the speed of projection
(c) must be independent of the speed of projection
(d) (a) and (b) both are correct

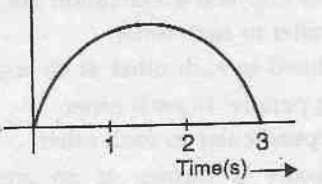
78. A particle is projected with speed v at an angle θ $\left(0 < \theta < \frac{\pi}{2}\right)$ above the horizontal from a height H above the ground. If v = speed with which particle hits the ground and t = time taken by particle to reach ground, then :
(a) as θ increases, v decreases and t increases
(b) as θ increases, v increases and t increases
(c) as θ increases, v remains same and t increases
(d) as θ increases, v remains same and t decreases

79. A particle of mass m is projected with a velocity v making an angle of 45° with the horizontal. The magnitude of angular momentum of projectile about the point of projection when the particle is at its maximum height h is :
(a) zero (b) $\frac{mvh}{\sqrt{2}}$
(c) $\frac{mvh^2}{\sqrt{2}}$ (d) none of these

80. Two particles are projected vertically upwards with the same velocity on two different planets with accelerations due to gravity g_1 and g_2 respectively. If they fall back to their initial points of projection after lapse of time t_1 and t_2 respectively, then :
(a) $t_1 t_2 = g_1 g_2$ (b) $t_1 g_1 = t_2 g_2$
(c) $\frac{t_1 g_2}{t_2 g_1} - 2$ (d) $t_1^2 + t_2^2 = g_1 + g_2$

81. A particle is projected from a horizontal plane to pass over two objects at heights h and k and a slant distance d apart. The least possible speed of projection will be :
(a) $g(h+k+d)$ (b) $\sqrt{g(h+k+d)}$
(c) $h(g+k+d)$ (d) $\sqrt{h(g+h+d)}$

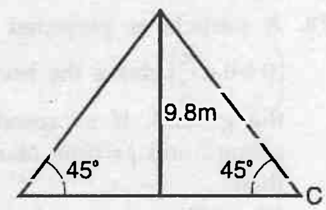
82. The graph below shows one half period of a sinusoidal wave. It might represent the time dependence of :



(a) height of a projectile
(b) vertical component of a projectile's velocity
(c) X-component of a projectile moving in uniform circular motion
(d) speed of an object subjected to a force that grows linearly with time

83. A number of particles are projected from a given point with equal velocities in different directions in the same vertical plane. At any instant, they will lie on :
(a) parabola (b) circle
(c) hyperbola (d) rectangle

84 Two inclined planes are located as shown in figure. A particle is projected from the foot one frictionless plane along its line with a velocity just sufficient to carry it to top after which the particle slides down the other frictionless inclined plane. The total time it will take to reach the point C is :



(a) 2 sec (b) 3 sec
(c) $2\sqrt{2}$ sec (d) 4 sec

85. Rain water is falling vertically downward with velocity v. When velocity of wind is u in horizontal direction, water is collected at the rate of R m^3/s. When velocity of wind becomes $2u$ in horizontal direction, the rate of collection of water in vessel is :
(a) R (b) $\frac{R}{2}$
(c) $2R$ (d) $\frac{R\sqrt{4u^2+v^2}}{\sqrt{u^2+v^2}}$

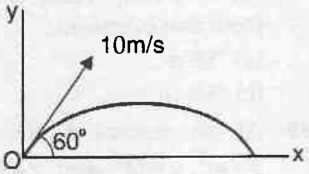
86. A particle is projected at an angle α with the horizontal from the foot of an inclined plane making an angle β with horizontal. Which of the following expression holds good if the particle strikes the inclined plane normally?
(a) $\cot\beta = \tan(\alpha-\beta)$ (b) $\cot\beta = 2\tan(\alpha-\beta)$
(c) $\cot\alpha = \tan(\alpha-\beta)$ (d) $\cot\alpha = 2\tan(\alpha-\beta)$

87. When the range of a projectile on an inclined plane is maximum then :
(a) the focus of the path is on the plane
(b) the focus of the path is below the plane
(c) the focus of the path is above the plane
(d) the focus of the path lies at any place

88. If a number of particles are projected from the same point in the same plane so as to describe equal parabolas, then the vertices of their paths lie on a :
(a) parabola (b) circle
(c) square (d) rectangle

89. The locus of foci of all parabolas described by the particles projected simultaneously from the same point with equal velocities but in different directions is a :
(a) circle (b) parabola
(c) ellipse (d) hyperbola

90. A particle is projected at an angle 60° with the horizontal with a speed 10 m/sec. Then latus rectum is :



(Take $g = 10$ m/s^2)
(a) 5 m (b) 15 m
(c) 10 m (d) 0

Relative Velocity

91. A bus moves over a straight level road with a constant acceleration a. A boy in the bus drops a ball out side. The acceleration of the ball with respect to the bus and the earth are respectively :
(a) a and g (b) $a+g$ and $g-a$
(c) $\sqrt{a^2+g^2}$ and g (d) $\sqrt{a^2+g^2}$ and a

92. A man swims relative to water with a velocity greater than river flow velocity. Then :
(a) man may cross the river along shortest path
(b) man cannot cross the river
(c) man cannot cross the river without drifting
(d) none of the above

93. Two cars move in the same direction along parallel roads. One of them is a 200 m long travelling with a velocity of 20 m/s. The second one is 800 m long travelling with a velocity of 7.5 m/s. How long will it take for the first car to overtake the second car ?
(a) 20 s (b) 40 s
(c) 60 s (d) 80 s

94. A motor boat covers the distance between two spots on the river banks in $t_1 = 8$ h and $t_2 = 12$ h in down stream and upstream respectively. The time required for the boat to cover this distance in still water will be :
(a) 6.9 hr (b) 9.6 hr
(c) 69 second (d) 96 second

* 95. A man rows directly across a river in time t second and rows an equal distance down the stream in T second. The ratio of man's speed in still water to the speed of river water is :
(a) $\frac{t^2-T^2}{t^2+T^2}$ (b) $\frac{t^2+T^2}{t^2-T^2}$
(c) $\frac{T^2-t^2}{T^2+t^2}$ (d) $\frac{T^2+t^2}{T^2-t^2}$

96. To a person going toward east in a car with a velocity of 25 km/hr, a train appears to move towards north with a velocity of $25\sqrt{3}$ km/hr. The actual velocity of the train will be :

(a) 25 km/hr (b) 50 km/hr
(c) 5 km/hr (d) 53 km/hr

97. A beautiful girl is going eastwards with a velocity of 4 km/hr. The wind appears to blow directly from the north. She doubles her speed and the wind seems to come from north east. The actual velocity of wind is :

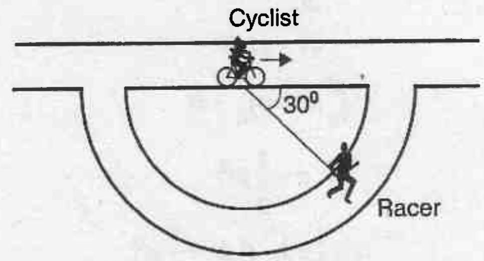
(a) $4\sqrt{2}$ km/hr towards south east
(b) $4\sqrt{2}$ km/hr towards north west
(c) $2\sqrt{2}$ km/hr towards south east
(d) none of the above

98. Rain drops fall vertically at a speed of 20 m/s. At what angle do they fall on the wind screen of a car moving with a velocity of 15 m/s if the wind screen velocity inclined at an angle of 23° to the vertical ?

$\left(\cot^{-1}\frac{4}{3}\approx 37°\right)$

(a) 60° (b) 30°
(c) 45° (d) 90°

*** 99.** A cyclist is moving with a constant acceleration of 1.2 m/s^2 on a straight track. A racer is moving on a circular path of radius 150 m at constant speed of 15 m/s. Find the magnitude of velocity of racer which is measured by the cyclist has reached a speed of 20 m/s for the position represented in the figure :



(a) 18.03 m/s (b) 25 m/s
(c) 20 m/s (d) 15 m/s

Answers

Level-1

1. (c)	2. (c)	3. (d)	4. (a)	5. (d)	6. (a)	7. (b)	8. (a)	9. (b)	10. (c)
11. (c)	12. (a)	13. (b)	14. (a)	15. (c)	16. (b)	17. (a)	18. (c)	19. (b)	20. (c)
21. (b)	22. (b)	23. (a)	24. (d)	25. (b)	26. (b)	27. (d)	28. (a)	29. (b)	30. (d)
31. (d)	32. (c)	33. (a)	34. (a)	35. (d)	36. (a)	37. (d)	38. (c)	39. (c)	40. (a)
41. (d)	42. (b)	43. (c)	44. (b)	45. (a)					

Level-2

1. (d)	2. (d)	3. (b)	4. (d)	5. (c)	6. (a)	7. (d)	8. (a)	9. (a)	10. (c)
11. (a)	12. (c)	13. (c)	14. (c)	15. (a)	16. (b)	17. (c)	18. (c)	19. (c)	20. (a)
21. (d)	22. (b)	23. (d)	24. (c)	25. (b)	26. (a)	27. (d)	28. (e)	29. (c)	30. (e)
31. (a)	32. (a)	33. (b)	34. (d)	35. (a)	36. (b)	37. (a)	38. (a)	39. (d)	40. (b)
41. (a)	42. (c)	43. (b)	44. (d)	45. (c)	46. (b)	47. (d)	48. (b)	49. (a)	50. (c)
51. (a)	52. (b)	53. (b)	54. (d)	55. (a)	56. (b)	57. (a)	58. (b)	59. (c)	60. (a)
61. (a)	62. (a)	63. (c)	64. (a)	65. (b)	66. (d)	67. (c)	68. (b)	69. (d)	70. (d)
71. (d)	72. (b)	73. (b)	74. (b)	75. (d)	76. (d)	77. (d)	78. (c)	79. (b)	80. (b)
81. (b)	82. (c)	83. (b)	84. (d)	85. (a)	86. (b)	87. (a)	88. (a)	89. (a)	90. (a)
91. (c)	92. (a)	93. (d)	94. (b)	95. (b)	96. (b)	97. (a)	98. (a)	99. (a)	

Solutions

Level-1

1.
$$v^2 - u^2 = 2al \quad \text{...(i)}$$

where l = length of train

and
$$v'^2 - u^2 = 2a \cdot \frac{l}{2}$$
$$(v')^2 - u^2 = al \quad \text{...(ii)}$$

From eqs. (i) and (ii)

$$v^2 - u^2 = 2\,[(v')^2 - u^2]$$
$$(v')^2 = \frac{v^2 + u^2}{2}$$
$$\therefore \quad v' = \sqrt{\left(\frac{v^2 + u^2}{2}\right)}$$

4

Newton's Laws of Motion and Friction

Syllabus: Force and inertia, Newton's laws of motion, conservation of linear momentum, inertial frames of references, static and kinetic friction, laws of friction, rolling friction.

Review of Concepts

1. Concept of Force and net Force: Force is familiar word in science. From your own experience, you know that forces can produce changes in motion. If a force is applied to a stationary body, the body comes in motion. It can speed up and slow down a moving body or change the direction of its motion. In nut shell, the force is cause of change in velocity of the body. In other words, force is the cause of acceleration of the body.

If a number of forces act on a body, the net or resultant force on the body is vector sum of all forces.

Newton's second law gives a good relation between net force and acceleration of body.

According to Newton's second law of motion,

$$\Sigma \vec{F} = m\vec{a}$$

If the resultant force on the body is zero, body remains either in rest or moves with constant velocity. A non-zero net force is referred to as an unbalanced force. Unbalanced force is cause of acceleration of the body.

2. Newton's Second Law: The resultant force on a body is equal to product of mass and acceleration of the body. The direction of acceleration is same as the direction of resultant force. Mathematically,

$$\vec{F} = m\vec{a}$$

Here, $\vec{F}$ = net force on the body

m = mass of the body

$\vec{a}$ = acceleration of the body

Application of methods using Newton's second law of motion :

(i) Concentrate your mind on the body which is considered by you.

(ii) Make a separate sketch for the considered body.

(iii) Show all forces acting on the body.

(iv) Reduce the considered body to a single point (point mass) and redraw the forces acting on the body, such that tails of all force vectors are on the point mass. This is known as free body diagram.

(v) Choose a co-ordinate system for the problem whose origin is at the point mass.

(vi) Find $\Sigma F_x, \Sigma F_y$ and ΣF_z.

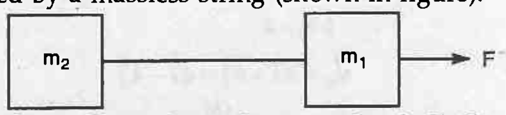
(vii) Write Newton's second law for each of the co-ordinate system.

i.e., $\Sigma F_x = ma_x, \quad \Sigma F_y = ma_y$

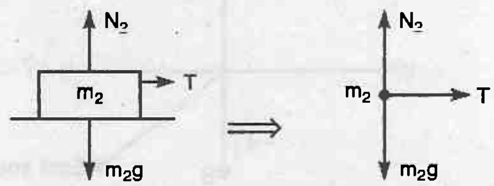
$$\Sigma F_z = ma_z$$

Case I: Free body diagram of connected bodies on a horizontal smooth surface.

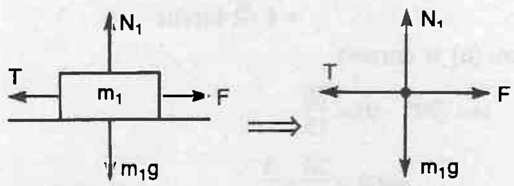
Situation: Two blocks of masses m_1 and m_2 are connected by a massless string (shown in figure).



Solution: Draw force diagram of each block :



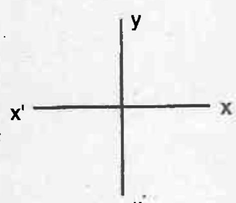
Force diagram of m_2 | Free body diagram of m_2



Force diagram of m_1 | Free body diagram of m_1

Case II: Choose co-ordinate system and apply Newton's second law :

For m_2: $\Sigma F_y = N_2 - m_2 g$



Since, both bodies move in horizontal direction (along x-axis), hence, y-component of acceleration of both blocks should be zero.

$\therefore$ $$a_y = 0$$

$\therefore$ $$\Sigma F_y = ma_y$$

$$N_2 - m_2 g = m \times 0 = 0$$

$$N_2 = m_2 g$$

Also, $$\Sigma F_x = F - T = m_2 a_{2x}$$

$\therefore$ $$F - T = m_2 a_{2x} \qquad \ldots(i)$$

Similarly for m_1,

$$\Sigma F_y = 0$$

$\therefore$ $$N_1 - m_1 g = 0$$

$\therefore$ $$N_1 = m_1 g$$

and $$\Sigma F_x = m_1 a_{1x}$$

$$T = m_1 a_{1x} \quad \text{...(ii)}$$

Since, the length of string remains constant,

$\therefore$ $$a_{1x} = a_{2x} = a$$

$\therefore$ $$F - T = m_2 a \quad \text{...(iii)}$$

and $$T = m_1 a \quad \text{...(iv)}$$

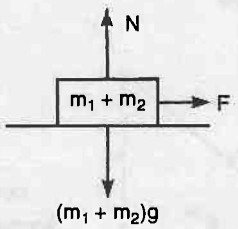
From equations (iii) and (iv)

or $$F - m_1 a = m_2 a$$

$\therefore$ $$a = \frac{F}{m_1 + m_2}$$

Also, $$T = m_1 a = \frac{m_1 F}{m_1 + m_2}$$

Alternative method: Since, the accelerations of both blocks are same, so, they are taken as a system.



From the force diagram (shown in figure),

$$N = (m_1 + m_2)\, g$$

and $$F = (m_1 + m_2)\, a$$

$\therefore$ $$a = \frac{F}{m_1 + m_2}$$

3. Newton's Third Law of Motion: Newton's third law of motion is often called the law of "action and reaction". For a simple introduction to the third law, consider the forces involved in kicking a ball by foot. If you kick a ball by your foot, the pain you feel is due to the force that the ball exerts on your foot.

From this point of view, it is obvious that a force acting on a body is always the result of its interaction with another body.

The direction of force which exerts by you on the ball is in the opposite direction to the force that ball exerts on your foot. This type of pair of forces is known as action-reaction pair. If you kick forcely the ball, you feel more pain. This is due to increase in the force which is exerted by ball on your foot.

It means, when action force increases, reaction force also increases. It shows that whenever two bodies interact, then two forces (action and reaction) that they exert on each other are always equal in magnitude and opposie in direction.

Statement of Newton's third law: "If a force is exerted on block A by block B, then a force is also exerted on block B by block A."

These forces are equal in magnitude but opposite in direction.

4. Different Types of Forces in Nature:

(a) Gravitational force: The force of attraction between bodies by virtue of their masses is known as gravitational force.

Let two blocks of masses m_1 and m_2 are separated by a distance r.

The force on block 1 by block 2 is $\vec{F}_{12}$ acting towards m_2 along line joining m_1 and m_2. Similarly, the force on block 2 by block 1 is $\vec{F}_{21}$ acting towards m_1 along line joining m_2 and m_1 (as shown in figure)

From the concept of Newton's third law,

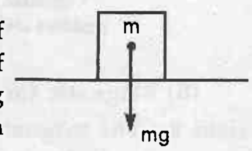
$$\vec{F}_{12} = -\vec{F}_{21}$$

In the sense of magnitude,

$$F_{12} = F_{21} = F = \frac{Gm_1 m_2}{r^2}$$

Here G = gravitational constant $= 6.7 \times 10^{-11}\ \text{Nm}^2/\text{kg}^2$

(b) Weight of body (mg): It is defined as the force by which earth attracts a body towards its centre. If body is situated either on the surface of earth or near the surface of earth, then gravitational acceleration is nearly constant and is equal to $g = 9.8\ \text{m/s}^2$. The force of gravity (weight) on a block of mass m is $w = mg$ acting towards centre of earth (shown in figure)



(c) Electromagnetic force

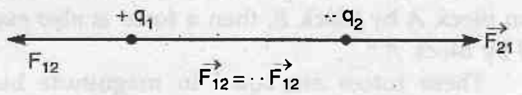
- Electrical force
  - Coulomb force
  - Electrical force in electrical field
- Magnetic force
- Force of tension
- Spring force
- Normal reaction
- Force of friction
- Viscous force
- Buoyancy force

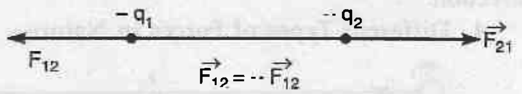
(A) Electrical force :

(i) Coulomb force or force of electrostatic interaction between charges : The force of interaction between two particles by virtue of their charges is known as electrostatic force of interaction. The force of electrostatic interaction takes place along the line joining the charges.

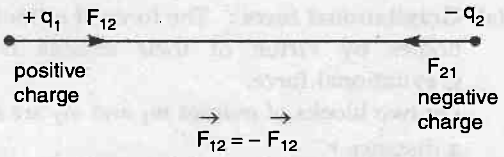
Some Important Points :

(i) Like point charges repel each other.

(a) 

(b) 

(ii) Unlike point charges attract each other.

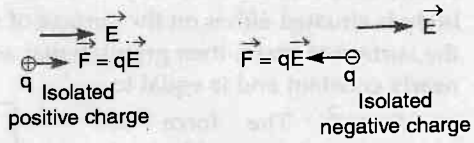


(iii) The magnitude of force of electrostatic interaction is

$$F_{12} = F_{21} = F = \frac{q_1 q_2}{4\pi\varepsilon_0 r^2}$$

Here : $\dfrac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \ \mathrm{Nm^2/C^2}$

(ii) Electrical force in an electric field : If a charged particle A of charge q is placed in a region where an electric field $\vec{E}$ created by other charges is present, the particle A experiences an electric force $\vec{F} = q\vec{E}$. The electric force on positive charge is in the direction of electric field. But the electric force on negative charge is in opposite direction of electric field (shown in figure).



(B) Magnetic force on a moving charge in an magnetic field $\vec{B}$: The magnetic force an a charged particle of charge q is given by $\vec{F} = q\vec{v} \times \vec{B}$.

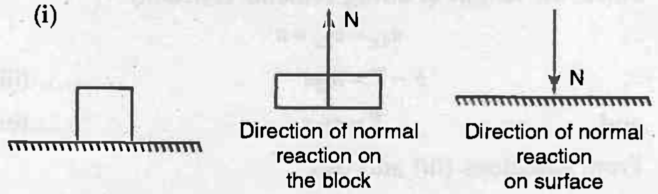
(C) Normal reaction force : If two blocks come in contact, they exert force on each other. The component of contact force perpendicular to the surface of contact is generally known as normal reaction.

For a simple introduction to the normal reaction force, consider a situation in whch you put a book on your head and continue your stationary position. In this case, the pain you feel is due to the force that the book exerts on your head. In the language of physics, the book exerts a force on your head normal to the surface of contact in downward direction. According to Newton's third law of motion, the head exerts a force of same magnitude on the book normal to the surface of contact in upward direction.

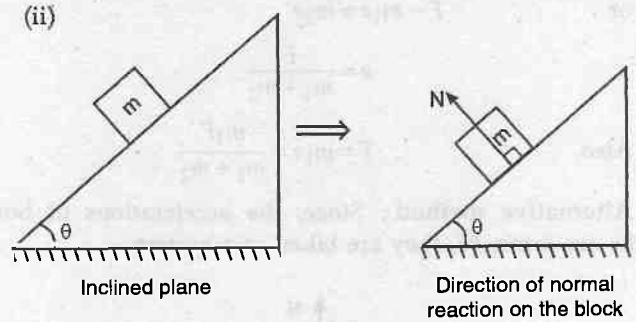
These forces are known as normal reaction forces.

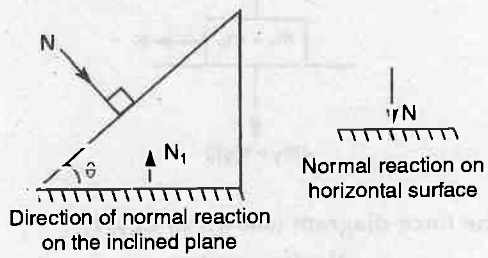
Normal reaction forces in different situations :

(i)



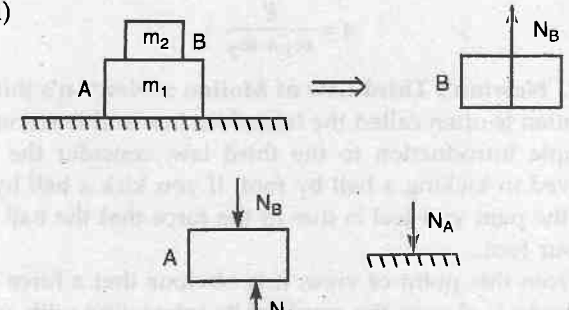
(ii)





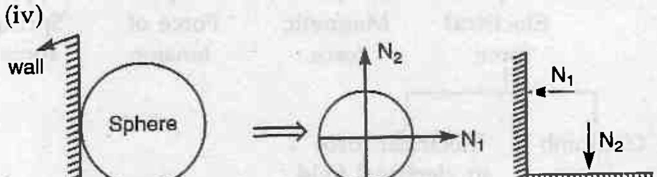
The number of normal reaction pairs is equal to number of contact surfaces.

(iii)

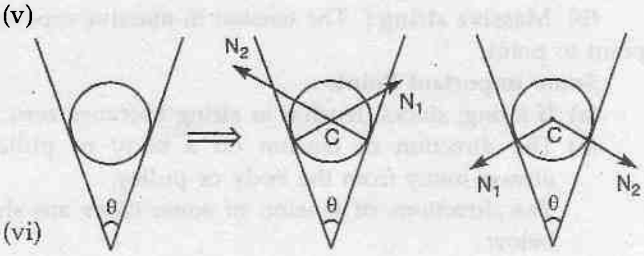


The normal reaction on upper block is in upward direction and normal reaction on lower block is in downward direction.

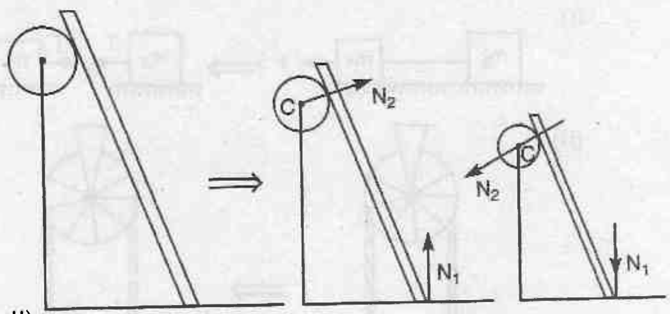
(iv)



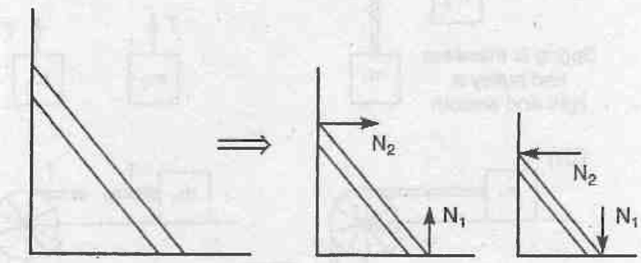
(v)



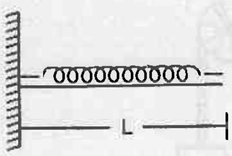
(vi)



(vii)



(D) Spring force: Coiled metallic wire is known as spring. The distance between two successive coillsions in a spring remains the same. If a spring is placed on a smooth surface, the length between ends of spring is known natural length (shown in figure).



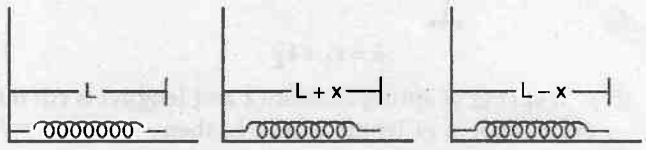
As you may have discovered itself, springs resist attempts to change their length. If the length of spring is greater than its natural length, the spring is in the condition of elongation (shown in figure ahead). If the length of spring is lesser than its natural length, the spring is in the condition of compression (shown in figure ahead). In fact, the more you alter a spring's length, the harder it resists. From this point of view, spring force increases, when elongation or compression increases.

For small elongation or compression of spring, spring force is proportional to its elongation or compression.

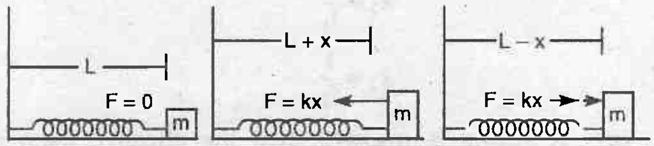
i.e., $$F \propto x$$

$$F = kx$$

where k is proportionality constant known as spring constant or stiffness constant. Its unit is N/m. The direction of spring force is always towards the natural length of spring.



Spring in natural length (a) | Spring in the condition of elongation (b) | Spring in the condition of compression (c)

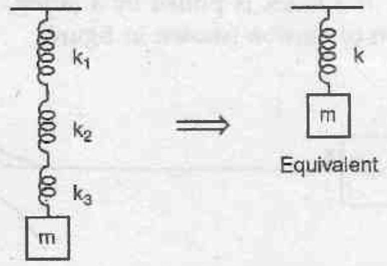


No spring force on body (d) | Spring force on the body is leftward (e) | Spring force on the body is rightward (f)

5. Combination of Springs:

(i) Springs in series:

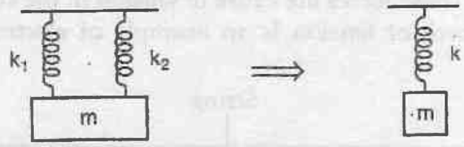
$$\frac{1}{k} = \frac{1}{k_1} + \frac{1}{k_2} + \frac{1}{k_3}$$



where k is equivalent spring constant.

In general, $\frac{1}{k} = \frac{1}{k_1} + \frac{1}{k_2} + \ldots$

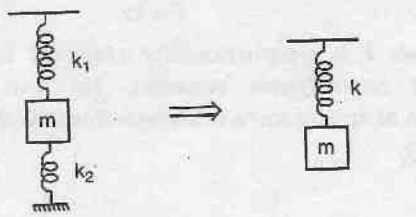
(ii) Springs in parallel:



$$k = k_1 + k_2$$

In general, $$k = k_1 + k_2 + k_3 + \ldots$$

(iii)



$$k = k_1 + k_2$$

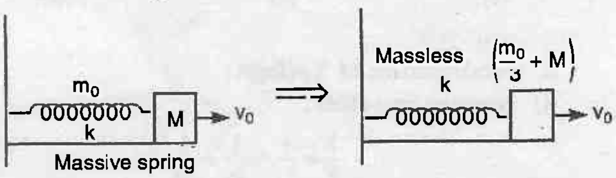
(iv) If spring of spring constant k and length l is cut into two pieces of length l_1 and l_2, then

$$k \propto \frac{1}{l_1 + l_2}$$

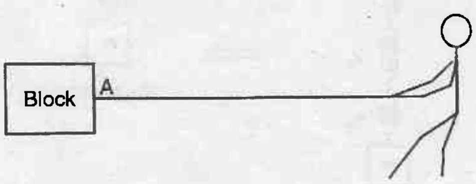
$$k_1 \propto \frac{1}{l_1}$$

$$k_2 \propto \frac{1}{l_2}$$

(v) If spring is massive then the effective mass of spring is $\frac{m_0}{3}$, where m_0 is mass of spring.



6. String : If a block is pulled by a string, the string is in the condition of tension (shown in figure)



From microscopic point of view, the electrons and protons near point A of string exerts forces on electrons and protons of the block. According to Newton's third law of motion electrons and protons of the block exerts same magnitude of force on electrons and protons near point A of the string. These forces are cause of tension in the string. This is why, force of tension is an example of electromagnetic force.

String

Massless string — Massive string

(a) Massless string : In the cae of massless string, the tension, every where remains the same in it.

(b) Massive string : The tension in massive rope varies point to point.

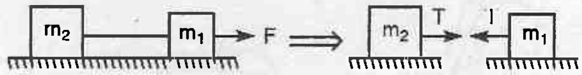
Some Important Points :

(a) If string, slacks, tension in string becomes zero.

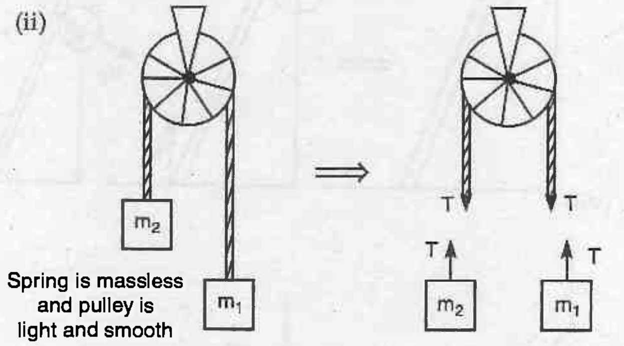
(b) The direction of tension on a body or pulley is always away from the body or pulley.

The directions of tension in some cases are shown below :

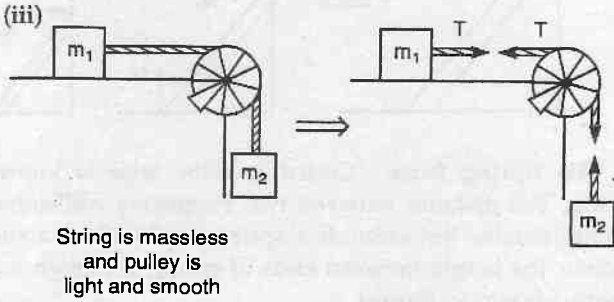
(i)



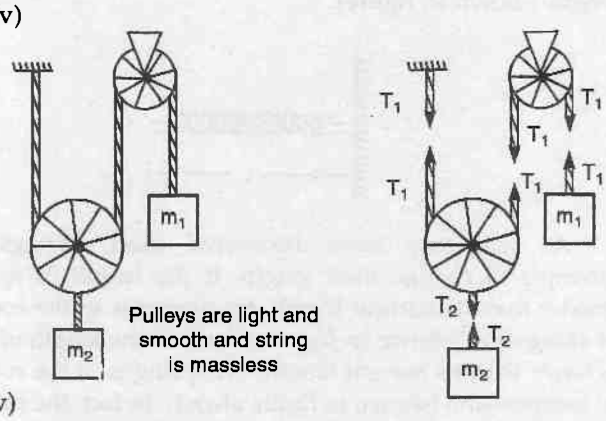
(ii)



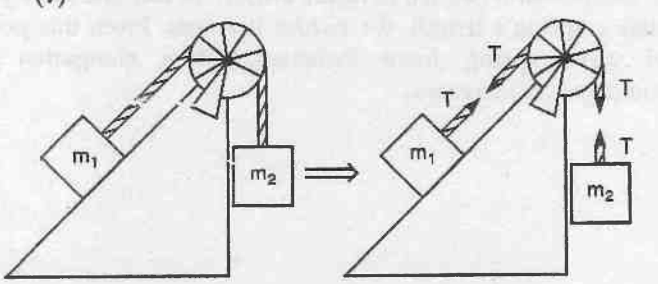
(iii)



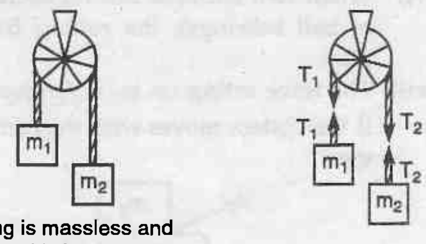
(iv)



(v)

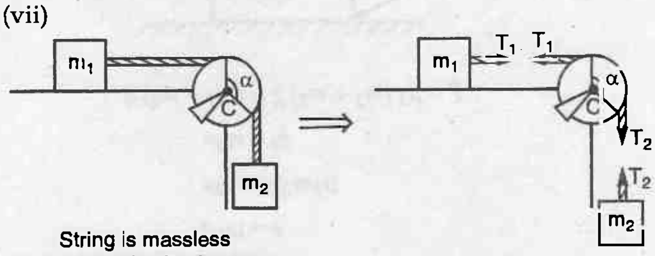


(vi)



String is massless and there is friction between string and pulley

(vii)



String is massless and there is friction between pulley and string

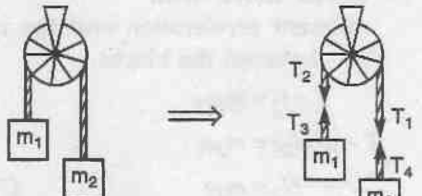
If m_2 tends to move downwards, then

$$T_2 > T_1 \quad \text{and} \quad T_2 = T_1 e^{\mu\alpha}$$

where μ = coefficient of friction

α = angle subtended by string at the centre of pulley

(viii)



String is massless and there is friction between pulley and string

Discussions :

(i) Momentum $= \vec{p} = m\vec{v}$

(ii) Change in momentum is known as Impulse $= \vec{p}_f - \vec{p}_i = m(\vec{v} - \vec{u}) = \vec{F}\,\Delta t$

(iii) If mass and velocity both are variable;

$$\vec{F} = \frac{d\vec{p}}{dt} = \vec{v}\frac{dm}{dt} + m\frac{d\vec{v}}{dt}$$

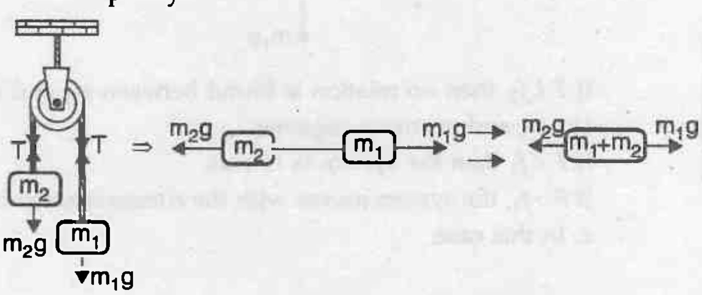
(iv) If mass of body remains constant

$$\vec{F} = m\vec{a}$$

where m = mass of body, $\vec{a}$ = acceleration of body

(v) Motion of connected bodies.

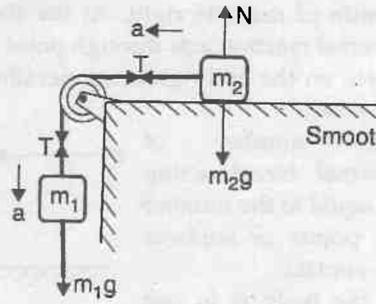
(a) Unequal masses ($m_1 > m_2$) suspended from a pulley:



$$\text{Acceleration} = a = \frac{(m_1 - m_2)\,g}{(m_1 + m_2)}$$

$$\text{Tension} = T = \left(\frac{2m_1 m_2}{m_1 + m_2}\right) g$$

(b) Bodies accelerated on a horizontal surface by a falling body:



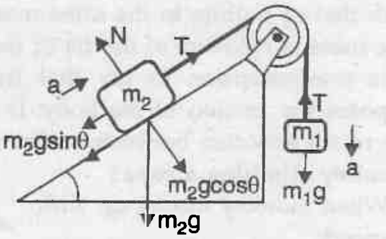
$$T = m_2 a \qquad \text{...(i)}$$

$$m_1 g - T = m_1 a \qquad \text{...(ii)}$$

$$\text{Acceleration} = a = \left(\frac{m_1}{m_1 + m_2}\right) g$$

$$\text{Tension} = T = \left(\frac{m_1 m_2}{m_1 + m_2}\right) g$$

(c) Motion on a smooth inclined plane:



$$m_1 g - T = m_1 a \qquad \text{...(i)}$$

$$T - m_2 g \sin\theta = m_2 a \qquad \text{...(ii)}$$

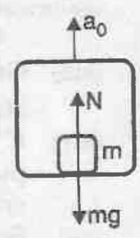
$$\therefore \quad a = \left(\frac{m_1 - m_2 \sin\theta}{m_1 + m_2}\right) g$$

and

$$T = \frac{m_1 m_2 (1 + \sin\theta)\, g}{(m_1 + m_2)}$$

(vi) Apparent weight of a moving lift:

(a) The weight that we feel is the normal force and not the actual weight.

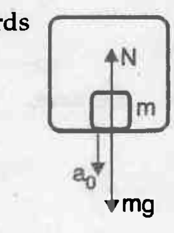


(b) If lift is moving upwards with constant acceleration a_0 :

$$N = mg + ma_0 = mg\left(1 + \frac{a_0}{g}\right)$$

Here apparent weight (*i.e.*, N) is greater than the actual weight (*i.e.*, mg).

(c) If lift is accelerated downwards with constant acceleration a_0 :



$$N = mg\left(1 - \frac{a_0}{g}\right)$$

Here apparent weight is lesser than the actual weight.
In this case, if $a_0 = g$ (Free fall)

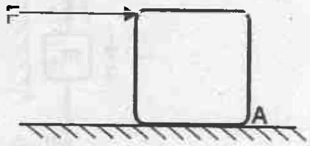
$$N = 0 \qquad \text{(weightlessness)}$$

Some Important Points :

(i) Normal reaction and weight of the body are not action-reaction pair.

(ii) When F increases, normal reaction shifts from centre of mass to right. At the time of toppling, normal reaction acts through point A. Also, the net force on the body gives acceleration of the centre of mass.

(iii) The number of normal forces acting is equal to the number of points or surfaces in contact.



(iv) If the body is in rest with respect to the surface, then $f_r < \mu_s N$.

(v) If the body is just in motion, then $f_r = \mu_s N$

(vi) If the body is in motion, then $f_r = \mu_k N$

(vii) If some bodies have same accelerations, then they are taken as a system. If they do not move together, bodies are not taken as a system.

(viii) During walking on ice, it is better to take short steps.

(ix) The force of friction during pushing is greater than that of pulling in the same manner.

(x) The mass is measure of inertia of the body.

(xi) It is misconception to say that friction always opposes the motion of the body. It only opposes the relative motion between surfaces.

(xii) **Monkey climbing a rope :**

Case I : When monkey moves up with constant speed:

In this case, $T = mg$

where m = mass of the monkey,

T = tension in the rope.

Case II : When monkey is accelerated upwards,

$$T - mg = ma$$

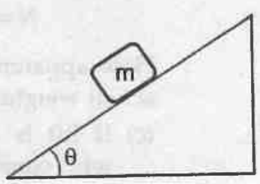
Case III : When monkey accelerated downwards,

$$mg - T = ma$$

(xiii) Gravitational force : Electromagnetic force : Strong force : Weak force = $1 : 10^{36} : 10^{38} : 10^{25}$.

(xiv) If a body is in rest on a rough surface and no pulling force is applied, then the force of friction on the body is zero.

(xv) For the equilibrium of a body on an inclined plane,



$$mg \sin\theta = \mu_s mg \cos\theta$$

$$\Rightarrow \quad \mu_s = \tan\theta$$

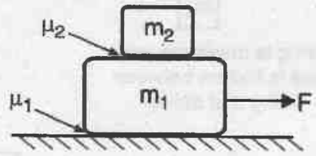
this case,

$$0 < \mu_s < 1$$

(xvi) When two surfaces roll on each other (as in case of ball bearings), the rolling friction comes into play.

(xvii) The force acting on m_2 is $f_2 = \mu_2 m_2 g$.

If the system moves with the common acceleration, then



$$F - \mu_1 (m_1 + m_2) g = (m_1 + m_2) a$$

$$f_2 = m_2 a$$

$$\mu_2 m_2 g = m_2 a$$

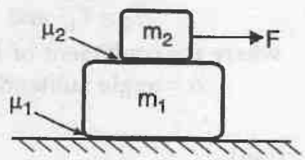
$$\therefore \quad a = \mu_2 g$$

(xviii) **If force is applied on upper block :**

f_2 = limiting friction between m_1 and $m_2 = \mu_2 m_2 g$.

f_1 = limiting friction between the surface and $m_1 = \mu_1 (m_1 + m_2) g$

If $F > f_1$, then both blocks move with different acceleration and the maximum friction acts between the blocks.



$$F - f_2 = m_2 a_2$$

$$F - \mu_2 m_2 g = m_2 a_2$$

$$N_2 = m_2 g$$

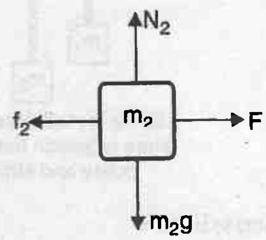
$$N_1 = N_2 + m_1 g$$

$$= (m_1 + m_2) g$$

$$\therefore \quad f_1 = \mu_1 N_1$$

$$= \mu_1 (m_1 + m_2) g$$

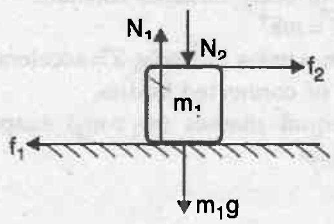
$$f_2 = \mu_2 m_2 g$$



If $f_2 < f_1$, then m_1 remains in rest.

If $f_2 > f_1$, then m_1 moves in the direction of f_2.

$$f_2 - f_1 = m_1 a_1$$



If $F < f_2$, then no relation is found between m_1 and m_2.
i.e., m_1 and m_2 move together.

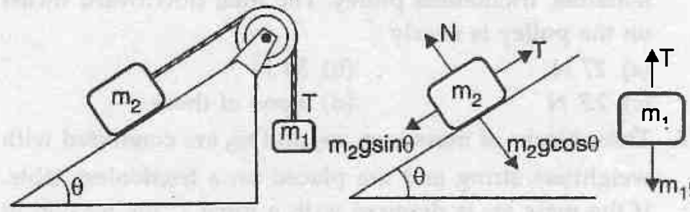
If $F < f_1$ then the system is in rest.

If $F > f_1$, the system moves with the common acceleration a. In this case,

$$F - f_1 = (m_1 + m_2)\, a$$

or $$F - \mu_1 (m_1 + m_2)\, g = (m_1 + m_2)\, a$$

(xix) **The ratio of masses on an inclined plane :** The coefficient of friction = μ.



(a) When m_1 starts moving downwards, then
$$\frac{m_1}{m_2} > \sin\theta + \mu\cos\theta$$

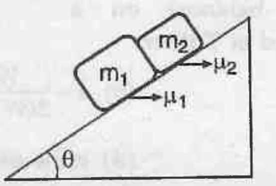
(b) When m_2 starts moving downwards,
$$\frac{m_1}{m_2} > \sin\theta - \mu\cos\theta$$

(c) When no motion takes place, $\dfrac{m_1}{m_2} = \sin\theta$.

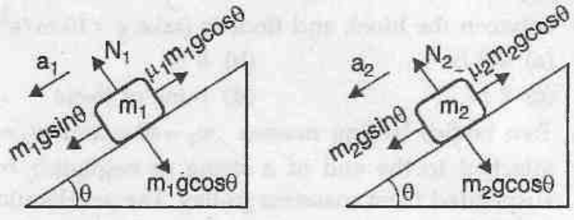
(xx) Frictional force does not depend upon the area of contact. The microscopic area of contact is about 10^{-4} times the actual area of contact.

$$\mu_s > \mu_k > \mu_r$$

(xxi) **Blocks in contact on an inclined plane:**



In this type of problem, find the accelerations of blocks without contact.



(a) If $a_1 > a_2$, then both blocks move separately with respective acceleration a_1 and a_2.

(b) If $a_1 < a_2$, then both blocks move together with a common acceleration a.

In this case, both blocks are treated as a system of mass $(m_1 + m_2)$

$$(m_1 + m_2)\, g\sin\theta - \mu_1 m_1 g\cos\theta - \mu_2 m_2 g\cos\theta = (m_1 + m_2)\, a$$

(xxii) To solve the problem involving the motion of a particle, we can use

$$\vec{F} = m\,(a_x\,\vec{i} + a_y\,\vec{j} + a_z\,\vec{k})$$

using normal and tangential components, we had

$$\Sigma\, F_t = m\frac{dv}{dt}, \quad \Sigma\, F_n = \frac{mv^2}{\rho}$$

where ρ = the radius of curvature.

(xxiii) In many problems involving the plane motion of a particle, it is found convenient to use radial and transverse components. In this method,

$$\Sigma\, F_r = m\left[\frac{d^2r}{dt^2} - \left(\frac{d\theta}{dt}\right)^2 r\right]$$

Objective Questions

Level-1

1. A ship of mass 3×10^7 kg initially at rest is pulled by a force of 5×10^4 N through a distance of 3 m. Assume that the resistance due to water is negligible, the speed of the ship is :
(a) 1.5 m/s (b) 60 m/s
(c) 0.1 m/s (d) 5 m/s

2. A young man of mass 60 kg stands on the floor of a lift which is accelerating downwards at 1 m/s^2 then the reaction of the floor of the lift on the man is : (Take $g = 9.8$ m/s^2)
(a) 528 N (b) 540 N
(c) 546 N (d) none of these

3. A block of mass M is kept on a smooth inclined plane of inclination θ. The force exerted by the plane on the block has a magnitude :
(a) $\dfrac{mg}{\cos\theta}$ (b) mg
(c) $mg\tan\theta$ (d) $mg\cos\theta$

4. A block of mass M is suspended by a string A from the ceiling and another string B is connected to the bottom of the block. If B is pulled on steadily :
(a) A breaks earlier than B
(b) B breaks earlier than A
(c) both break simultaneously
(d) not possible to say which one will break earlier

5. A machine gun fires 10 bullets per second, each of mass 10 g, the speed of each bullet is 20 cm/s, then force of recoil is :
(a) 200 dyne (b) 2000 dyne
(c) 20 dyne (d) none of these

6. A block of mass 2 kg is placed on the floor. The coefficient of static friction is 0.4. If a force of 2.8 N is applied on the block parallel to floor, the force of friction between the block and floor is (take $g = 10\ m/s^2$) :
(a) 2.8 N (b) 8 N
(c) 2 N (d) none of these

7. Two bodies having masses $m_1 = 40$ g and $m_2 = 60$ g are attached to the end of a string of negligible mass and suspended from massless pulley. The acceleration of the bodies is :
(a) $1\ m/s^2$ (b) $2\ m/s^2$
(c) $0.4\ m/s^2$ (d) $4\ m/s^2$

8. The ratio of the weight of a man in a stationary lift and when it moving downwards with uniform acceleration a is 3 : 2 then the value of a is :
(a) $\frac{3}{2}g$ (b) $\frac{g}{3}$
(c) g (d) $\frac{2}{3}g$

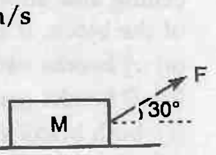
9. In a rocket fuel burns at rate 1 kg/s and ejected with velocity 48 km/s, then the force exerted by the exhaust gases on the rocket is :
(a) 48000 N (b) 48 N
(c) 480 N (d) none of these

10. An open knife edge of mass 200 g is dropped from height 5 m on a cardboard. If the knife edge penetrates distance 2 m into the cardboard, the average resistance offered by the cardboard to the knife edge is :
(a) 7 N (b) 25 N
(c) 35 N (d) none of these

11. A block is released from top of a smooth inclined plane. It reaches the bottom of the plane in 6 sec. The time taken by the body to cover the first half of the inclined plane is :
(a) 3 sec (b) 4 sec
(c) $3\sqrt{2}$ sec (d) 5 sec

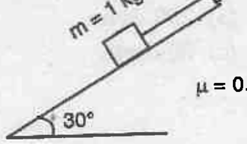
12. A disc of mass 100 g is kept floating horizontally in air by firing bullets, each of mass 5 g with the same velocity at the same rate of 10 bullets per second. The bullets rebound with the same speed in opposite direction, the velocity of each bullet at the time of impact is :
(a) 196 cm/s (b) 9.8 cm/s
(c) 98 cm/s (d) 980 cm/s

13. A block of mass 10 kg is kept on a horizontal surface. A force F is acted on the block as shown in figure. For what minimum value of F, the block will be lifted up ?



(a) 98 N (b) 49 N
(c) 200 N (d) None of these

14. Figure shows a block of mass m kept on inclined plane with inclination θ. The tension in the string is :



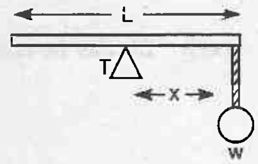
(a) 8 N (b) 10 N
(c) 0.8 N (d) zero

15. Two blocks of masses $m_1 = 4$ kg and $m_2 = 2$ kg are connected to the ends of a string which passes over a massless, frictionless pulley. The total downward thrust on the pulley is nearly :
(a) 27 N (b) 54 N
(c) 2.7 N (d) none of these

16. Three blocks of masses m_1, m_2 and m_3 are connected with weightless string and are placed on a frictionless table. If the mass m_3 is dragged with a force T, the tension in the string between m_2 and m_3 is :
(a) $\frac{Tm_3}{m_1 + m_2 + m_3}$ (b) $\frac{Tm_2}{m_1 + m_2 + m_3}$
(c) $\frac{(m_1 + m_2)T}{m_1 + m_2 + m_3}$ (d) none of these

17. A body weighs 8 g when placed in one pan and 18 g when placed on the other pan of a false balance. If the beam is horizontal when both the pan are empty, the true weight of the body is :
(a) 13 g (b) 12 g
(c) 15.5 g (d) 15 g

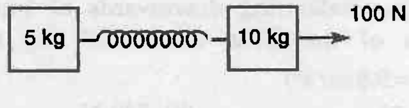
18. A rod of length L and weight W is kept horizontally. A small weight w is hung at one end. If the system balances on a fulcrum placed at T then :



(a) $x = \frac{L}{2}$ (b) $x = \frac{WL}{2(W + w)}$
(c) $x = \frac{wL}{W}$ (d) none of these

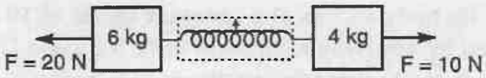
19. A rope of length L is pulled by a constant force F. What is the tension in the rope at a distance x from the end when the force is applied ?
(a) $\frac{F(L - x)}{L}$ (b) $\frac{FL}{L - x}$
(c) $\frac{FL}{x}$ (d) $\frac{Fx}{L - x}$

20. Two blocks of masses 5 kg and 10 kg are connected by a massless spring as shown in figure. A force of 100 N acts on the 10 kg mass. At the instant shown the 5 kg mass has acceleration $10\ m/s^2$. The acceleration of 20 kg mass is :



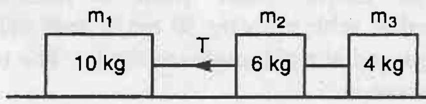
(a) $10\ m/s^2$ (b) $5\ m/s^2$
(c) $2\ m/s^2$ (d) none of these

21. Two blocks of masses 6 kg and 4 kg are connected with spring balance. Two forces 20 N and 10 N are applied on the blocks as shown in figure. The reading of spring balance is :



(a) 14 N (b) 20 N
(c) 6 N (d) 10 N

22. Three blocks of masses m_1, m_2 and m_3 are placed on a horizontal frictionless surface. A force of 40 N pulls the system then calculate the value of T, if $m_1 = 10$ kg, $m_2 = 6$ kg, $m_3 = 4$ kg :



(a) 40 N (b) 20 N
(c) 10 N (d) 5 N

23. A block A of mass 2 kg rests on another block B of mass 8 kg which rests on a horizontal floor. The coefficient of friction between A and B is 0.2 while that between B and floor is 0.5. When a horizontal force 25 N is applied on the block B, the force of friction between A and B is :
(a) zero (b) 3.9 N
(c) 5.0 N (d) 49 N

24. A heavy uniform chain lies on a horizontal top of table. If the coefficient of friction between the chain and the table is 0.25 then the maximum percentage of the length of the chain that can hang over one edge of the table is :
(a) 20% (b) 25%
(c) 35% (d) 15%

25. A block of mass 4 kg is kept on a rough horizontal surface. The coefficient of static friction is 0.8. If a force of 19 N is applied on the block parallel to the floor, then the force of friction between the block and floor is :
(a) 32 N (b) 18 N
(c) 19 N (d) 9.8 N

26. A chain lies on a rough horizontal table. It starts sliding when one-fourth of its length hangs over the edge of the table. The coefficient of static friction between the chain and the surface of the table is :
(a) $\frac{1}{2}$ (b) $\frac{1}{3}$
(c) $\frac{1}{4}$ (d) $\frac{1}{5}$

27. A block of mass 0.1 kg is held against a wall by applying a horizontal force of 5 N on the block. If the coefficient of friction between the block and the wall is 0.5, the magnitude of the frictional force acting on the block is :
(a) 2.5 N (b) 0.98 N
(c) 4.9 N (d) 0.49 N

28. A block is moving up an inclined plane of inclination 60° with velocity of 20 m/s and stops after 2.00 sec. If $g = 10\ \text{m/s}^2$ then the approximate value of coefficient of friction is :
(a) 3 (b) 3.3
(c) 0.27 (d) 0.33

Level-2

Newton's Laws of Motion

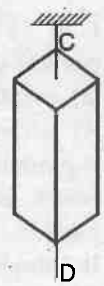
1. Two bodies have same mass and speed, then :
(a) their momentums are same
(b) the ratio of momentums is not determined
(c) the ratio of their magnitudes of momentum is one
(d) both (b) and (c) are correct.

2. Mark correct option or options :
(a) The body of greater mass needs more forces to move due to more inertia
(b) Force versus time graph gives impulse
(c) Microscopic area of contact is about 10^{-4} times actual area of the contact
(d) All of the above

3. In the superhit film 'Raja Hindustani', Amir Khan greets his beloved by shaking hand. What kind of force do they exert ?
(a) Nuclear (b) Gravitational
(c) Weak (d) Electromagnetic

4. Impulse indicates :
(a) the momentum generated in the direction of force
(b) the combined effect of mass and velocity
(c) the main characteristics of particle nature
(d) both (b) and (c) are correct

5. A heavy block of mass m is supported by a cord C attached to the ceiling, and another cord D is attached to the bottom of the block. If a sudden jerk is given to D, then :

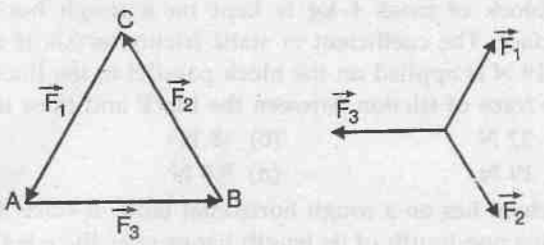


(a) cord C breaks
(b) cord D breaks
(c) cord C and D both break
(d) none of the cords breaks

6. At time t second, a particle of mass 3 kg has position vector $\vec{r}$ metre where $\vec{r} = 3t\hat{i} - 4\cos t\,\hat{j}$. The impulse of the force during the time interval $0 < t < \frac{\pi}{2}$ is :
(a) $12\hat{j}$ N-s (b) $9\hat{j}$ N-s
(c) $4\hat{j}$ N-s (d) $14\hat{j}$ N-s

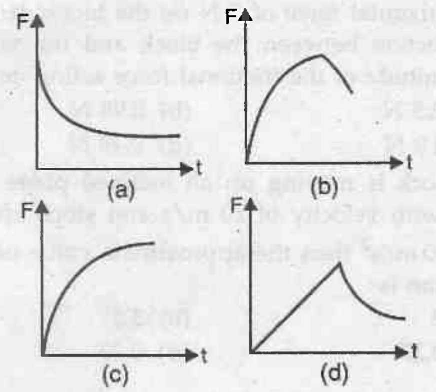
7. A parrot is sitting on the floor of a closed glass cage which is in a boy's hand. If the parrot starts flying with a constant speed, the boy will feel the weight of cage as
(a) unchanged
(b) reduced
(c) increased
(d) nothing can be said

8. A particle is acted by three forces as shown in the figure. Then :



(a) the resultant force on the particle may or may not be zero
(b) the particle must be in rest
(c) the direction of acceleration is in indeterminate form
(d) the particle moves with variable velocity

9. If $F = F_0(1 - e^{-t/\lambda})$, the F-t graph is :



10. A particle of mass m is moving under the variable force $\vec{F}$. If $|\vec{F}|$ is constant, then the possible path of the particle can never be :
(a) rectilinear (b) circular
(c) parabolic (d) elliptical

11. A particle is acted upon by a force of constant magnitude which is always perpendicular to the velocity of the particle. The motion of the particle takes place in a plane. It follows that :
(a) its velocity is constant
(b) its kinetic energy is constant
(c) it moves in a circular path
(d) both (b) and (c) are correct

12. A particle of mass m moves on the x-axis as follows. It starts from rest at $t = 0$ from the point $x = 0$, and comes to rest at $t = 1$ at the point $x = 1$. No other information is available about its motion at intermediate time $(0 < t < 1)$. If α denotes the instantaneous acceleration of the particle, then :
(a) α cannot remain positive for all t in the interval $0 < t < 1$
(b) $|\alpha|$ cannot exceed 2 at any point in its path
(c) $|\alpha|$ be ≥ 4 at point or some points in its path
(d) both (a) and (c) are correct

13. A 0.1 kg body moves at a constant speed of 10 m/s. It is pushed by applying a constant force for 2 sec. Due to this force, it starts moving exactly in the opposite direction with a speed of 4 m/s. Then :
(a) the deceleration of the body is 7 m/s^2
(b) the magnitude of change in momentum is 1.4 kg-m/sec
(c) impulse of the force is 1.4 Ns
(d) the force which acts on the ball is 0.7 N
(e) all of the above

14. Water jet issues water from a nozzle of 2 cm^2 cross-section with velocity 30 cm/s and strikes a plane surface placed at right angles to the jet. The force exerted on the plane is :
(a) 200 dyne (b) 400 dyne
(c) 1800 dyne (d) none of these

15. Mark correct option or options :
(a) The normal reaction and gravitational force on a body placed on a surface are action-reaction pair
(b) The normal reaction on a body placed on a rough surface is always equal to weight of the body
(c) $v^2 = u^2 + 2gh$ is always applicable to a falling body on the earth in the absence of air
(d) All are wrong

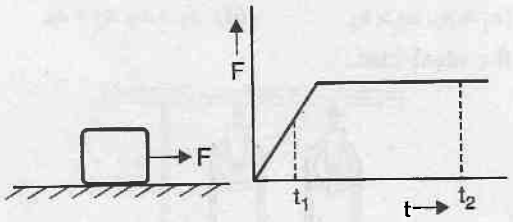
16. The action and reaction forces referred to Newton's third law of motion :
(a) must act upon the same body
(b) must act upon different bodies
(c) need not to be equal in magnitude but must have the same line of action
(d) must be equal in magnitude but need not have the same line of action

17. Choose the correct option or options :
(a) Tension force always pulls a body
(b) Tension can never push a body or rope
(c) Tension across massless or frictionless pulley remains constant
(d) Rope becomes slack when tension force becomes zero
(e) All of the above

18. A man is pulling a rope attached to a block on a smooth horizontal table. The tension in the rope will be the same at all points :
(a) if and only if the rope is not accelerated
(b) if and only if the rope is massless
(c) if either the rope is not accelerated or is massless
(d) always

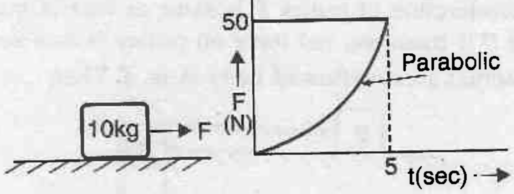
19. A particle of mass m moves on the x-axis under the influence of a force of attraction towards the origin O given by $F = -\frac{k}{x^2}\vec{i}$. If the particle starts from rest at $x = a$. The speed it will attain to reach at distance x from the origin O will be :
(a) $\sqrt{\frac{2k}{m}}\left[\frac{x-a}{ax}\right]^{1/2}$ (b) $\sqrt{\frac{2k}{m}}\left[\frac{a+k}{ax}\right]^{1/2}$
(c) $\sqrt{\frac{k}{m}}\left[\frac{ax}{x-a}\right]$ (d) $\sqrt{\frac{m}{2k}}\left[\frac{a-x}{ax}\right]^{1/2}$

20. A particle is on a smooth horizontal plane. A force F is applied whose F-t graph is given. Then :



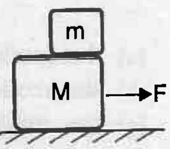
(a) at t_1 acceleration is constant
(b) initially body must be in rest
(c) at t_2, acceleration is constant
(d) initially acceleration is zero
(e) both (c) and (d) are correct

21. A force F is applied to the initially stationary cart. The variation of force with time is shown in the figure. The speed of cart at $t = 5$ sec is :



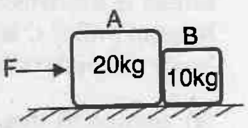
(a) 10 m/s (b) 8.33 m/s
(c) 2 m/s (d) zero

22. The mass m is placed on a body of mass M. There is no friction. The force F is applied on M and it moves with acceleration a. Then the force on the top body is :



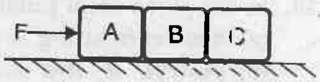
(a) F (b) ma
(c) $F - ma$ (d) none of these

23. Two bodies A and B of masses 20 kg and 10 kg respectively are placed in contact on a smooth horizontal surface (as shown in the figure) A force of 10 N is applied on either A or B in comfortable manner.



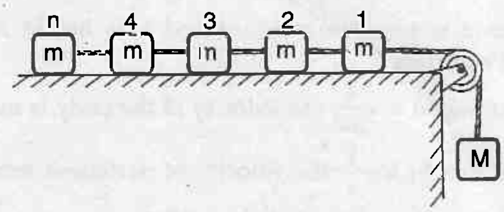
Then the force F must be applied on :
(a) A (b) B
(c) either A or B (d) all

24. Three identical blocks each of mass M are along a frictionless table and a force F is acting as shown. Which of the following statements is false ?



(a) The net vertical force on block A is zero
(b) The net force on block A is $F/3$
(c) The acceleration of block C is $F/3M$
(d) The force of interaction between A and B is $2F/3$

25. In the given arrangement, n number of equal masses are connected by strings of negligible masses. The tension in the string connected to n^{th} mass is :

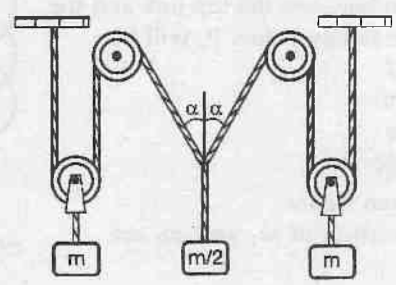


(a) $\dfrac{mMg}{nm + M}$ (b) $\dfrac{mMg}{nmM}$
(c) mg (d) mng

26. A 40 N block is supported by two ropes. One rope is horizontal and the other makes an angle of 30° with the ceiling. The tension in the rope attached to the ceiling is approximately :
(a) 80 N (b) 40 N
(c) 34.6 N (d) 46.2 N

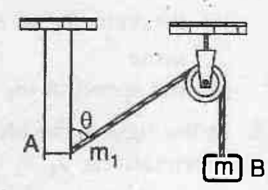
27. A weight W is suspended from the midpoint of a rope, whose ends are at the same level. In order to make the rope perfectly horizontal, the force applied to each of its ends must be :
(a) less than W (b) equal to W
(c) equal to $2W$ (d) infinitely large

28. In the given figure, pulleys and strings are massless. For equilibrium of the system, the value of α is :



(a) 60° (b) 30°
(c) 90° (d) 120°

29. A ring of mass 5 kg sliding on a frictionless vertical rod is connected by a block B of mass 10 kg by the help of a massless string. Then at the equilibrium of the system the value of θ is :



(a) 30° (b) 60°
(c) 90° (d) 0°

30. A body of mass 10 kg is to be raised by a massless string from rest to rest, through a height 9.8 m. The greatest tension which the string can safely bear is 20 kg wt. The least time of ascent is :
(a) 2 sec (b) 3 sec
(c) 4 sec (d) none of these

* 31. A body of mass m is hauled from the earth's surface by applying a force

$$F = 2(ah - 1)\, m\vec{g}$$

where a is positive constant and h is height from the earth's surface.

(a) at height $h = \frac{1}{2a}$, the velocity of the body is maximum

(b) at height $h = \frac{1}{a}$, the velocity of particle is zero

(c) the motion of particle is oscillatory

(d) all the above are correct

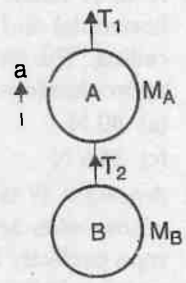
* 32. Which of the following expressions correctly represents T_1 and T_2 if the system is given an upward acceleration by a pulling up mass A?

(a) $T_1 = M_A(a - g) + M_B(a - g)$,
$T_2 = M_B(a - g)$

(b) $T_1 = M_A(g - a) + M_B(g - a)$,
$T_2 = M_B(g - a)$

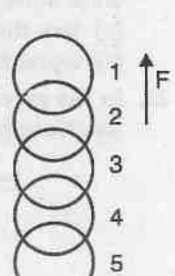
(c) $T_1 = M_A(g + a) + M_B(g + a)$,
$T_2 = M_B(g + a)$

(d) $T_1 = M_A(g + a)$, $T_2 = M_B(g + a)$



* 33. A chain consisting of 5 links each of mass 0.1 kg is lifted vertically with a constant acceleration of 2.5 m/s^2 as shown in the figure. The force of interaction between the top link and the link immediately below it, will be:

(a) 6.15 N
(b) 4.92 N
(c) 3.69 N
(d) 2046 N



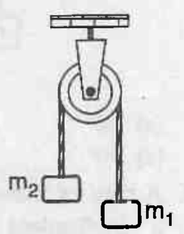
34. In the given figure:

(a) acceleration of m_1 and m_2 are same

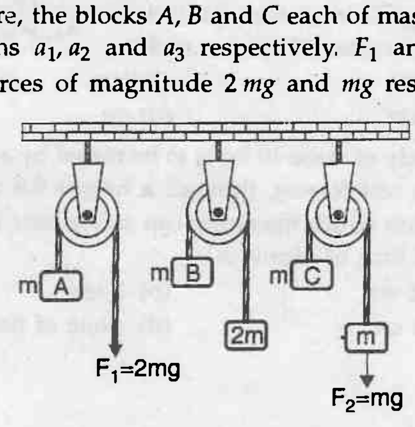
(b) the magnitude of relative acceleration of m_1 with respect to m_2 is twice the magnitude of acceleration of m_1

(c) the velocity of m_1 and m_2 are same

(d) the speed of m_1 and m_2 are not same



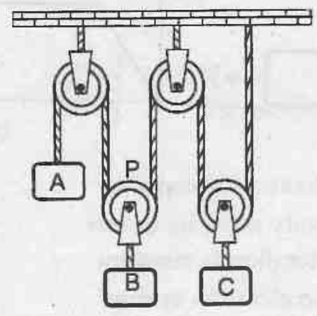
* 35. In the figure, the blocks A, B and C each of mass m have accelerations a_1, a_2 and a_3 respectively. F_1 and F_2 are external forces of magnitude $2\,mg$ and mg respectively.



Then:

(a) $a_1 = a_2 = a_3$
(b) $a_1 > a_3 > a_2$
(c) $a_1 = a_2$, $a_2 > a_3$
(d) $a_1 > a_2$, $a_2 = a_3$

* 36. In the ideal case:



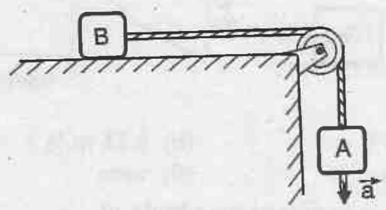
(a) magnitude of acceleration of A is sum of magnitude of acceleration of B and C

(b) magnitude of acceleration of A is arithmetic mean of magnitude of acceleration of B and C

(c) acceleration of pulley P is same as that of mass B

(d) if P is massless, net force on pulley is non-zero

37. The actual acceleration of body A is $\vec{a}$. Then:



(a) the acceleration of B is $\vec{a}$

(b) the acceleration of B is $2\vec{a}$

(c) the magnitude of relative acceleration of B with respect to A is $\sqrt{2}\,\vec{a}$

(d) the momentum of A may be equal to that of B

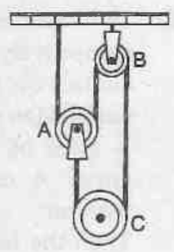
* 38. In the arrangement shown in figure, pulleys A and B are massless and the thread is inextensible. Mass of pulley C is equal to m. If friction in all the pulleys is negligible, then

(a) tension in thread is equal to $\frac{1}{2}mg$

(b) acceleration of pulley C is equal to $g/2$ (downward)

(c) acceleration of pulley A is equal to g (upward)

(d) acceleration of pulley A is equal to $2g$ (upward)



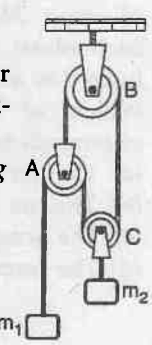
39. In the given ideal pulley system:

(a) tension in string is zero

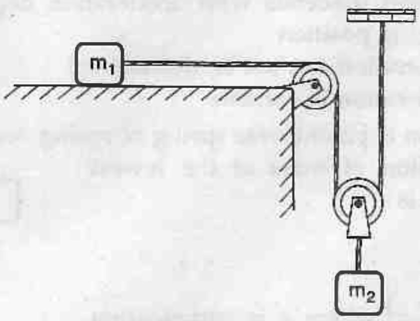
(b) pulleys B and C rotate counter clockwise and the pulley A clockwise

(c) A and B are same and is equal to g

(d) all the above



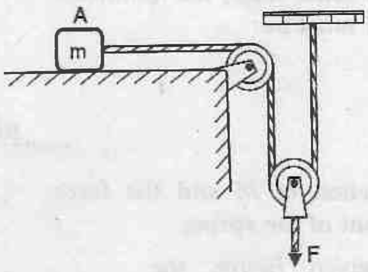
40. If the surface is smooth, the acceleration of the block m_2 will be :



(a) $\frac{m_2 g}{4m_1 + m_2}$ (b) $\frac{2m_2 g}{4m_1 + m_2}$

(c) $\frac{2m_1 g}{m_1 + 4m_2}$ (d) $\frac{2m_1 g}{m_1 + m_2}$

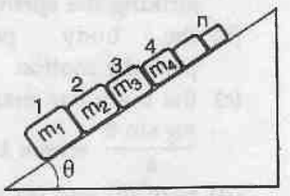
41. Pulleys and string are massless. The horizontal surface is smooth. The acceleration of the block A is :



(a) $\frac{F}{m}$ (b) $\frac{F}{2m}$

(c) $\frac{F}{4m}$ (d) 0

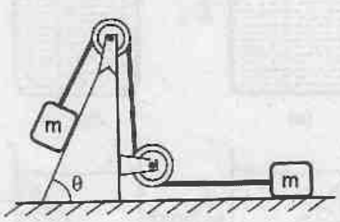
42. n-blocks of different masses are placed on the frictionless inclined plane in contact. They are released at the same time. The force of interaction between $(n-1)^{th}$ and n^{th} blocks is :



(a) $(m_{n-1} - m_n) g \sin\theta$ (b) zero

(c) $m_n g \cos\theta$ (d) none of these

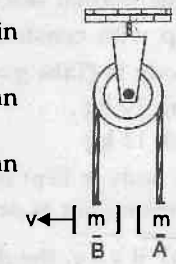
43. For the system shown in the figure, the pulleys are light and frictionless. The tension in the string will be :



(a) $\frac{2}{3} mg \sin\theta$ (b) $\frac{3}{2} mg \sin\theta$

(c) $\frac{1}{2} mg \sin\theta$ (d) $2mg \sin\theta$

44. In the given figure :



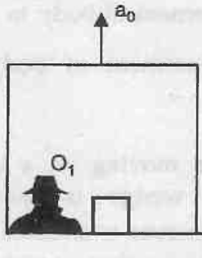
(a) both masses always remain in same level

(b) after some time, A is lower than B

(c) after some time, B is lower than A

(d) no sufficient information

45. Observer O_1 is in a lift going upwards and O_2 is on the ground. Both apply Newton's law, and measure normal reaction on the body :



(a) the both measure the same value

(b) the both measure zero

(c) the both measure different value

(d) no sufficient data

46. A particle is found to be at rest when seen from frame S_1 and moving with a constant velocity when seen from another frame S_2. Mark the possible points from the following :

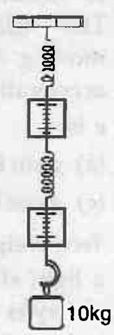
(a) both the frames are inertial

(b) both the frames are non-inertial

(c) S_1 is non-inertial and S_2 is inertial

(d) both (a) and (b) are correct

47. A block of mass 10 kg is suspended through two light springs which are balanced as shown in the figure. Then :



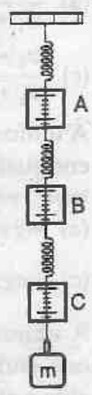
(a) both the scales will read 10 kg

(b) both the scales will read 5 kg

(c) the upper scale will read 10 kg and the lower zero

(d) the readings may be of any value but their sum will be 10 kg

48. A block of mass m is suspended through three light springs balanced as shown in the figure :



(a) the reading of A is greater than B

(b) the reading of B is greater than C

(c) the readings of A, B and C are the same

(d) the readings of A and C are not the same

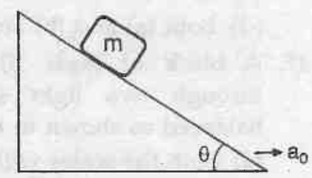
49. The normal reaction on a body placed in a lift moving up with constant acceleration $2\ m/s^2$ is 120 N. Mass of body is (Take $g = 10\ m/s^2$)
(a) 10 kg (b) 15 kg
(c) 12 kg (d) 5 kg

50. A body is kept on the floor of a lift at rest. The lift starts descending at acceleration a:
(a) if $a > g$, the displacement of body in time t is $\frac{1}{2}gt^2$
(b) if $a < g$, the displacement of body in time t is $\frac{1}{2}gt^2$
(c) if $a > g$, the displacement of body in time t is $\frac{1}{2}at^2$
(d) if $a < g$, the displacement of body in time t is $\frac{1}{2}(a+g)t^2$

51. A block of mass m is moving on a wedge with the acceleration a_0. The wedge is moving with the acceleration a_1. The observer is situated on wedge. The magnitude of pseudo force on the block is ?
(a) ma_0 (b) ma_1
(c) $m\sqrt{a_0^2 + a_1^2}$ (d) $m\left(\frac{a_1 + a_0}{2}\right)$

52. A simple pendulum hangs from the roof of a moving train. The string is inclined towards the rear of the train. What is the nature of motion of the train ?
(a) Accelerated (b) Uniform
(c) Retarded (d) None of above

53. A point mass m is moving along inclined plane with acceleration a with respect to smooth triangular block. The triangular block is moving horizontally with acceleration a_0. The value of a is:



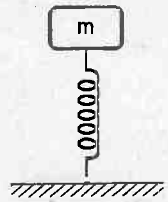
(a) $g \sin\theta + a_0 \cos\theta$ (b) $g \sin\theta - a_0 \cos\theta$
(c) $g \cos\theta - a_0 \sin\theta$ (d) $g \cos\theta - a_0 \tan\theta$

54. Two weights w_1 and w_2 are suspended from the ends of a light string passing over a smooth fixed pulley. If the pulley is pulled up with acceleration g, the tension in the string will be:
(a) $\frac{4w_1w_2}{w_1 + w_2}$ (b) $\frac{2w_1w_2}{w_1 + w_2}$
(c) $\frac{w_1 - w_2}{w_1 + w_2}$ (d) $\frac{w_1w_2}{2(w_1 - w_2)}$

55. A uniform fine chain of length l is suspended with lower end just touching a horizontal table. The pressure on the table, when a length x has reached the table is:
(a) mgx (b) $2mgx$
(c) $3mgx$ (d) $\frac{mgx}{2}$

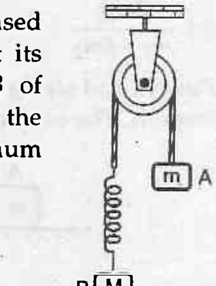
56. A uniform chain is coiled up on a horizontal plane and one end passes over a small light pulley at a height 'a' above the plane. Initially, a length 'b' hangs freely on the other side. If $b = 2a$:
(a) the end descends with a constant acceleration $g/3$.
(b) the end descends with acceleration depends upon hanging position
(c) acceleration can not be determined
(d) acceleration is variable

57. A mass m is placed over spring of spring constant k, the acceleration of mass at the lowest position is:



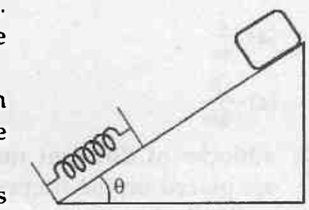
(a) g
(b) zero
(c) $\left(\frac{kx}{m} - g\right)$ where x is compression in spring
(d) none of the above

58. In the figure, the ball A is released from rest when the spring is at its natural length. For the block B of mass M to leave contact with the ground at some stage, the minimum mass of A must be:



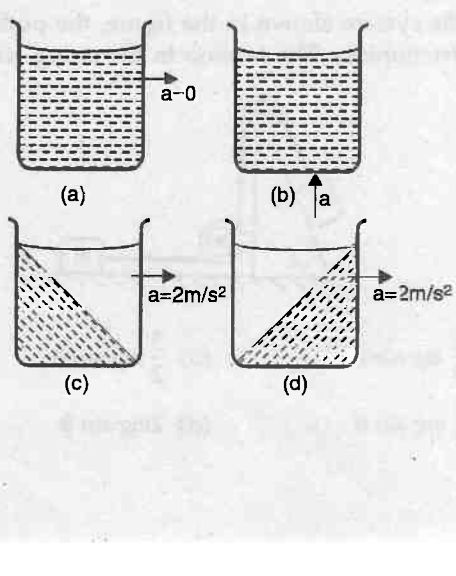
(a) $2M$
(b) M
(c) $\frac{M}{2}$
(d) a function of M and the force constant of the spring.

59. In the given figure, the inclined surface is smooth. The body releases from the top. Then:



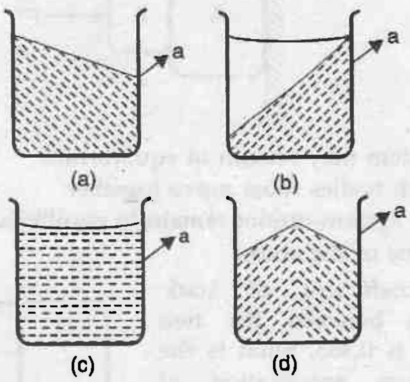
(a) the body has maximum velocity just before striking the spring
(b) the body performs periodic motion
(c) the body has maximum velocity at the compression $\frac{mg \sin\theta}{k}$ where k is spring constant
(d) both (b) and (c) are correct

60. Which of the following does not represent actual surface of water ?



(a) (b) (c) (d)

61. A vessel containing water is moving with a constant acceleration as shown in figure. Which of the following diagrams represents surface liquid ?



Friction

62. Mark correct option or options :
(a) Friction always opposes the motion of a body
(b) Friction only opposes the relative motion between surfaces.
(c) Kinetic friction depends on the speed of body when the speed of body is less than 10 m/s
(d) The coefficient of friction is always less than or equal to one

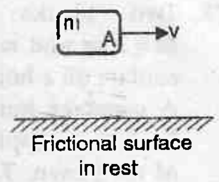
63. A bicycle is in motion. When it is not pedaled, the force of friction exerted by the ground on the two wheels is such that it acts :
(a) in the backward direction on the front wheel and in the forward direction on the rear wheel
(b) in the forward direction on the front wheel and in the backward direction on rear wheel
(c) in the backward direction on both the front and the rear wheels
(d) in the forward direction on both the front and the rear wheels

64. If a body of mass m is moving on a rough horizontal surface of coefficient of kinetic friction μ, the net electromagnetic force exerted by surface on the body is :
(a) $mg\sqrt{1+\mu^2}$ (b) μmg
(c) mg (d) $mg\sqrt{1-\mu^2}$

65. A block is placed on a rough floor and a horizontal force F is applied on it. The force of friction by the floor on the block is measured for different values of F and a graph is plotted between them, then :
(a) the graph is a straight line of slope 45°
(b) the graph is a straight line parallel to the F-axis
(c) the graph is a straight line of slope 45° for small F and a straight line parallel to the F-axis for large F
(d) there is a small knik on the graph

66. When body is in rest in the condition of a horizontal applied force. Then the slope of force-friction graph is :
(a) 1 (b) μ
(c) 0 (d) -1

67. Look at the situation, when the body is in air and is moving with pure translation. This situation is shown in the figure. What happens when the body hits the surface ?



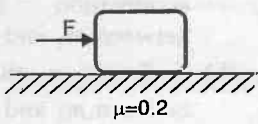
(a) Sliding friction will act in the backward direction
(b) The velocity of the point of contact gradually decreases
(c) The sliding friction acts in such a way so as to try to make the point of contact velocity of the body same as that of the surface
(d) Both (a) and (b) are correct

68. Let F, F_N and f denote the magnitudes of the contact force, normal force and the frictional force exerted by one surface on the other kept in contact. If one of these is zero, then :
(a) $F > F_N$ (b) $F > f$
(c) $F_N - f < F_N + f$ (d) all the above

69. A car starts from rest to cover a distance s. The coefficient of friction between the road and the tyres is μ. The minimum time in which the car can cover the distance is proportional to :
(a) μ (b) $\sqrt{\mu}$
(c) $1/\mu$ (d) $1/\sqrt{\mu}$

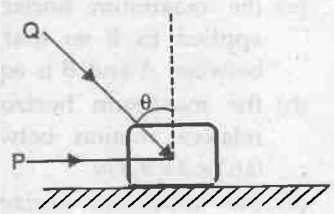
70. A block 'A' of mass 2 kg rests on a rough horizontal plank, the coefficient of friction between the plank and the block = 0.2. If the plank is pulled horizontally with a constant acceleration of 3.96 m/s^2, the distance moved in metre by the block on the plank in 5 second after starting from rest, is :
(a) 25 (b) 25×0.98
(c) 25×1.98 (d) 0

71. A body of mass 2 kg is placed on rough horizontal plane. The coefficient of friction between body and plane is 0.2. Then :



(a) body will move in forward direction if $F = 5$ N
(b) body will be move in backward direction with acceleration 0.5 m/s^2 if force $F = 3$ N
(c) If $F = 3$ N then body will be in rest condition
(d) both (a) and (c) are correct

72. A block of mass m lying on a rough horizontal plane is acted upon by a horizontal force P and another force Q inclined at an angle θ to the vertical. The block will remain in equilibrium if the coefficient of friction between it and the surface is :

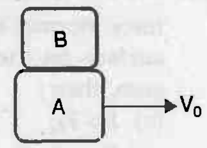


(a) $\dfrac{P + Q\sin\theta}{mg + Q\cos\theta}$ (b) $\dfrac{P\cos\theta + Q}{mg - Q\sin\theta}$
(c) $\dfrac{P + Q\cos\theta}{mg + Q\sin\theta}$ (d) $\dfrac{P\sin\theta - Q}{mg - Q\cos\theta}$

73. Two blocks of masses $M = 3$ kg and $m = 2$ kg are in contact on a horizontal table. A constant horizontal force $F = 5$ N is applied to block M as shown. There is a constant frictional force of 2 N between the table and the block m but no frictional force between the table and the first block M, then acceleration of the two blocks is :

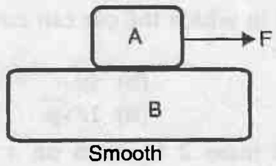
(a) 0.4 ms^{-2} (b) 0.6 ms^{-2}
(c) 0.8 ms^{-2} (d) 1 ms^{-2}

74. The coefficient of static friction between the bodies A and B is 0.30. Determine minimum stopping distance that the body A can have a speed of 70 km/h and constant deceleration, if the body B is not to slip forward, is :



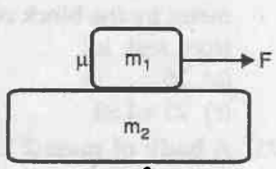
(a) 3 m (b) 30.3 m
(c) 70 km (d) 63 m

75. In the given figure force of friction on body B is :



(a) towards left (b) towards right
(c) either left or right (d) no sufficient data

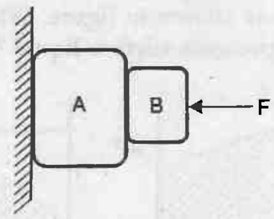
76. In the given figure, the coefficient of friction between m_1 and m_2 is μ and m_2 and horizontal surface is zero :



(a) if $F > \mu m_1 g$, then relative acceleration is found between m_1 and m_2
(b) if $F < \mu m_1 g$, then relative acceleration is found between m_1 and m_2
(c) if $F > \mu m_1 g$, then both bodies move together
(d) a and (b) are correct

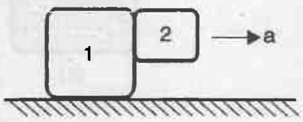
77. Two blocks A and B of masses 4 kg and 3 kg respectively rest on a smooth horizontal surface. The coefficient of friction between A and B is 0.36. Then :
(a) the maximum horizontal force F which can be applied to B so that there is no relative motion between A and B is equal to $0.36 \times 3 \times 9.8$ N
(b) the maximum horizontal force F on B with no relative motion between A and B is equal to $0.63 \times 3 \times 9.8$ N
(c) the maximum horizontal force F which can be applied to A (no force on B) with no relative motion between A and B is $0.84 \times 3 \times 9.8$ N
(d) both (b) and (c) are correct

78. Consider the situa- tion shown in the figure. The wall is smooth but the surfaces of A and B in contact are rough. Then :



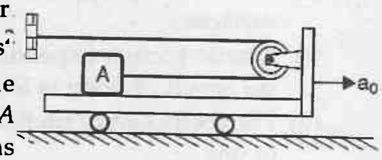
(a) system may remain in equilibrium
(b) both bodies must move together
(c) the system cannot remain in equilibrium
(d) none of the above

79. The coefficient of static friction between the two blocks is 0.363, what is the minimum acceleration of block 1 so that block 2 does not fall ?



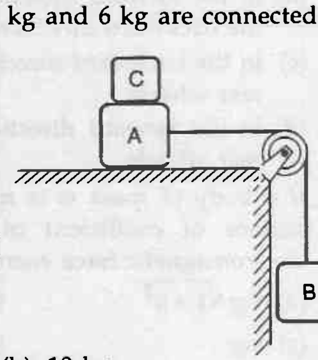
(a) 6 ms^{-2} (b) 12 ms^{-2}
(c) 18 ms^{-2} (d) 27 ms^{-2}

* 80. A flat car is given an acceleration $a_0 = 2 \text{ m/s}^2$ starting from rest. A cable is connected to a crate A of weight 50 kg as shown. Neglect friction between the floor and the car wheels and also the mass of the pulley. Calculate corresponding tension in the cable if $\mu = 0.30$ between the crate and the floor of the car :



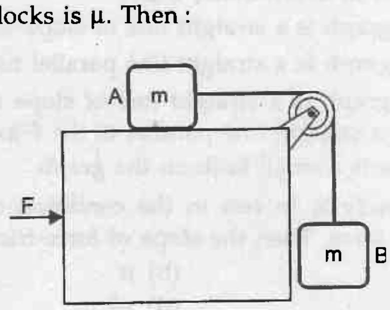
(a) 350 (b) 250
(c) 300 (d) 400

81. Two masses A and B of 5 kg and 6 kg are connected by a string passing over a frictionless pulley fixed at the corner of table as shown in the figure. The coefficient of friction between A and table is 0.3. The minimum mass of C that must be placed on A to prevent it from moving is equal to :



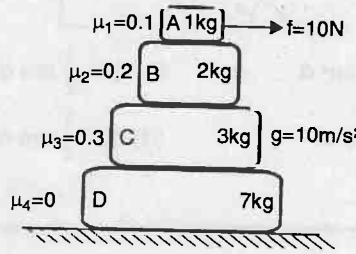
(a) 15 kg (b) 10 kg
(c) 5 kg (d) 3 kg

82. In the given figure, the horizontal surface below the bigger block is smooth. the co-efficient of friction between blocks is μ. Then :



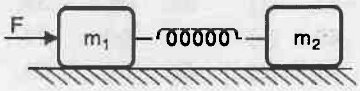
(a) if block B slips upward, F is maximum
(b) if block B slips upward, F is minimum
(c) if block B slips downward, F is maximum
(d) if block B slips downward, F is minimum
(e) both (a) and (d) are correct

83. In the given figure (Take $g = 10\ \text{m/s}^2$) :



(a) the acceleration of A and B are same to each other
(b) the acceleration of A is $9\ \text{m/s}^2$
(c) the acceleration of B, C and D are not same to each other
(d) all bodies move with common acceleration

84. Two bodies of masses m_1 and m_2 connected by an ideal massless spring of constant k. The coefficient of friction between the bodies and surface is μ. The minimum force required to shift the body m_2 is F. Then :



(a) the mass m_1 will first accelerate then deaccelerate
(b) the mass m_1 is first accelerated upto a maximum velocity v_0 and then declerates to come to rest
(c) the mass m_1 will accelerate continuously
(d) both (a) and (b) are correct

85. A body is in equilibrium on a rough inclined plane under its own weight. If the angle of inclination of the inclined plane is α and the angle of friction is λ, then :
(a) $\alpha > \lambda$ (b) $\alpha > \lambda/2$
(c) $\alpha = \lambda$ (d) $\alpha > \lambda$

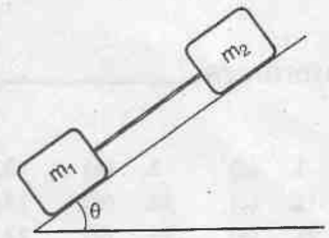
86. For the equilibrium of a body on an inclined plane of inclination 45°, the coefficient of static friction will be :
(a) greater than one (b) less than one
(c) zero (d) less than zero

87. Fine particles of a substance are to be stored in a heap on a horizontally circular plate of radius a. if the coefficient of static friction between the particles is k. The maximum possible height of cone is :
(a) ak (b) $\frac{a}{2}k$
(c) a/k (d) ak^2

88. A body is moving down a long inclined plane of slope 37°. The coefficient of friction between the body and plane varies as $\mu = 0.3\,x$, where x is distance travelled down the plane. The body will have maximum speed. ($\sin 37° = \frac{3}{5}$ and $g = 10\ \text{m/s}^2$)
(a) at $x = 1.16$ m (b) at $x = 2$ m
(c) at bottom of plane (d) at $x = 2.5$ m

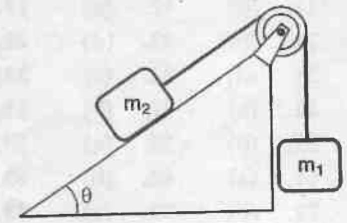
89. A given object takes n times as much time to slide down a 45° rough incline as it takes to slide down a prefectly smooth 45° incline. The coefficient of kinetic friction between the object and the incline is given by :
(a) $\mu = \frac{1}{(1-n^2)}$ (b) $\mu = 1 - \frac{1}{n^2}$
(c) $\mu = \sqrt{\left(\frac{1}{1-n^2}\right)}$ (d) $\mu = \sqrt{\left(1 - \frac{1}{n^2}\right)}$

90. Two blocks having masses m_1 and m_2 are connected by a thread and are placed on smooth inclined plane with thread loose as shown in figure. When blocks are released :



(a) thread will remain loose if $m_1 < m_2$
(b) thread will remain loose if $m_2 < m_1$
(c) thread will remain loose for all values of m_1 and m_2
(d) none of the above

91. The coefficient of friction between m_2 and inclined plane is μ (shown in the figure). If $\frac{m_1}{m_2} = \sin\theta$:

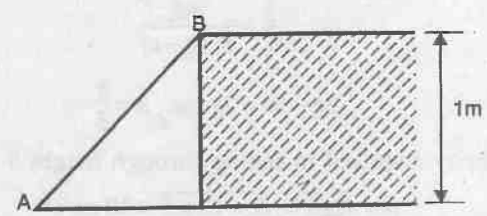


(a) no motion takes place
(b) m_1 moves downward
(c) m_1 moves upward
(d) no sufficient information

92. In the above question m_1 starts coming down if :
(a) $\frac{m_1}{m_2} > \sin\theta + \mu\cos\theta$ (b) $\frac{m_1}{m_2} < \sin\theta + \mu\cos\theta$
(c) $\frac{m_1}{m_2} = \sin\theta + \mu\cos\theta$ (d) $\frac{m_1}{m_2} > \sin\theta - \mu\cos\theta$

93. In the above question, when m_2 starts coming down ?
(a) $\frac{m_1}{m_2} < \sin\theta - \mu\cos\theta$ (b) $\frac{m_1}{m_2} > \sin\theta - \mu\cos\theta$
(c) $\frac{m_1}{m_2} = \sin\theta - \mu\cos\theta$ (d) no sufficient information

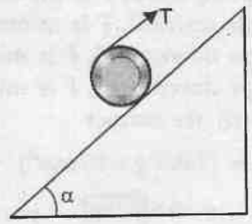
94. A plank is required as a ramp where by people may get up a one metre step as shown in the figure. What is the



least length of wood you would consider suitable for this purpose if the coefficient of friction between the person and the plank is $\frac{1}{4}$?

(a) 2 m (b) 3 m
(c) 4 m (d) 5 m

95. A heavy circular disc whose plane is vertical is kept at rest on rough inclined plane by a string parallel to the plane and touching the circle (shown in the figure). Disc starts to slip if :



(a) $\mu < \frac{1}{2} \tan \alpha$ (b) $\mu > \frac{1}{2} \tan \alpha$
(c) $\mu < \tan \alpha$ (d) $\mu > \frac{1}{4} \tan \alpha$

Answers

Level-1

1. (c)	2. (a)	3. (d)	4. (a)	5. (b)	6. (a)	7. (b)	8. (b)	9. (a)	10. (a)
11. (c)	12. (d)	13. (c)	14. (d)	15. (b)	16. (c)	17. (b)	18. (b)	19. (a)	20. (b)
21. (a)	22. (b)	23. (a)	24. (a)	25. (c)	26. (b)	27. (b)	28. (c)		

Level-2

1. (d)	2. (d)	3. (d)	4. (a)	5. (b)	6. (a)	7. (a)	8. (c)	9. (c)	10. (c)
11. (d)	12. (a)	13. (e)	14. (c)	15. (d)	16. (b)	17. (d)	18. (c)	19. (a)	20. (e)
21. (b)	22. (d)	23. (a)	24. (d)	25. (a)	26. (a)	27. (d)	28. (a)	29. (b)	30. (a)
31. (d)	32. (c)	33. (b)	34. (b)	35. (b)	36. (c)	37. (c)	38. (d)	39. (b)	40. (a)
41. (b)	42. (b)	43. (c)	44. (c)	45. (c)	46. (d)	47. (a)	48. (c)	49. (a)	50. (a)
51. (b)	52. (a)	53. (b)	54. (a)	55. (c)	56. (a)	57. (c)	58. (c)	59. (d)	60. (d)
61. (a)	62. (b)	63. (c)	64. (a)	65. (d)	66. (a)	67. (d)	68. (c)	69. (d)	70. (a)
71. (d)	72. (a)	73. (b)	74. (d)	75. (b)	76. (d)	77. (d)	78. (c)	79. (d)	80. (b)
81. (a)	82. (e)	83. (b)	84. (d)	85. (c)	86. (a)	87. (a)	88. (d)	89. (b)	90. (c)
91. (a)	92. (a)	93. (b)	94. (c)	95. (a)					

Solutions

Level-1

5. Time taken for 1 bullet $= \frac{1}{n}$

Force = the rate of change of momentum $= mvn$

$$= 10 \times 20 \times 10 = 2000 \text{ dyne}$$

7.
$$a = \frac{(m_2 - m_1)}{(m_1 + m_2)} g$$
$$= \frac{(60 - 40) \times 10}{60 + 40}$$
$$= \frac{20 \times 10}{100} = 2 \text{ m/s}^2$$

8.
$$\frac{3}{2} = \frac{mg}{m(g-a)}$$
$$3g - 3a = 2g \Rightarrow a = \frac{g}{3}$$

10. Velocity acquired in falling through height h
$$u = \sqrt{2gh} = \sqrt{2 \times 10 \times 5} = 10 \text{ m/s}^2$$

Again $v^2 = u^2 + 2as,$

$$\Rightarrow (0)^2 = (10)^2 + 2a \times 2$$
$$a = -\frac{100}{2 \times 2} = -25 \text{ m/s}^2$$

This is total retardation due to gravity and air resistance.

$\therefore$ Retardation due to air resistance
$$a' = g + a = (10 + 25) \text{ m/s}^2 = 35 \text{ m/s}^2$$

Force due to air resistance $= Ma'$
$$= 200 \times 10^{-3} \times 35 = 7000 \times 10^{-3} = 7 \text{ N}$$

11. We get $l = \frac{1}{2} at^2$

$$\therefore \quad t^2 \propto l$$
$$\left(\frac{t_1}{t_2}\right)^2 = \frac{l}{l/2}$$
$$\Rightarrow \left(\frac{t_1}{t_2}\right)^2 = 2 \Rightarrow \frac{t_1^2}{2} = t_2^2$$
$$\frac{36}{2} = t_2^2$$
$$\therefore \quad t_2 = \sqrt{18} = 3\sqrt{2} \text{ sec}$$

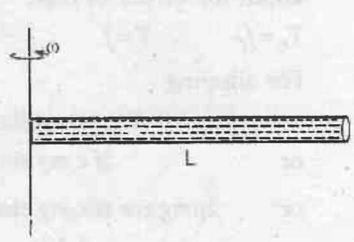
5

Circular Motion

Syllabus: Uniform circular motion and its applications.

Review of Concepts

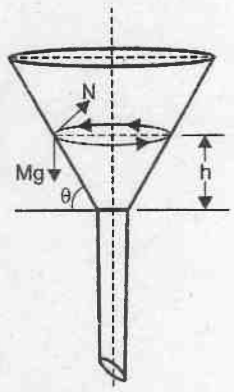
(a) If a tube filled with an incompressible fluid of mass m and closed at both ends is rotated with constant angular velocity ω about an axis passing through one end then the force exerted by liquid at the other end is $\frac{1}{2} mL\omega^2$.



(b) If a particle moves on a curved path and radial acceleration is a function of time, then tangential acceleration may or may not be the function of time.

(c) If a particle moves on a curved path as tangential acceleration is either constant or the function of time, then the radial acceleration must be the function of time.

(d) When a particle describes a horizontal circle on the smooth inner surface of a conical funnel as such the height of the plane of circle above the vertex of cone is h. Then the speed of the particle is $\sqrt{gh}$.



(e) Tangential acceleration changes the magnitude of the velocity of the particle.

Total acceleration $a = \sqrt{a_T^2 + a_r^2}$

(f) **Regarding circular motion following possibilities will exist:**

(i) If $a_r = 0$ and $a_T = 0$, then $a = 0$ and motion is uniform translatory.

(ii) If $a_r = 0$ and $a_T \neq 0$, then $a = a_T$ and motion is accelerated translatory.

(iii) If $a_r \neq 0$ but $a_T = 0$, then $a = a_r$ and motion is uniform circular.

(iv) If $a_r \neq 0$ and $a_T \neq 0$, then $a = \sqrt{a_T^2 + a_r^2}$ and motion is non-uniform circular.

(g) A cyclist moves on a curve leans towards the centre to maintain radial force from the frictional force. In this case,

$$\mu mg = \frac{mv^2}{r} \Rightarrow \mu = \frac{v^2}{rg}$$

The angle of banking,

$$\tan\theta = \frac{v^2}{rg}$$

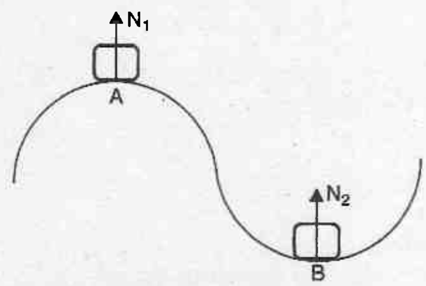
(h) The maximum velocity of vehicle on a banked road is $\sqrt{rg\tan\theta}$.

(i) The height of the outer edge over inner edge in a road $= h = l\sin\theta$ where l is the width of the road.

(j) When a vehicle is moving over a convex bridge, the maximum velocity $v = \sqrt{rg}$, where r is the radius of the road.

When the vehicle is at the maximum height, reaction

$$N_1 = mg - \frac{mv^2}{r}$$



When vehicle is moving in a dip B, then

$$N_2 = mg + \frac{mv^2}{r}$$

(k) The weight that we feel is the normal force and not the actual weight.

(l) **Centripetal force :** Centripetal force can be expressed as

$$\vec{F} = -m\omega^2\vec{r} = -m\omega^2 r\,\hat{r} = -\left(\frac{mv^2}{r}\right)\hat{r}$$

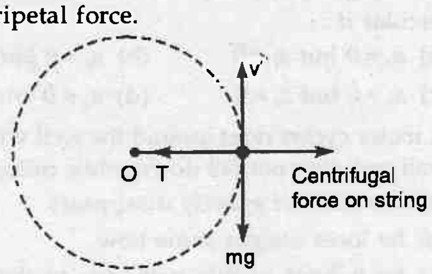
(i) If the body comes to rest on a circular path *i.e.*, $\vec{v} \to 0$, the body will move along the radius towards the centre and if a_r vanishes, the body will fly off tangentially, so a tangential velocity and radial acceleration are necessary for uniform circular motion.

(ii) As $F \neq 0$, so the body is not in equilibrium and linear momentum of the particle does not remain conserved but angular momentum is conserved as the force is central *i.e.*, $\tau = 0$.

(iii) In the case of circular motion, centripetal force changes only the direction of velocity of the particle.

(m) **Centrifugal force :**

(i) Centrifugal force is equal and opposite to centripetal force.



(ii) Under centrifugal force, body moves only along a straight line. It appears when centripetal force ceases to exist.

(iii) In an inertial frame, the centrifugal force does not act on the object.

(iv) In non-inertial frames, centrifugal force arises as pseudo forces and need to be considered.

(n) When body losses the contact. normal force reduces to zero.

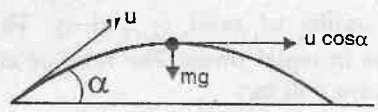
(o) **The concept of radius of curvature :** The normal on tangent at a point on the curve gives the direction of radius.

i.e., $$\rho = \frac{\left[1+\left(\frac{dy}{dx}\right)^2\right]^{3/2}}{d^2y/dx^2}$$

where ρ is radius of curvature.

(p) $\rho = \dfrac{mv^3}{|\vec{F} \times \vec{v}|}$

(q) Expression for the radius of curvature for a particle at the highest point in the case of projectile motion:



$$mg = \frac{mv^2}{r} \qquad \text{But } v = u\cos\alpha$$

or $$r = \frac{v^2}{g} = \frac{u^2\cos^2\alpha}{g}$$

where r is the radius of curvature.

(r) In vertical circular motion :

(i) critical velocity at upper most point $v_c = \sqrt{rg}$.

(ii) critical velocity at lowest point $v_c = \sqrt{5rg}$.

(s) Maximum velocity for no skidding $v_{max} = \sqrt{\mu rg}$.

(t) Maximum speed for no over turning $v_{max} = \sqrt{\left(\frac{rdg}{2h}\right)}$

where, $h \to$ height of centre of gravity.

$d \to$ distance between outer and inner wheels.

Objective Questions

Level-1

1. A car moving on a horizontal road may be thrown out of the road in taking a turn :
(a) by a gravitational force
(b) due to lack of proper centripetal force
(c) due to the rolling frictional force between the tyre and road
(d) due to the reaction of the ground

2. When a body moves with constant speed in a circular path, then :
(a) work done will be zero
(b) acceleration will be zero
(c) no force acts on a body
(d) its velocity remains constant

3. Two planets of masses m_1 and m_2 $(m_1 > m_2)$ are revolving round the sun in circular orbits of radii r_1 and r_2 $(r_1 > r_2)$ respectively. The velocities of planets be v_1 and v_2 respectively. Which of the following statements is true ?
(a) $v_1 = v_2$ (b) $v_1 > v_2$
(c) $v_1 < v_2$ (d) $\frac{v_1}{r_1} = \frac{v_2}{r_2}$

4. A national roadway bridge over a canal is in the form of an arc of a circle of radius 49 m. What is the maximum speed with which a car can move without leaving the ground at the highest point ? (take $g = 9.8$ m/s^2)
(a) 19.6 m/s (b) 40 m/s
(c) 22 m/s (d) none of these

5. A bucket full of water is rotated in a vertical circle of radius R. If the water does not split out, the speed of the bucket at top most point will be :
(a) $\sqrt{Rg}$ (b) $\sqrt{5Rg}$
(c) $\sqrt{2Rg}$ (d) $\sqrt{\left(\frac{R}{g}\right)}$

6. In an atom two electrons move round the nucleus in circular orbits of radii R and $4R$ respectively. The ratio of the time taken by them to complete one revolution is :
(a) $\frac{1}{4}$ (b) $\frac{4}{1}$
(c) $\frac{8}{1}$ (d) $\frac{1}{8}$

7. When a simple pendulum is rotated in a vertical plane with constant angular velocity, centripetal force is :
(a) maximum at highest point
(b) maximum at lowest point
(c) same at all points
(d) zero

8. The wheel of toy car rotates about a fixed axis. It slows down from 400 rps to 200 rps in 2 sec. Then its angular retardation in rad/s^2 is :
(a) 200π (b) 100
(c) 400π (d) none of these

9. Two toy cars of masses m_1 and m_2 are moving along the circular paths of radii r_1 and r_2. They cover equal distances in equal times. The ratio of angular velocities of two cars will be :
(a) $m_1 : m_2$ (b) $r_1 : r_2$
(c) $1 : 1$ (d) $m_1 r_1 : m_2 r_2$

10. A stone tied to the end of 20 cm long string is whirled in a horizontal circle. If the centripetal acceleration is 9.8 ms^{-2}, its angular speed in radian per sec is :
(a) $\frac{22}{7}$ (b) 7
(c) 14 (d) 20

11. A particle of mass 100 g tied to a string is rotated along a circle of radius 0.5 m. The breaking tension of string is 10 N. The maximum speed with which particle can be rotated without breaking the string is :
(a) 10 m/s (b) 9.8 m/s
(c) 7.7 m/s (d) 7.07 m/s

12. A car wheel is rotated to uniform angular acceleration about its axis. Initially its angular velocity is zero. It rotates through an angle θ_1 in the first 2 sec, in the next 2 sec, it rotates through an additional angle θ_2, the ratio of $\frac{\theta_2}{\theta_1}$ is :
(a) 1 (b) 2
(c) 3 (d) 5

13. A mass of stone 1 kg is tied at one end of string of length 1 m. It is whirled in a vertical circle at constant speed of 4 m/s. The tension in the string is 6 N when the stone is at : ($g = 10$ m/s^2)
(a) top of the circle (b) bottom of the circle
(c) half way down (d) none of these

14. A car travels with a uniform velocity in north direction. It goes over a piece of mud which sticks to the tyre, the particles of the mud, as it leaves the ground are thrown :
(a) vertically downward (b) vertically upward
(c) horizontally to north (d) horizontally to south

15. A chain of 125 links is 1.25 m long and has a mass of 2 kg with the ends fastened together. It is set for rotating at 50 rev/s, the centripetal force on each link is :
(a) 3.14 N (b) 0.314 N
(c) 314 N (d) none of these

16. A coin placed on a rotating turntable just slips if it is placed at a distance of 8 cm from the centre. If angular velocity of the turntable is doubled, it will just slip at a distance of :
(a) 1 cm (b) 2 cm
(c) 4 cm (d) 8 cm

17. The radial and tangential acceleration are represented by a_r and a_T respectively. The motion of a particle will be circular if :
(a) $a_r = 0$ but $a_t \neq 0$ (b) $a_r = 0$ and $a_t = 0$
(c) $a_r \neq 0$ but $a_t = 0$ (d) $a_r \neq 0$ and $a_t \neq 0$

18. A motor cyclist rides around the well with a round vertical wall and does not fall down while riding because :
(a) the force of gravity disappears
(b) he loses weight some how
(c) he is kept in this path due to the force exerted by surrounding air
(d) the frictional force of the wall balances his weight

19. The string of a pendulum is horizontal. The mass of bob attached to it is m. Now the string is released. The tension in the string in the lowest position, is :
(a) mg (b) $2mg$
(c) $3mg$ (d) $4mg$

20. A stone of mass 1 kg tied to a light inextensible string of length $L = \frac{10}{3}$ is whirling in a circular path of radius L in vertical plane. If the ratio of the maximum tension to the mininum tension in the string is 4, what is the speed of stone at the highest point of the circle ? (Taking $g = 10$ m/s^2)
(a) 10 m/s (b) $5\sqrt{2}$ m/s
(c) $10\sqrt{3}$ m/s (d) 20 m/s

21. A wheel of radius R is rolling in a straight line without slipping on a plane surface, the plane of the wheel is vertical. For the instant when the axis of the wheel is moving with a speed v relative to the surface, the instantaneous velocity of any point P on the rim of the wheel relative to the surface will be :
(a) v (b) $v(1 + \cos\theta)$
(c) $v\sqrt{2(1 + \cos\theta)}$ (d) none of these

22. A small body of mass m slides down from the top of a hemisphere of radius R. The surface of block and hemisphere are frictionless. The height at which the body lose contact with the surface of the sphere is :
(a) $\frac{3}{2}R$ (b) $\frac{2}{3}R$ (c) $\frac{1}{2}R$ (d) $\frac{1}{3}R$

23. 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 :
(a) $\frac{M\omega}{(M + m)}$ (b) $\frac{\omega(M - 2m)}{(M + 2m)}$
(c) $\frac{M\omega}{M + 2m}$ (d) $\frac{\omega(M + 2m)}{M}$

24. A heavy stone hanging from a massless string of length 15 m is projected horizontally with speed 147 m/s. The speed of the particle at the point where the tension in the string equals the weight of the particle is :
(a) 10 m/s (b) 7 m/s
(c) 12 m/s (d) none of these

25. A stone of mass 1 kg is tied to a string 4 m long and is rotated at constant speed of 40 m/s in a vertical circle. The ratio of the tension at the top and the bottom is : ($g = 10\ m/s^2$)
(a) 11 : 12
(b) 39 : 41
(c) 41 : 39
(d) 12 : 11

Level-2

1. In circular motion :
(a) radial acceleration is non-zero
(b) radial velocity is zero
(c) body is in equilibrium
(d) all of the above

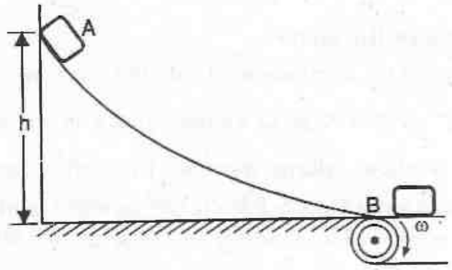
2. Mark correct option or options from the following :
(a) In the case of circular motion of a particle, centripetal force may be balanced by centrifugal force
(b) In the non-inertial reference frame centrifugal force is real force
(c) In the inertial reference frame, centrifugal force is real force
(d) Centrifugal force is always pseudo force

3. A particle is acted upon by a force of constant magnitude which is always perpendicular to the velocity of the particle. The motion of the particle takes place in a plane. It follows that :
(a) its velocity is constant
(b) its acceleration is constant
(c) its kinetic energy is constant
(d) it does not move on a circular path

4. A stone of mass m tied to a string of length l is rotated in a circle with the other end of the string as the centre. The speed of the stone is v. If the string breaks, the stone will :
(a) move towards the centre
(b) move away from the centre
(c) move along a tangent
(d) stop

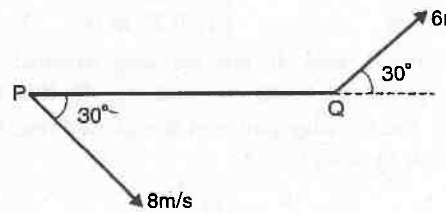
5. Two particles A and B having mass m each and charge q_1 and $-q_2$ respectively, are connected at the ends of a non conducting flexible and inextensible string of the length l. The particle A is fixed and B is whirled along a vertical circle with centre at A. If a vertically upward electric field of strength E exists in the space, then for minimum velocity of particle B :
(a) the tension force in string at lowest point is zero
(b) the tension force at the lowest point is non-zero
(c) the tension force at the highest point is zero
(d) the work done by interaction force between particles A and B is non-zero

6. Particles are released from rest at A and slide down the smooth surface of height h to a conveyor B. The correct angular velocity ω of the conveyor pulley of radius r to prevent any sliding on the belt as the particles transfer to the conveyor is :



(a) $\sqrt{2gh}$
(b) $\frac{2gh}{r}$
(c) $\frac{\sqrt{2gh}}{r}$
(d) $\frac{2gh^2}{r^2}$

7. Two moving particles P and Q are 10 m apart at a certain instant. The velocity of P is 8 m/s making an angle of 30° with the line joining P and Q and that of Q is 6 m/s making on angle 30° with PQ as shown in figure. Then angular velocity of P with respect to Q is :



(a) zero
(b) 0.1 rad/sec
(c) 0.4 rad/sec
(d) 0.7 rad/sec

8. A solid body rotates about a stationary axis so that its angular velocity depends on the rotational angle ϕ as $\omega = \omega_0 - k\phi$ where ω_0 and k are positive constants. At the moment $t = 0$, $\phi = 0$, the time dependence of rotation angle is :
(a) $k\omega_0 e^{-kt}$
(b) $\frac{\omega_0}{k} e^{-kt}$
(c) $\frac{\omega_0}{k}(1 - e^{-kt})$
(d) $\frac{k}{\omega_0}(e^{-kt} - 1)$

9. The position of a point P is $\vec{r} = a \cos\theta\,\hat{i} + b \sin\theta\,\hat{j}$, where a and b are constants and θ is angle between r and x-axis. If the rate of increasing of θ is ω, the equation of path of particle is :
(a) circle
(b) parabola
(c) ellipse
(d) straight line

10. A boat which is rowed with constant velocity u, starts from point A on the bank of river which flows with a constant velocity v and it points always towards a point

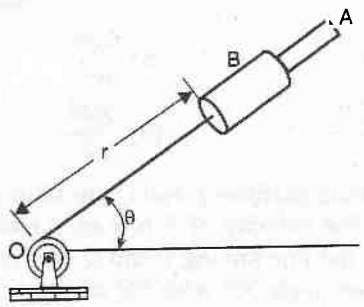
B. On the other bank exactly opposite to A, the equation of the path of boat is :

(a) $r \sin \theta = c \left(\tan \frac{\theta}{2} \right)^{u/v}$ (b) $r \sin \theta = \frac{u}{v}$

(c) $r^2 \sin \theta = \frac{u}{v}$ (d) $ur^2 = v \sin^2 \theta$

(e) none of the above

*11. The angular displacement of the rod is defined as $\theta = \frac{3}{20} t^2$ where θ is in radian and t is in second. The collar B slides along the rod in such a way that its distance from O is, $r = 0.9 - 0.12t^2$ where r is in metre and t is in second. The velocity of collar at $\theta = 30°$ is :



(a) 0.45 m/s (b) 0.48 m/s
(c) 0.52 m/s (d) 0.27 m/s

12. Two buses A and B are moving around concentric circular paths of radii r_A and r_B. If the two buses complete the circular paths in the same time, the ratio of their linear speeds is :

(a) 1 (b) $\frac{r_A}{r_B}$

(c) $\frac{r_B}{r_A}$ (d) none of these

13. A stone of mass 0.3 kg attached to a 1.5 m long string is whirled around in a horizontal circle at a speed of 6 m/s. The tension in the string is :
(a) 10 N (b) 20 N
(c) 7.2 N (d) none of these

14. A cyclist goes round a circular path of length 400 m in 20 second. The angle through which he bends from vertical in order to maintain the balance is :
(a) $\sin^{-1}(0.64)$ (b) $\tan^{-1}(0.64)$
(c) $\cos^{-1}(0.64)$ (d) none of these

15. The maximum speed with which an automobile can round a curve of radius 8 m without slipping if the road is unbanked and the co-efficient of friction between the road and the tyres is 0.8 is ($g = 10 \text{ m/s}^2$) :
(a) 8 m/s (b) 10 m/s
(c) 20 m/s (d) none of these

16. A tube of length L is filled completely with an incompressible liquid of mass M and closed at both 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 :

(a) $\frac{ML\omega^2}{2}$ (b) $ML\omega^2$

(c) $\frac{ML\omega^2}{4}$ (d) $\frac{ML^2\omega^2}{2}$

17. A point on the periphery of a rotating disc has its acceleration vector making an angle of 30° with the velocity vector. The ratio a_c/a_t (a_c is centripetal acceleration and a_t is tangential acceleration) equals :
(a) sin 30° (b) cos 30°
(c) tan 30° (d) none of these

18. A car of 1400 kg is moving on a circular path of radius 30 m with a speed of 40 km/h. When the driver applies the brakes and the car continues to move along the circular path, what is the maximum deceleration possible if the tyres are limited to a total horizontal friction of 10.6 kN ?
(a) 10 m/s^2 (b) 6.36 m/s^2
(c) 4 m/s^2 (d) None of these

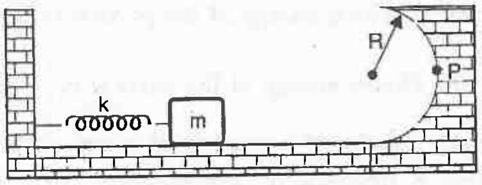
19. A cyclist is travelling on a circular section of highway of radius 2500 ft at the speed of 60 mile/h. The cyclist suddenly applies the brakes causing the bicycle to slow down at constant rate. Knowing that after eight second, the speed has been reduced to 45 mile/h. The acceleration of the bicycle immediately after the brakes have been applied is :
(a) 2 ft/s^2 (b) 4.14 ft/s^2
(c) 3.10 ft/s^2 (d) 2.75 ft^2/s

20. A road of width 20 m forms an arc of radius 15 m, its outer edge is 2 m higher than its inner edge. For what velocity the road is banked ?
(a) $\sqrt{10}$ m/s (b) $\sqrt{14.7}$ m/s
(c) $\sqrt{9.8}$ m/s (d) None of these

21. Three identical cars A, B and C are moving at the same speed on three bridges. The car A goes on a plane bridge, B on a bridge convex upwards and C goes on a bridge concave upwards. Let F_A, F_B and F_C be the normal forces exerted by the cars on the bridges when they are at the middle of the bridges. Then :
(a) F_A is maximum of the three forces
(b) F_B is maximum of the three forces
(c) F_C is maximum of the three forces
(d) $F_A = F_B = F_C$

22. A car runs from east to west and another car B of the same mass runs from west to east at the same path along the equator. A presses the track with a force N_1 and B presses the track with a force N_2. Then :
(a) $N_1 > N_2$ (b) $N_1 < N_2$
(c) $N_1 = N_2$ (d) none of these

*23. A smooth track is shown in the figure. A part of track is a circle of radius R.
A block of mass m is pushed against a spring of constant k fixed at the left end and is then released. The initial compression of the spring so that the block presses the



track with a force mg when it reaches the point P of the track, where radius of the track is horizontal:

(a) $\sqrt{\dfrac{mgR}{3k}}$ (b) $\sqrt{\dfrac{3gR}{mk}}$

(c) $\sqrt{\dfrac{3mgR}{k}}$ (d) $\sqrt{\dfrac{3mg}{kR}}$

24. A person wants to drive on the vertical surface of a large cylindrical wooden well commonly known as death well in a circus. The radius of well is R and the coefficient of friction between the tyres of the motorcycle and the wall of the well is μ_s. The minimum speed, the motorcyclist must have in order to prevent slipping should be:

(a) $\sqrt{\dfrac{Rg}{\mu_s}}$ (b) $\sqrt{\dfrac{\mu_s}{Rg}}$

(c) $\sqrt{\dfrac{\mu_s g}{R}}$ (d) $\sqrt{\dfrac{R}{\mu_s g}}$

25. A car is moving in a circular horizontal track of radius 10 m with a constant speed of 10 m/s. A plumb bob is suspended from the roof of the car by a light rigid rod of length 1 m. The angle made by the rod with the track is:

(a) zero (b) 30°

(c) 45° (d) 60°

26. A particle of mass m is attached to one end of a string of length l while the other end is fixed to a point h above the horizontal table, the particle is made to revolve in a circle on the table, so as to make P revolutions per second. The maximum value of P if the particle is to be in contact with the table will be:

(a) $2P\sqrt{gh}$ (b) $\sqrt{\left(\dfrac{g}{h}\right)}$

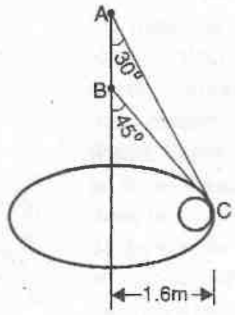
(c) $2P\sqrt{\left(\dfrac{h}{g}\right)}$ (d) $\dfrac{1}{2\pi}\sqrt{\left(\dfrac{g}{h}\right)}$

27. A rod of length L is hinged from one end. It is brought to a horizontal position and released. The angular velocity of the rod when it is in vertical position is:

(a) $\sqrt{\left(\dfrac{2g}{L}\right)}$ (b) $\sqrt{\left(\dfrac{3g}{L}\right)}$

(c) $\sqrt{\left(\dfrac{g}{2L}\right)}$ (d) $\sqrt{\left(\dfrac{g}{L}\right)}$

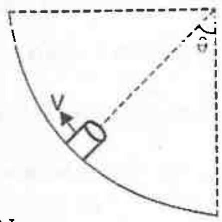
28. Two wires AC and BC are tied at C of small sphere of mass 5 kg, which revolves at a constant speed v in the horizontal circle of radius 1.6 m. The minimum vlaue of v is:



(a) 3.01 m/s (b) 4.01 m/s

(c) 8.2 m/s (d) 3.96 m/s

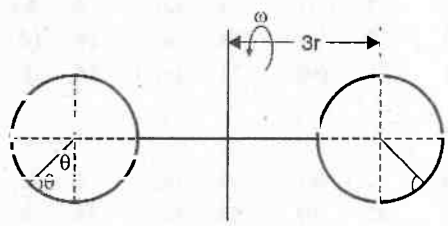
29. The skate board negotiates the circular surface of radius 4.5 m (shown in the figure). At $\theta = 45°$, its speed of centre of mass is 6 m/s. The combined mass of skate board and the person is 70 kg and his centre of mass is 0.75 m from the surface. The normal reaction between the surface and the skate board wheel is:



(a) 500 N (b) 2040 N

(c) 1045 N (d) zero

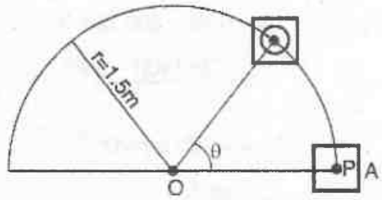
30. The small spherical balls are free to move on the inner surface of the rotating spherical chamber of radius $R = 0.2$ m. If the balls reach a steady state at angular position $\theta = 45°$, the angular speed ω of device is:



(a) 8 rad/sec (b) 2 rad/sec

(c) 3.64 rad/sec (d) 9.34 rad/sec

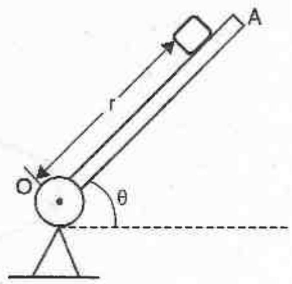
31. In the given figure, the square plate is at rest at position A at time $t = 0$ and moves as such $\theta = 1.5t^2$, where angular displacement θ is in radian and time t is in second. A small object P of mass 0.4 kg is temporarily fixed to the plate with adhesive. The adhesive force F that the adhesive must support at time $t = 3$ sec is:



(a) 20 N (b) 10 N

(c) 45.6 N (d) zero

* **32.** A rod OA rotates about a horizontal axis through O with a constant anti-clockwise velocity $\omega = 3$ rad/sec. As it passes the position $\theta = 0$ a small block of mass m is placed on it at a radial distance $r = 450$ mm. If the block is observed to slip at $\theta = 50°$, the coefficient of static friction between the block and the rod is :



(Given that $\sin 50° = 0.766$, $\cos 50° = 0.64$)

(a) 0.2 (b) 0.55
(c) 0.8 (d) 1

33. A particle of mass m is moving in a horizontal circle of radius r under a centripetal force given by $\left(\frac{-k}{r^2}\right)$, where k is a constant, then :

(a) the total energy of the particle is $\left(\frac{-k}{2r}\right)$

(b) the kinetic energy of the particle is $\left(\frac{k}{r}\right)$

(c) the potential energy of the particle is $\left(\frac{k}{2r}\right)$

(d) the kinetic energy of the particle is $\left(-\frac{k}{r}\right)$

34. Kinetic energy of a particle moving along a circle of radius R depends on the distance covered as $T = ks^2$ where k is a constant. The force acting on the particle as a function of s is :

(a) $\frac{2k}{s}\sqrt{1+\left(\frac{s}{R}\right)^2}$ (b) $2ks\sqrt{1+\left(\frac{R}{s}\right)^2}$

(c) $2ks\sqrt{1+\left(\frac{s}{R}\right)^2}$ (d) $\frac{2s}{k}\sqrt{1+\left(\frac{R}{s}\right)^2}$

35. A projectile is projected at an angle 60° with horizontal with speed 10 m/s. The minimum radius of curvature of the trajectory described by the projectile is :

(a) 2.55 m (b) 2 m
(c) 10 m (d) none of these

36. A particle moves on a curved path with constant speed v. The acceleration of the particle at $x = 0$ is $2av^2$. The path of particle is :

(a) straight line (b) parabolic
(c) elliptical (d) none of these

Answers

Level-1

1. (b)	2. (a)	3. (c)	4. (c)	5. (a)	6. (d)	7. (c)	8. (a)	9. (c)	10. (a)
11. (d)	12. (c)	13. (a)	14. (d)	15. (c)	16. (b)	17. (c)	18. (d)	19. (c)	20. (a)
21. (c)	22. (b)	23. (c)	24. (b)	25. (b)					

Level-2

1. (d)	2. (c)	3. (c)	4. (c)	5. (a)	6. (c)	7. (d)	8. (c)	9. (c)	10. (a)
11. (c)	12. (b)	13. (c)	14. (b)	15. (a)	16. (a)	17. (c)	18. (b)	19. (b)	20. (b)
21. (c)	22. (a)	23. (c)	24. (a)	25. (c)	26. (d)	27. (b)	28. (d)	29. (c)	30. (c)
31. (c)	32. (b)	33. (a)	34. (c)	35. (a)	36. (b)				

Solutions

Level-1

4. $v = \sqrt{gR} = \sqrt{9.8 \times 49}$

$= 21.9 \text{ m/s} \simeq 22 \text{ m/s}$

8. $\omega_1 = 2\pi \times 400$ rad/s

$\omega_2 = 2\pi \times 200$ rad/s

$$a = \frac{2\pi\,(400-200)}{2}$$

$$a = 200\,\pi \text{ rad/s}^2$$

11. Centripetal force $F = \frac{mv^2}{r}$;

$$v = \sqrt{\left(\frac{rF}{m}\right)} = \sqrt{\frac{0.5 \times 10 \times 1000}{100}}$$

$= \sqrt{50}$ m/s $= 7.07$ m/s

15. We know $F = mr\omega^2$

$$= \frac{2}{125} \times \frac{1.25}{2\pi} \times (100\pi)^2 \quad (\because \omega = 2\pi f = 2 \times 50 \times \pi)$$

$= 100\,\pi$ N $= 314$ N

16. We know $F = mr\omega^2$

$r\omega^2 = \text{constant}$

$$\omega^2 \propto \frac{1}{r}$$

$$\left(\frac{\omega_2}{\omega_1}\right)^2 = \frac{r_1}{r_2}$$

$$\frac{4\omega_1^2}{\omega_1^2} = \frac{8}{r_2} \quad \therefore \; r_2 = 2 \text{ cm}$$

6

Work, Energy and Power

Syllabus: Concept of work, energy and power, energy-kinetic and potential. Conservation of energy. Different forms of energy.

Review of Concepts

1. Work :

(i) Work is said to be done by a force. It depends on two factors:
(a) force applied and
(b) distance travelled by the body in the direction of force.

(ii) The work done by constant force is $W = \vec{F} \cdot \vec{s} = Fs \cos\theta$. If
(a) $\theta = 0$; $W = Fs$, (b) $\theta = 90°$; $W = 0$,
(c) $\theta = 180°$, $W < 0$, (d) $F = 0$, $W = 0$,
(e) $s = 0$, $W = 0$

(iii) Unit of work :
Joule or Nm or kg m^2/s^2 $\longrightarrow$ S.I.
erg or dyne cm or g cm^2/s^2 $\longrightarrow$ C.G.S.
Foot pound $\longrightarrow$ F.P.S.

(iv) Work depends upon the frame of reference.

(v) If a man is pushing a box inside a moving train, the work done in the frame of train will be $\vec{F} \cdot \vec{s}$, while in the frame of ground will be $\vec{F}(\vec{s} \cdot \vec{s}_0)$ where $\vec{s}_0$ is the displacement of the train relative to the ground.

(vi) Work done by conservative force does not depend upon path followed by the body.

(vii) The work done by constant force does not depend upon path.

(viii) If a particle moves in a plane curve under conservative forces, the change in kinetic energy is equal to work done on the body.

(ix) Power of heart $= h\rho g \times$ blood pumping by heart per second.

(x) If a light body of mass m_1 and a heavy body of mass m_2 have same momentum, then

$$\frac{K_1}{K_2} = \frac{m_2}{m_1}$$

where K_1 is the kinetic energy possessed by m_1 and K_2 is KE possessed by m_2. The lighter body has more kinetic energy.

(xi) When a porter moves with a suitcase in his hand on a horizontal level road, the work done by the lifting force or the force of gravity is zero.

(xii) Work done by a variable force is given by $dW = \vec{F} \cdot d\vec{r}$

If

$$\vec{F} = F_x\hat{i} + F_y\hat{j} + F_z\hat{k}$$

$$d\vec{r} = dx\hat{i} + dy\hat{j} + dz\hat{k}$$

$$W = \int \vec{F} \cdot d\vec{r} = \int (F_x\,dx + F_y\,dy + F_z\,dz)$$

(xiii) The work done by a force $\vec{F}$ exerted by a spring on a body A, during a finite displacement of the body from $A_1 (x = x_1)$ to $A_2 (x = x_2)$ was obtained by writing

$$W_{1 \to 2} = -\int_{x_1}^{x_2} kx\,dx$$

$$W_{1 \to 2} = \frac{1}{2}kx_1^2 - \frac{1}{2}kx_2^2$$

(xiv) The work of force $\vec{F}$ is positive when the spring is returning to its undeformed position.

(xv) The work is said to be done when the point of application of force makes the body to move. Work may be negative.

(xvi) The work done by a boy lifting a bucket of water is positive, while work done by gravitational force in this case is negative.

(xvii) When two springs A and B are such that $k_A > k_B$, then work done when they are stretched by the same amount, $W_A > W_B$. But when they are stretched by the same force then $W_B > W_A$.

2. **Energy :**

(i) The energy of a body is defined as the capacity of doing work.

(ii) The unit of energy is same as that of work.

(iii) Energy can be classified further into various well defined forms such as:
(a) mechanical, (b) heat
(c) electrical, (d) atomic energy, etc.

(iv) In the case of a simple pendulum, as the pendulum vibrates there is a continuous transformation between kinetic energy and potential energy and the total energy remains conserved.

(v) When the velocity of a body changes from u to v, the work done by the resultant force

$$W = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$$

(vi) The total work done by an external force $\vec{F}$ in carrying a particle from a point A to a point B along a curve C is equal to the kinetic energy gained in the process.

(vii) If $\vec{F} = k\vec{s}$ where k is a constant and $\vec{s}$ is a unit vector along the tangent to the element of arc $d\vec{s}$ on a curve, on which a particle is constrained to move under the force $\vec{F}$. Then $\vec{F}$ is non- conservative.

(viii) If a single particle is moving under a conservative field of force, the sum of the kinetic energy and potential energy is always constant.

(ix) Two bodies of mass m_1 (heavy) and mass m_2 (light) are moving with same kinetic energy. If they are stopped by the same retarding force, then

(a) The bodies cover the same distance before coming to rest.

(b) The time taken to come to rest is lesser for m_2 as it has less momentum *i.e.*, $t = \frac{p}{F}$

(c) The time taken to come to rest is more for m_1 as it has greater momentum.

(x) When a light and a heavy body have same kinetic energy, the heavy body has greater momentum $= p = \sqrt{(2mK)}$, where K = kinetic energy.

(xi) When two blocks A and B, coupled by a spring on a frictionless table are stretched and released, then kinetic energy of blocks are inversely proportional to their masses.

(xii) A body cannot have momentum without kinetic energy.

(xiii) (a) Mechanical energy of a particle, object or system is defined as the sum of kinetic and potential energy *i.e.*, $E = K + U$.

(b) A body can have mechanical energy without having either kinetic or potential energy.

(c) Mechanical energy of a body or a system can be negative and negative mechanical energy implies that potential energy is negative and in magnitude it is more than KE. Such a state is called bound state.

(xiv) The concept of potential energy exists only in the case of conservative forces.

3. Power:

(i) Rate of doing work is called power. If velocity vector makes an angle θ with the force vector, then

$$P = \vec{F} \cdot \vec{v} = Fv\cos\theta$$

(ii) **Unit of power :**

erg/sec $\longrightarrow$ CGS system

horse power (= 746 watt) $\longrightarrow$ FPS system

J/sec or watt $\longrightarrow$ SI system

(iii) In rotatory motion

$$P = \tau\frac{d\theta}{dt} = \tau\omega$$

(iv) If a body moves along a rough horizontal surface, with a velocity v, then the power required is

$$P = \mu mgv$$

(v) (a) If a block of mass m is pulled along the rough inclined plane of angle θ then power is

$$P = (mg\sin\theta + \mu mg\cos\theta)\,v$$

(b) If a same block is pulled along the smooth inclined plane with constant velocity v, the power spent is

$$P = (mg\sin\theta)\,v$$

Objective Questions

Level-1

1. A lorry and a car, moving with the same KE are brought to rest by applying the same retarding force then :
(a) lorry will come to rest in a shorter distance
(b) car will come to rest in a shorter distance
(c) both will come to rest in the same distance
(d) none of the above

2. In a certain situation, $\vec{F}$ and $\vec{s}$ are not equal to zero but the work done is zero. From this, we conclude that:
(a) $\vec{F}$ and $\vec{s}$ are in same direction
(b) $\vec{F}$ and $\vec{s}$ are perpendicular to each other
(c) $\vec{F}$ and $\vec{s}$ are in opposite direction
(d) none of the above

3. A gas expands from 5 litre to 205 litre at a constant pressure 50 N/m^2. The work done is:
(a) 2000 J (b) 1000 J
(c) 10000 J (d) none of these

4. A flywheel of mass 60 kg, radius 40 cm is revolving 300 revolutions per min. Its kinetic energy will be :
(a) $480\pi^2$ J (b) 48 J
(c) 48πJ (d) $\frac{4}{\pi}$J

5. A constant force of 5 N is applied on a block of mass 20 kg for a distance of 2.0 m, the kinetic energy acquired by the block is:
(a) 20 J (b) 15 J
(c) 10 J (d) 5 J

6. Under the action of a force, a 2 kg body moves such that its position x as function of time t is given by $x = \frac{t^3}{3}$ where x is in metre and t is in sec, the work done by the force in first two sec is :
(a) 16 J (b) 32 J
(c) 8 J (d) 64 J

7. The momentum of a body of mass 5 kg is 10 kg m/s. A force of 2 N acts on the body in the direction of motion for 5 sec, the increase in the kinetic energy is:
(a) 15 J (b) 50 J
(c) 30 J (d) none of these

8. A block of mass 5 kg slides down a rough inclined surface. The angle of inclination is 45°. The coefficient of sliding friction is 0.20. When the block slides 10 m, the work done on the block by force of friction is:
(a) $50\sqrt{2}$ J (b) $-50\sqrt{2}$ J
(c) 50 J (d) -50 J

9. A particle moves along the x-axis from $x=0$ to $x=5$ m under the influence of a force given by $F=7-2x+3x^2$. The work done in the process is:
(a) 70 J (b) 270 J
(c) 35 J (d) 135 J

10. A 2 kg brick of dimension 5 cm × 2.5 cm × 1.5 cm is lying on the largest base. It is now made to stand with length vertical, then the amount of work done is: (taken $g=10\ m/s^2$)
(a) 35 J (b) 5 J
(c) 7 J (d) 9 J

11. A bomb of 12 kg explodes into two pieces of masses 4 kg and 8 kg. The velocity of 8 kg mass is 6 m/s. The kinetic energy of other mass is:
(a) 48 J (b) 32 J
(c) 24 J (d) 288 J

12. A torque equal to $\left(\frac{5}{\pi}\right)\times 10^{-6}$ Nm acting on a body produces 2 revolutions per second, then the rotational power expended is:
(a) $\frac{1}{\pi}\times 10^{-5}$ J/s (b) 2×10^{-5} J/s
(c) $2.5\pi\times 10^{-6}$ J/s (d) $\frac{2\pi}{5}\times 10^{-8}$ J/s

13. A coolie 1.5 m tall raises a load of 80 kg in 2 sec from the ground to his head and then walks a distance of 40 m in another 2 second. The power developed by the coolie is: ($g=10\ m/s^2$)
(a) 0.2 kW (b) 0.4 kW
(c) 0.6 kW (d) 0.8 kW

14. A lorry of mass 2000 kg is travelling up a hill of certain height at a constant speed of 10 m/s. The frictional resistance is 200 N, then the power expended by the engine is approximately: (take $g=10\ m/s^2$)
(a) 22 kW (b) 220 kW
(c) 2000 W (d) none of these

15. A spring of force constant 10 N/m has initial stretch 0.2 m. In changing the stretch to 0.25 m, the increase of PE is about:
(a) 0.1 J (b) 0.2 J
(c) 0.3 J (d) 0.5 J

16. Sand falls vertically at the rate of 2 kg/s on to a conveyer belt moving horizontally with velocity of 0.2 m/s, the extra power required to keep the belt moving is:
(a) 0.08 W (b) 0.04 W
(c) 4 W (d) 1 W

17. Ten litre of water per second is lifted from well through 20 m and delivered with a velocity of 10 m/s, then the power of the motor is:
(a) 1.5 kW (b) 2.5 kW
(c) 3.5 kW (d) 4.5 kW

18. A bomb of mass M at rest explodes into two fragments of masses m_1 and m_2. The total energy released in the explosion is E. If E_1 and E_2 represent the energies carried by masses m_1 and m_2 respectively, then which of the following is correct?
(a) $E_1=\frac{m_2}{M}E$ (b) $E_1=\frac{m_1}{m_2}E$
(c) $E_1=\frac{m_1}{M}E$ (d) $E_1=\frac{m_2}{m_1}E$

19. The earth's radius is R and acceleration due to gravity at its surface is g. If a body of mass m is sent to a height $h=\frac{R}{5}$ from the earth's surface, the potential energy increases by:
(a) mgh (b) $\frac{4}{5}mgh$
(c) $\frac{5}{6}mgh$ (d) $\frac{6}{7}mgh$

20. At a certain instant, a body of mass 0.4 kg has a velocity of $(8\hat{i}+b\hat{j})$ m/s. The kinetic energy of the body is:
(a) 10 J (b) 40 J
(c) 20 J (d) none of these

21. A chain of mass M is placed on a smooth table with 1/3 of its length L hanging over the edge. The work done in pulling the chain back to the surface of the table is:
(a) $\frac{MgL}{3}$ (b) $\frac{MgL}{6}$
(c) $\frac{MgL}{9}$ (d) $\frac{MgL}{18}$

22. When a man increases his speed by 2 m/s, he finds that his kinetic energy is doubled, the original speed of the man is:
(a) $2(\sqrt{2}-1)$ m/s (b) $2(\sqrt{2}+1)$ m/s
(c) 4.5 m/s (d) none of these

23. Two springs A and B are stretched by applying forces of equal magnitudes at the four ends. If spring constant is 2 times greater than that of spring constant B, and the energy stored in A is E, that in B is:
(a) $E/2$ (b) $2E$
(c) E (d) $\frac{E}{4}$

24. A block of mass m slides from the rim of a hemispherical bowl of radius R. The velocity of the block at the bottom will be:
(a) $\sqrt{Rg}$ (b) $\sqrt{2Rg}$
(c) $\sqrt{2\pi Rg}$ (d) $\sqrt{\pi Rg}$

25. A glass ball is dropped from height 10 m. If there is 20% loss of energy due to impact, then after one impact, the ball will go upto :
(a) 2 m (b) 4 m
(c) 6 m (d) 8 m

26. A moving neutron collides with a stationary α particle. The fraction of the kinetic energy lost by the neutron is :
(a) 16/25 (b) 9/25
(c) 3/5 (d) 2/5

27. A stone of mass 2 kg is projected upward with KE of 98 J. The height at which the KE of the body becomes half its original value, is given by : (take $g = 9.8\ m/s^2$)
(a) 5 m (b) 2.5 m
(c) 1.5 m (d) 0.5 m

Level-2

1. A body of mass 10 kg is moving on a horizontal surface by applying a force of 10 N in forward direction. If body moves with constant velocity, the work done by applied force for a displacement of 2 m is :
(a) 20 joule (b) 10 joule
(c) 30 joule (d) 40 joule

2. In previous problem Q. (1), the work done by force of friction is :
(a) – 20 joule (b) 10 joule
(c) 20 joule (d) – 5 joule

3. In previous problem Q. (1), the work done by normal reaction is :
(a) 20 joule (b) 196 joule
(c) zero (d) none of these

4. A body of mass 10 kg is moving on an inclined plane of inclination 30° with an acceleration $2\ m/s^2$. The body starts from rest. The work done by force of gravity in 2 second is :
(a) 10 joule (b) zero
(c) 98 joule (d) 196 joule

5. In previous problem Q. (4), the work done by force of friction is :
(a) – 58 joule (b) 58 joule
(c) 98 joule (d) – 116 joule

6. A body of mass 1 kg moves from point A (2 m, 3 m, 4 m) to B (3 m, 2 m, 5 m). During motion of body, a force $\vec{F} = (2N)\hat{i} - (4N)\hat{j}$ acts on it. The work done by the force on the particle during displace- ment is :
(a) $2\hat{i} - 4\hat{j}$ joule (b) 2 joule
(c) – 2 joule (d) none of these

7. A force $F = Ay^2 + By + C$ acts on a body in the y-direction. The work done by this force during a displacement from $y = -a$ to $y = a$ is :
(a) $\frac{2Aa^3}{3}$ (b) $\frac{2Aa^3}{3} + 2Ca$
(c) $\frac{2Aa^3}{3} + \frac{Ba^2}{2} + Ca$ (d) none of these

8. A force $\vec{F} = -k(y\hat{i} + x\hat{j})$ (where k is a positive constant) acts on a particle moving in the x-y plane starting from the origin, the particle is taken along the positive x-axis to the point $(a, 0)$ and the parallel to the y-axis to the point (a, a). The total work done by the force $\vec{F}$ on the particle is :
(a) $-2ka^2$ (b) $2ka^2$
(c) $-ka^2$ (d) ka^2

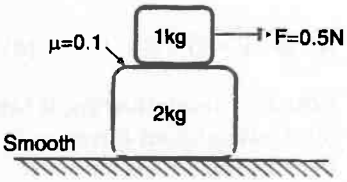
9. During swinging of simple pendulum :
(a) the work done by gravitational force is zero
(b) the work done by tension force is always zero
(c) the mechanical energy of bob does not remain constant in the absence of air
(d) the mechanical energy remains constant in the presence of air resistance

10. If a man having bag in his hand moves up on a stair, then :
(a) the work done by lifting force is zero
(b) the work done by lifting force is non-zero with respect to ground
(c) the work done by lifting force is zero with respect to ground
(d) the work done with respect to ground is same as that with respect to him

11. Work done during raising a box on to a platform :
(a) depends upon how fast it is raised
(b) does not depend upon how fast it is raised
(c) does not depend upon mass of the box
(d) both (a) and (b) are correct

12. A Swimmer swims upstream at rest with respect to the shore :
(a) in the mechanical sense, he does not perform work
(b) in physical sense, he does not perform work
(c) in the mechanical sense, he may perform work
(d) in physical sense, he may perform work

13. A force of 0.5 N is applied on upper block as shown in figure. The work done by lower block on upper block for a displacement 3 m of the upper block is : (Take $g = 10\ m/s^2$)

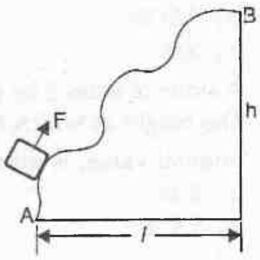


(a) 1 joule (b) – 1 joule
(c) 2 joule (d) – 2 joule

14. In previous problem, work done by lower block on upper block in the frame of lower block is :
(a) – 1 joule (b) – 2 joule
(c) 2 joule (d) zero

15. In previous problem, work done by upper block on lower block is :
(a) 1 joule (b) – 1 joule
(c) – 2 joule (d) 2 joule

16. A body of mass m was slowly halved upon the hill by a force which at each point was directed along a tangent to the path. The work done by the applied force :



(a) does not depend upon path followed by the body
(b) depends upon path
(c) does not depend upon position of A and B
(d) both (a) and (c) are correct

17. In an elastic string whose natural length is equal to that of a uniform rod be attached to the rod at both ends and suspended by the middle point :
(a) the rod will sink until the total work done is non-zero
(b) the rod will sink until the total work done is zero
(c) sinking of rod is not determined on the basis of work done
(d) sinking of rod is not possible

18. A particle moves along a curve of unknown shape but magnitude of force F is constant and always acts along tangent to the curve. Then :
(a) $\vec{F}$ may be conservative
(b) $\vec{F}$ must be conservative
(c) $\vec{F}$ may be non-conservative
(d) $\vec{F}$ must be non-conservative

19. If a particle is compelled to move on a given smooth plane curve under the action of given forces in the plane $\vec{F} = \vec{x}i + \vec{y}j$, then :
(a) $\vec{F} \cdot \vec{dr} = xdx + ydy$ (b) $\int \vec{F} \cdot \vec{dr} \neq \frac{1}{2} mv^2$
(c) $\vec{F} \cdot \vec{dr} \neq xdx \times ydy$ (d) $\frac{1}{2} mv^2 \neq \int (xdx + ydy)$

20. If c is a closed curve, then for conservative force $\vec{F}$:
(a) $\oint \vec{F} \cdot \vec{dr} \neq 0$ (b) $\oint \vec{F} \cdot \vec{dr} < 0$
(c) $\oint_c \vec{F} \cdot \vec{dr} > 0$ (d) $\oint \vec{F} \cdot \vec{dr} = 0$

21. Which of the following is/are not conservative force ?
(a) Gravitational force
(b) Electrostatic force in the coulomb field
(c) Frictional force
(d) All of the above

22. If $\vec{F} = F_x \hat{i} + F_y \hat{j} + F_z \hat{k}$ is conservative, then :
(a) $\frac{\partial F_x}{\partial y} = \frac{\partial F_y}{\partial x}, \frac{\partial F_y}{\partial z} = \frac{\partial F_z}{\partial y}, \frac{\partial F_z}{\partial x} = \frac{\partial F_x}{\partial z}$
(b) $\frac{\partial F_x}{\partial y} \neq \frac{\partial F_y}{\partial x}$
(c) $\frac{\partial F_x}{\partial y} + \frac{\partial F_y}{\partial x} = \frac{\partial F_z}{\partial z}$
(d) none of the above

23. If a man of mass M jumps to the ground from a height h and his centre of mass moves a distance x in the time taken by him to hit the ground, the average force acting on him is :
(a) $\frac{Mgh}{x}$ (b) $\frac{Mgx}{h}$
(c) $Mg\left(\frac{h}{x}\right)^2$ (d) $Mg\left(\frac{x}{h}\right)^2$

24. The potential energy of a particle of mass 0.1 kg moving along the x-axis is given by $U = 5x(x-4)$ J, where x is in metre. It can be concluded that :
(a) the particle is acted upon by a constant force
(b) the speed of the particle is maximum at $x = 2$ m
(c) the particle cannot execute simple harmonic motion
(d) the period of oscillation of the particle is $\frac{\pi}{20}$ s

25. The potential energy as a function of the force between two atoms in a diatomic 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 position of stable equilibrium for the system of the two atoms is given by :
(a) $x = \frac{a}{b}$ (b) $x = \sqrt{\frac{a}{b}}$
(c) $x = \frac{\sqrt{3a}}{b}$ (d) $x = \sqrt[6]{\left(\frac{2a}{b}\right)}$

26. The potential energy of a particle of mass 5 kg moving in the x-y plane is given by $U = (-7x + 24y)$ J. x and y being in meter. If the particle starts from rest from origin then speed of particle at $t = 2$ sec is :
(a) 5 m/s (b) 14 m/s
(c) 17.5 m/s (d) 10 m/s

27. The potential energy of a particle of mass 5 kg moving in the x-y plane is given by $U = -7x + 24y$ joule, x and y being in metre. Initially at $t = 0$ the particle is at the origin. (0, 0) moving with a velocity of $6[2.4\hat{i} + 0.7\hat{j}]$ m/s. The magnitude of force on the particle is :
(a) 25 units (b) 24 units
(c) 7 units (d) none of these

28. Which one of the following units measures energy ?
(a) kilo-watt-hour (b) $(\text{volt})^2 (\text{sec})^{-1} (\text{ohm})^{-1}$
(c) $(\text{pascal}) (\text{foot})^2$ (d) none of the above

29. A balloon is rising from the surface of earth. Then its potential energy :
(a) increases
(b) decreases
(c) first increases then decreases
(d) remains constant

30. If a compressed spring is dissolved in acid :
(a) the energy of the spring increases
(b) the energy of acid decreases
(c) the potential energy and kinetic energy of molecules of acid increases
(d) the temperature of acid decreases

31. Two identical cylindrical shape vessels are placed, A at ground and B at height h. Each contains liquid of density ρ and the heights of liquid in A and B are h_1 and h_2 respectively. The area of either base is A. The total potential energy of liquid system with respect to ground is :

(a) $\frac{A\rho g}{2}(h_1^2+h_2^2+2hh_2)$ (b) $\frac{A\rho g}{2}(h_1+h_2)^2+h_2^2$

(c) $h \cdot A\rho g\,(h_1+h+h_2)$ (d) $\frac{A\rho g}{2}\left(\frac{h_1+h}{2}\right)+h_2^2$

32. A long spring, when stretched by x cm has a potential energy U. On increasing the length of spring by stretching to nx cm, the potential energy stored in the spring will be :

(a) $\frac{U}{n}$ (b) nU

(c) n^2U (d) $\frac{U}{n^2}$

33. Two identical massless springs A and B consist spring constant k_A and k_B respectively. Then :

(a) if they are compressed by same force, work done on A is more expanded when $k_A > k_B$

(b) if they are compressed by same amount, work done on A is more expanded when $k_A < k_B$

(c) if they are compressed by same amount, work done on A is more expanded when $k_A > k_B$

(d) both (a) and (b) are correct

34. Mark correct option :

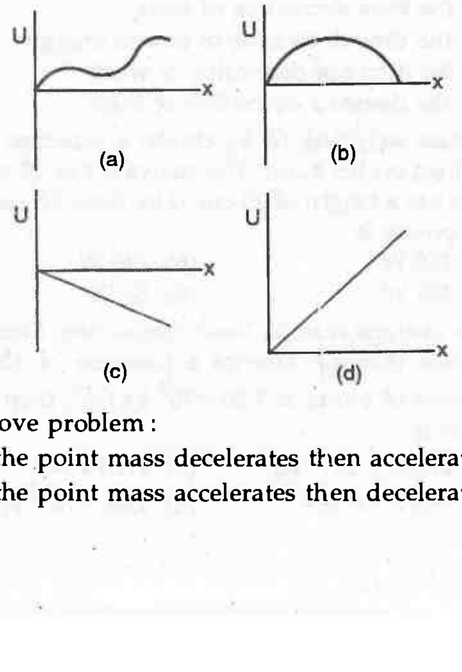
(a) The negative change in potential energy is equal to work done

(b) Mechanical energy of a system remains constant

(c) If internal forces are non-conservative, the net work done by internal forces must be zero

(d) None of the above

35. A point mass m is released from rest on an undeformed massless spring of force constant k. Which of the following graphs represents U-x graph for reference level of gravitational potential energy at initial position ?



36. In the above problem :

(a) first the point mass decelerates then accelerates

(b) first the point mass accelerates then decelerates

(c) at the maximum compression of spring, acceleration of mass is zero

(d) the point mass moves with constant velocity

37. An object kept on a smooth inclined plane of height 1 unit and length l can be kept stationary relative to inclined plane by a horizontal acceleration equals to :

(a) $\frac{g}{\sqrt{l^2-1}}$ (b) $\frac{g}{\sqrt{l^2+1}}$

(c) $\frac{1}{g\sqrt{l^2-1}}$ (d) $g\sqrt{l^2-1}$

38. The work done on a particle is equal to the change in its kinetic energy :

(a) always

(b) only if the force acting on the body are conservative

(c) only if the forces acting on the body are gravitational

(d) only if the forces acting on the body are elastic

39. If a car is moving on a straight road with constant speed, then :

(a) work is done against force of friction

(b) net work done on car is zero

(c) net work done may be zero

(d) both (a) and (b) are correct

40. The kinetic energy of a particle moving on a curved path continuously increases with time. Then :

(a) resultant force on the particle must be parallel to the velocity at all instants

(b) the resultant force on the particle must be at an angle less than 90° all the time

(c) its height above the ground level must continuously decrease

(d) the magnitude of its linear momentum is increasing continuously

(e) both (b) and (d) are correct

41. Force F acts on a body of mass 1 kg moving with an initial velocity v_0 for 1 sec. Then :

(a) distance covered by the body is $v_0+\frac{F}{2}$

(b) final velocity of body is (v_0+F)

(c) momentum of body is increased by F

(d) all of the above

42. A block of mass m is hanging over a smooth and light pulley through a light string. The other end of the string is pulled by a constant force F. The kinetic energy of the block increases by 20 J in 1 s is :

(a) the tension in the string is mg

(b) the tension in the string is F

(c) the work done by the tension on the block is 20 J in the above 1 s

(d) the work done by the force of gravity is 20 J in the above 1 s

43. When a bullet of mass 10 g and speed 100 m/s penetrates up to distance 1 cm in a human body in rest. The resistance offered by human body is :

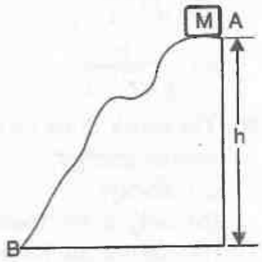
(a) 2000 N (b) 1500 N

(c) 5000 N (d) 1000 N

44. A 60 g bullet is fired through a stack of fibre board sheet, 200 mm thick. If the bullet approaches the stack with a velocity of 600 m/s, the average resistance offered to the bullet is :

(a) 54 kN (b) 2 kN
(c) 20.25 kN (d) 10 kN

45. In the given curved road, if particle is released from A then:



(a) kinetic energy at B must be mgh
(b) kinetic energy at B may be zero
(c) kinetic energy at B must be less than mgh
(d) kinetic energy at B must not be equal to zero

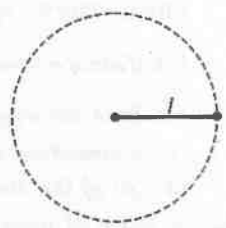
46. A bucket tied to a string is lowered at a constant acceleration of $\frac{g}{4}$. If the mass of the bucket is m and is lowered by a distance d, the work done by the string will be :

(a) $\frac{mgd}{4}$ (b) $-\frac{3}{4}mgd$
(c) $-\frac{4}{3}mgd$ (d) $\frac{4}{3}mgd$

47. A stone tied to a string of length L is whirled in a vertical circle with the other end of the string at 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 its velocity as it reaches a position where the string is horizontal is :

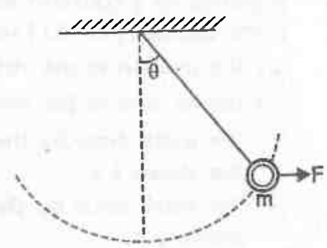
(a) $\sqrt{u^2 - 2gL}$ (b) $\sqrt{2gL}$
(c) $\sqrt{u^2 - gL}$ (d) $\sqrt{2(u^2 - gL)}$

48. A small sphere of mass m is suspended by a thread of length l. It is raised upto the height of suspension with thread fully stretched and released. Then the maximum tension in thread will be :



(a) mg (b) $2mg$
(c) $3mg$ (d) $6mg$

49. An object of mass m is tied to a string of length L and a variable horizontal force is applied on it which starts at zero and gradually increases until the string makes an angle θ with the vertical. Work done by the force F is :



(a) $mgL(1 - \sin\theta)$ (b) mgL
(c) $mgL(1 - \cos\theta)$ (d) $mgL(1 + \cos\theta)$

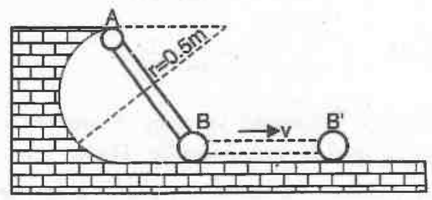
50. An elastic string of unstretched length L and force constant k is stretched by a small length x. It is further stretched by another small length y. The work done in the second stretching is :

(a) $\frac{1}{2}ky^2$ (b) $\frac{1}{2}k(x^2 + y^2)$
(c) $\frac{1}{2}k(x + y)^2$ (d) $\frac{1}{2}ky(2x + y)$

51. An insect is crawling up a fixed hemispherical bowl of radius R. The coefficient of friction between insect and bowl is $\frac{1}{3}$. The insect can only crawl upto a height :

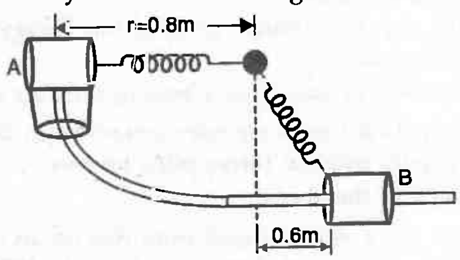
(a) 60% of R (b) 10% of R
(c) 5% of R (d) 100% of R

***52.** Two small balls of equal mass are joined by a light rigid rod. If they are released from rest in the position shown and slide on the smooth track in the vertical plane. The speed of balls when A reaches B's position and B is at B' is :



(a) 4 m/s (b) 4.21 m/s
(c) 2.21 m/s (d) none of these

***53.** In the given figure, the natural length of spring is 0.4 m and spring constant is 200 N/m. The 3kg slider and attached spring are released from rest at end move in the vertical plane. The slider comes in rest at the point B. The work done by the friction during motion of slider is :



(a) − 3.52 J (b) − 0.8 J
(c) − 100 J (d) − 10.54 J

54. Power is :

(a) the time derivative of force
(b) the time derivative of kinetic energy
(c) the distance derivative of work
(d) the distance derivative of force

55. A man weighing 60 kg climbs a staircase carrying a 20 kg load on his hand. The staircase has 20 steps and each step has a height of 20 cm. If he takes 20 second to climb, his power is :

(a) 160 W (b) 230 W
(c) 320 W (d) 80 W

56. The average human heart forces four litre of blood per minute through arteries a pressure of 125 mm. If the density of blood is 1.03×10^3 kg/m^3, then the power of heart is :

(a) 112.76×10^{-6} HP (b) 112.76 HP
(c) 1.03×10^{-5} HP (d) 1.03×10^{-6} HP

57. An object of mass M, initially at rest under the action of a constant force F attains a velocity v in time t. Then the average power supplied to the mass is :

(a) Fv (b) $\frac{1}{2}Fv$

(c) zero (d) $\frac{mv^2}{2t}$

58. The power supplied by a force acting on a particle moving in a straight line is constant. The velocity of the particle varies with the displacement x as :

(a) $\sqrt{x}$ (b) x

(c) x^2 (d) $x^{1/3}$

59. A particle of mass m is moving in a circular path of constant radius r such that its centripetal acceleration a_c is varying with time t as $a_c = k^2rt^2$. The power is :

(a) $2\pi mk^2r^2t$ (b) mk^2r^2t

(c) $\frac{mk^4r^2t^5}{3}$ (d) zero

60. A wind powered generator converts wind energy into electrical energy. Assume that the generator converts a fixed fraction of the wind energy intercepted by its blades into electrical energy for wind speed v, the electrical power output will be proportional to :

(a) v (b) v^2

(c) v^3 (d) v^4

61. A particle moves with a velocity $(5\hat{i} - 3\hat{j} + 6\hat{k})$ m/s under the influence of a constant force $\vec{F} = 10\hat{i} + 10\hat{j} + 20\hat{k}$ N. The instantaneous power applied to the particle is

(a) 200 J/sec (b) 40 J/sec

(c) 140 J/sec (d) 170 J/sec

Answers

Level-1

1. (c)	2. (b)	3. (c)	4. (a)	5. (c)	6. (a)	7. (c)	8. (a)	9. (d)	10. (a)
11. (d)	12. (b)	13. (c)	14. (a)	15. (a)	16. (a)	17. (b)	18. (a)	19. (c)	20. (c)
21. (d)	22. (b)	23. (b)	24. (b)	25. (d)	26. (a)	27. (b)			

Level-2

1. (a)	2. (a)	3. (c)	4. (d)	5. (d)	6. (c)	7. (b)	8. (c)	9. (b)	10. (b)
11. (b)	12. (a)	13. (b)	14. (d)	15. (a)	16. (a)	17. (b)	18. (d)	19. (a)	20. (d)
21. (c)	22. (a)	23. (a)	24. (b)	25. (d)	26. (d)	27. (a)	28. (a)	29. (b)	30. (c)
31. (a)	32. (c)	33. (c)	34. (d)	35. (b)	36. (b)	37. (a)	38. (a)	39. (d)	40. (e)
41. (d)	42. (b)	43. (c)	44. (a)	45. (b)	46. (b)	47. (d)	48. (c)	49. (c)	50. (d)
51. (c)	52. (c)	53. (a)	54. (b)	55. (a)	56. (a)	57. (b)	58. (d)	59. (b)	60. (c)
61. (c)									

Solutions

Level-1

2. $$0 = |\vec{F}|\,|\vec{s}|\cos\theta$$

$$\cos\theta = 0$$

$\therefore$ $$\theta = 90^\circ$$

3. $$W = PdV = 50\,(205 - 5) = 10000\text{ J}$$

4. $$n = \frac{300}{60} = 5\text{ rev/s}$$

$$\omega = 2\pi n = 10\,\pi$$

$$KE = \frac{1}{2}mv^2 = \frac{1}{2}mr^2\omega^2$$

$$= \frac{1}{2} \times 60 \times (0.4)^2 \times (10\pi)^2$$

$$= \frac{1}{2} \times 60 \times 0.16 \times 100\,\pi^2 = 480\pi^2\text{ J}$$

5. Acceleration $$a = \frac{5}{20} = \frac{1}{4}\text{ m/s}^2$$

$$v = \sqrt{(2as)} = \sqrt{\left(\frac{2 \times 2}{4}\right)} = 1\text{ m/s}$$

$$KE = \frac{1}{2}mv^2 = \frac{1}{2} \times 20 \times (1)^2 = 10\text{ J}$$

or Work done, $W = Fs$

$$= 5 \times 2 = 10\text{ J}$$

6. Given : $x = \frac{t^3}{3} \Rightarrow \frac{dx}{dt} = \frac{3t^2}{3} \Rightarrow v = t^2$

Work done, $W = \frac{1}{2}mv^2$

$$= \frac{1}{2} \times 2 \times t^4 = \frac{1}{2} \times 2 \times (2)^4 = 16\text{ J}$$

7. Initial velocity $= \frac{mv}{m} = \frac{10}{5} = 2$ m/s

Acceleration $= \frac{2}{5} = 0.4$ m/s^2

From euqation of motion

$$s = ut + \frac{1}{2}at^2 = 2 \times 5 + \frac{1}{2} \times 0.4 \times 5 \times 5$$

7

Centre of Mass, Momentum and Collision

Syllabus: Elastic collisions in one and two dimensions, conservation of linear momentum, rocket propulsion, centre of mass of a two particle system, centre of mass of a rigid body.

Review of Concepts

1. Centre of Mass :

(a) The centre of mass need not to lie in the body.

(b) Internal forces do not change the centre of mass.

(c) When a cracker explodes in air, the centre of mass of fragments travel along parabolic path.

(d) The sum of moment of masses about its centre of mass is always zero.

(e) The position of centre of mass does not depend upon the co-ordinate system chosen.

(f) If we take any closed area in a plane and generate a solid by moving it through space such that each point is always moved perpendicular to the plane of the area, the resulting solid has a total volume equal to area of the cross-section times the distance that the centre of mass moved. The volume generated by spinning it about an axis is the distance that the centre of mass goes around times the area of the plane.

(g) When a body is allowed to fall freely from a height h_1 and if it rebounds to height h_2, then $e = \sqrt{\frac{h_2}{h_1}}$.

(h) When a bullet of mass m penetrates upto a distance x in the large stationary wooden block, the resistance offered by the block $= R = \frac{mv^2}{2x}$

$$v^2 = \text{constant} \quad \text{or} \quad \frac{v_1^2}{x_1} = \frac{v_2^2}{x_2}$$

2. Momentum :

(a) The linear momentum of a body is defined as the product of mass of body and its velocity *i.e.*,

$$\vec{p} = m\vec{v}$$

(b) It depends on frame of reference.

(c) A body cannot have momentum without having energy but the body may have energy (*i.e.*, potential energy) without having momentum.

(d) The momentum of a body may be negative.

(e) The slope of p versus t curve gives the force.

(f) The area under F versus t curve gives the change in momentum.

(g) A meteorite burns in the atmosphere. Its momentum is transferred to air molecules and the earth.

(h) If light (m_1) and heavy (m_2) bodies have same momentum, then $\frac{E_1}{E_2} = \frac{m_2}{m_1}$.

(i) Momentum transferred to a floor when a ball hits the floor is $\Delta p = p\left(\frac{1+e}{1-e}\right)$

where e = coefficient of restitution explained in article 4(e).

3. Conservation of Momentum :

(a) If the external force acting on a system of particles (or body) is zero, then net linear momentum of the system (or body) is conserved.

i.e., If $\vec{F}_{ext} = 0$ then $\vec{F}_{ext} = \frac{d\vec{p}}{dt} = 0$

i.e., $\quad d\vec{p} = 0$

(b) Law of conservation of linear momentum always holds good for a closed system.

(c) It is a consequence of Newton's third law.

4. Collision :

(a) When elastic collision takes place in one dimension between two bodies of masses m_1 and m_2 having initial velocities as u_1, u_2 and v_1, v_2 as the final velocities after collision, then

$$u_1 - u_2 = v_2 - v_1$$

$$v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)u_1 + \left(\frac{2m_2}{m_1 + m_2}\right)u_2$$

$$v_2 = \left(\frac{m_2 - m_1}{m_1 + m_2}\right)u_2 + \frac{2m_1u_1}{m_1 + m_2}$$

(b) Two bodies of equal masses exchange their velocities after suffering one dimensional elastic collision. It means

$$m_1 = m_2, \quad v_1 = u_2 \quad \text{and} \quad v_2 = u_1$$

(c) When two bodies of same mass are approaching each other with different velocities and collide, then they simply exchange the velocities and move in the opposite direction.

(d) When a heavy body moving with velocity u collides with a lighter body at rest, then the heavier body remains moving in the same direction with almost same velocity. The lighter body moves in the same direction with a nearly velocity of $2u$.

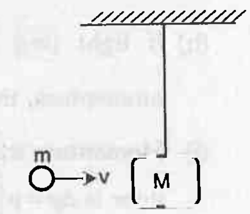
(e) The coefficient of restitution $= e = \dfrac{v_1 - v_2}{u_2 - u_1}$.

(i) For a perfectly elastic collision, $e = 1$.
(ii) For a perfectly inelastic collision, $e = 0$.
(iii) For an elastic collision, $0 < e < 1$.

(f) The relation between momentum and kinetic energy E:

$E = \dfrac{p^2}{2m}$, p = momentum of the particle of the mass m.

(g) When a body of mass M suspended by a string is hit by a bullet of mass m moving with velocity v and embeds in the body, then common velocity of the system,



$$v_1 = \frac{mv}{m + M}$$

(h) The height to which system rises:

$$(M + m)\, gh = \frac{1}{2}(m + M)\, v_1^2$$

$$\therefore \quad h = \frac{v_1^2}{2g}$$

The velocity of bullet $= v = \left(\dfrac{M + m}{m}\right)\sqrt{2gh}$

(i) When a body brought in rest by frictional force, then

$$\mu mgs = \frac{1}{2} mv^2$$

(j) Fraction of kinetic energy lost in an elastic collision.

$$\frac{\Delta K_{\text{lost}}}{K_i} = \frac{4m_1 m_2}{(m_1 + m_2)^2}$$

(k) The fraction of energy lost (which may appear as heat, light, sound, etc.) in an inelastic collision is

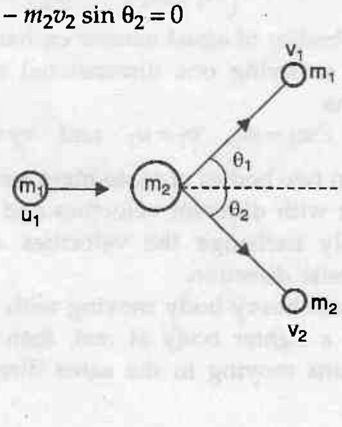
$$\frac{\Delta K_{\text{lost}}}{K_i} = \frac{m_2 (1 - e^2)}{(m_1 + m_2)}$$

5. When Elastic Collision Takes Place in Two Dimensions:

$$\frac{1}{2} m_1 u_1^2 + \frac{1}{2} m_2 u_2^2 = \frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2$$

$$m_1 u_1 + m_2 u_2 = m_1 v_1 \cos\theta_1 + m_2 v_2 \cos\theta_2$$

$$m_1 v_1 \sin\theta_1 - m_2 v_2 \sin\theta_2 = 0$$



(a) Two bodies of mass m_1 (heavy) and mass m_2 (light) are moving with same kinetic energy. If they are stopped by the same retarding force, then

(i) The bodies cover the same distance before coming to rest.
(ii) The time taken to come to rest is lesser for m_2 as it has less momentum *i.e.*, $t = \dfrac{p}{F}$.
(iii) The time taken to come to rest is more for m_1 as it has greater momentum.

(b) Two bodies A and B having masses m_1 and m_2 have equal kinetic energies. If they have velocities v_1 and v_2, then

$$\frac{v_1}{v_2} = \sqrt{\frac{m_2}{m_1}}$$

and $$\frac{p_1}{p_2} = \sqrt{\left(\frac{m_1}{m_2}\right)}$$

where p_1 and p_2 are their momenta.

(c) If a single particle is moving under a conservative field of force, the sum of the kinetic energy and potential energy is always constant.

(d) The impulse of a force in a given time is equal to the change in momentum in the direction of the force during that time.

(e) If a bullet of mass m_1 moving with a velocity u, strikes a mass m_2 which is free to move in the direction of the bullet and is embedded in it, then the loss of kinetic energy is $= \dfrac{1}{2}\left(\dfrac{m_1 m_2 u^2}{m_1 + m_2}\right)$

(f) A shell of mass m_1 is ejected from a gun of mass m_2 by an explosion which generates kinetic energy equals to E. Then the initial velocity of the shell is $\sqrt{\left[\dfrac{2m_2 E}{m_1 (m_1 + m_2)}\right]}$

(g) A gun of mass m_2 fires a shell of mass m_1 horizontally and the energy of explosion is such as would be sufficient to project the shell vertically to a height h. Then the velocity of recoil of the gun is $\sqrt{\left[\dfrac{2m_1^2 gh}{m_2 (m_1 + m_2)}\right]}$.

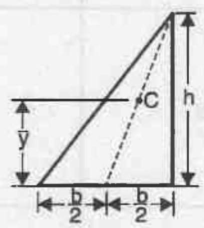
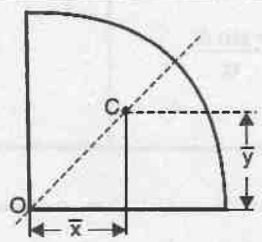
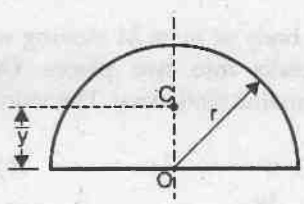
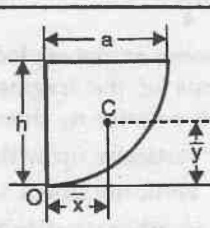
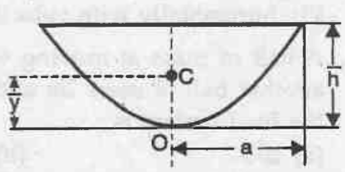
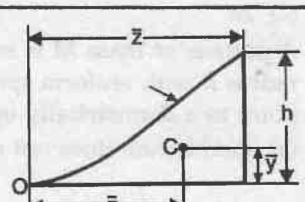
(h) A bullet of mass m_1 penetrates a thickness of a fixed plate of mass m_2. If m_2 is free to move and the resistance is supposed to be uniform, then the thickness penetrated is $\dfrac{m_2 s}{m_1 + m_2}$.

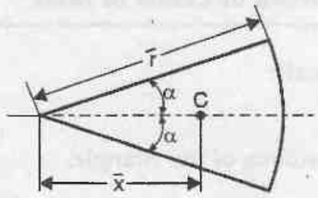
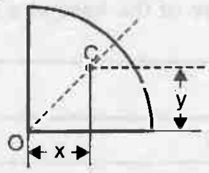
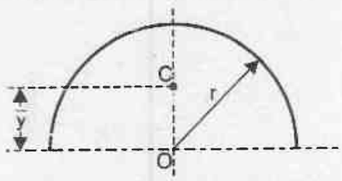
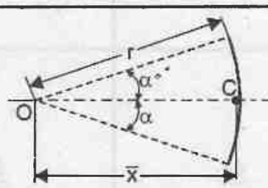
(i) The position of centre of mass remains unchanged in rotatory motion while the position is changed in translatory motion.

6. **The centre of Mass of Some Rigid Bodies :**

Shape of the Body	Position of Centre of Mass
Uniform rod	The middle point of the rod.
Cubical box	The point of intersection of diagonals.
Circular ring	Centre of the ring.
Circular disc	Centre of the disc.
Triangular plane lamina	The point of intersection of the medians of the triangle.
Cylinder	Middle point of the axis.
Sphere	Centre of the sphere.
Cone	On the line joining the apex to the centre of the base at a distance 1/4 of the length of this line from the base.

7. **Centre of Mass of Common Shapes of Areas and Lines :**

Shape	Figure	$\bar{x}$	$\bar{y}$	Area
Triangular area			$\frac{h}{3}$	$\frac{bh}{2}$
Quarter circular area		$\frac{4r}{3\pi}$	$\frac{4r}{3\pi}$	$\frac{\pi r^2}{4}$
Semicircular area		0	$\frac{4r}{3\pi}$	$\frac{\pi r^2}{2}$
Semiparabolic area		$\frac{3a}{8}$	$\frac{3h}{5}$	$\frac{2ah}{3}$
Parabolic area			$\frac{3h}{5}$	$\frac{4ah}{3}$
Parabolic spandrel		$\frac{3a}{4}$	$\frac{3h}{10}$	$\frac{ah}{3}$

Shape	Figure	$\bar{x}$	$\bar{y}$	Area
Circular sector		$\frac{2r \sin \alpha}{3\alpha}$	0	πr^2
Quarter circular arc		$\frac{2r}{\pi}$	$\frac{2r}{\pi}$	$\frac{\pi r}{2}$
Semicircular arc		0	$\frac{2r}{\pi}$	πr
Arc of circle		$\frac{r \sin \alpha}{\alpha}$	0	$2\alpha r$

Objective Questions

Level-1

1. In an elastic collision :
   (a) only KE of system is conserved
   (b) only momentum is conserved
   (c) both KE and momentum are conserved
   (d) neither KE nor momentum is conserved
2. An example of inelastic collision is :
   (a) scattering of α particle from a nucleus
   (b) collision of ideal gas molecules
   (c) collision of two steel balls lying on a frictionless table
   (d) collision of a bullet with a wooden block
3. Two solid rubber balls A and B having masses 200 g and 400 g respectively are moving in opposite directions with velocity of A which is equal to 0.3 m/s. After collision the two balls come to rest when the velocity of B is :
   (a) 0.15 m/s (b) 1.5 m/s
   (c) – 0.15 m/s (d) none of these
4. Two bodies of identical mass m are moving with constant velocity v but in the opposite directions and stick to each other, the velocity of the compound body after collision is :
   (a) v (b) $2v$
   (c) zero (d) $\frac{v}{2}$
5. A body of mass M moving with velocity v m/s suddenly breaks into two pieces. One part having mass $M/4$ remains stationary. The velocity of the other part will be :
   (a) v (b) $2v$
   (c) $\frac{3v}{4}$ (d) $\frac{4v}{3}$
6. A bomb at rest explodes in air into two equal fragments. If one of the fragments is moving vertically upwards with velocity v_0, then the other fragment will move :
   (a) vertically up with velocity v_0
   (b) vertically down with velocity v_0
   (c) in arbitrary direction with velocity v_0
   (d) horizontally with velocity v_0
7. A ball of mass m moving with velocity v collides with another ball of mass $2m$ and sticks to it. The velocity of the final system is :
   (a) $v/3$ (b) $v/2$
   (c) $2v$ (d) $3v$
8. A particle of mass M is moving in a horizontal circle of radius R with uniform speed v. When it moves from one point to a diametrically opposite point, its :
   (a) momentum does not change

(b) momentum changes by $2Mv$
(c) KE changes by Mv^2
(d) none of the above

9. Two balls of masses 2 g and 6 g are moving with KE in the ratio of 3 : 1. What is the ratio of their linear momenta ?
(a) 1 : 1 (b) 2 : 1
(c) 1 : 2 (d) None of these

10. A body of mass 3 kg is moving with a velocity of 4 m/s towards left, collides head on with a body of mass 4 kg moving in opposite direction with a velocity of 3 m/s. After collision the two bodies stick together and move with a common velocity, which is :
(a) zero (b) 12 m/s towards left
(c) 12 m/s towards right (d) $\frac{12}{7}$ m/s towards left

11. A ball of mass m moving with velocity v collides elastically with another ball of identical mass coming from opposite direction with velocity $2v$. Their velocities after collision will be :
(a) $-v, 2v$ (b) $-2v, v$
(c) $v, -2v$ (d) $2v, -v$

12. Two perfectly elastic objects A and B of identical mass are moving with velocities 15 m/s and 10 m/s respectively, collide along the direction of line joining them. Their velocities after collision are respectively :
(a) 10 m/s, 15 m/s (b) 20 m/s, 5 m/s
(c) 0 m/s, 25 m/s (d) 5 m/s, 20 m/s

13. A bullet of mass 5 g is moving with a velocity 10 m/s strikes a stationary body of mass 955 g and enter it. The percentage loss of kinetic energy of the bullet is :
(a) 85 (b) 0.05
(c) 99.5 (d) none of these

14. A ball of mass m_1 is moving with velocity v. It collides head on elastically with a stationary ball of mass m_2. The velocity of ball becomes $\frac{v}{3}$ after collision, then the value of the ratio $\frac{m_2}{m_1}$ is :
(a) 1 (b) 2
(c) 3 (d) 4

15. A bomb of mass 1 kg explodes in the ratio 1 : 1 : 3. The fragments having same mass move mutually perpendicular to each other with equal speed 30 m/s, the velocity of the heavier part is :
(a) $10\sqrt{2}$ m/s (b) $20\sqrt{2}$ m/s
(c) $30\sqrt{2}$ m/s (d) none of these

16. Two spherical bodies of the same mass M are moving with velocities v_1 and v_2. These collide perfectly inelastically, then the loss in kinetic energy is :
(a) $\frac{1}{2}M(v_1 - v_2)^2$ (b) $\frac{1}{2}M(v_1^2 - v_2^2)$
(c) $\frac{1}{4}M(v_1 - v_2)^2$ (d) $2M(v_1^2 - v_2^2)$

17. A body of mass 8 kg collides elastically with a stationary mass of 2 kg. If initial KE of moving mass be E, the kinetic energy left with it after the collision will be :
(a) $0.80E$ (b) $0.64E$
(c) $0.36E$ (d) $0.08E$

18. A ball falling freely from a height of 4.9 m hits a horizontal surface. If $e = \frac{3}{4}$, then the ball will hit the surface second time after :
(a) 0.5 sec (b) 1.5 sec
(c) 3.5 sec (d) 3.4 sec

Level-2

1. Four particles of masses 1 kg, 2 kg, 3 kg and 4 kg are placed at the corners A, B, C and D respectively of a square $ABCD$ of edge 1 m. If point A is taken as origin, edge AB is taken along X-axis and edge AD is taken along Y-axis, the co-ordinates of centre of mass in S.I. is :
(a) (1, 1) (b) (5, 7)
(c) (0.5, 0.7) (d) none of these

2. Two homogeneous spheres A and B of masses m and $2m$ having radii $2a$ and a respectively are placed in touch. The distance of centre of mass from first sphere is :
(a) a (b) $2a$
(c) $3a$ (d) none of these

3. A circular hole of radius 1 cm is cut off from a disc of radius 6 cm. The centre of hole is 3 m from the centre of the disc. The position of centre of mass of the remaining disc from the centre of disc is :
(a) $-\frac{3}{35}$ cm (b) $\frac{1}{35}$ cm
(c) $\frac{3}{10}$ cm (d) None of these

4. A non-uniform thin rod of length L is placed along X-axis as such its one of end is at the origin. The linear mass density of rod is $\lambda = \lambda_0 x$. The distance of centre of mass of rod from the origin is :
(a) $\frac{L}{2}$ (b) $\frac{2L}{3}$ (c) $\frac{L}{4}$ (d) $\frac{L}{5}$

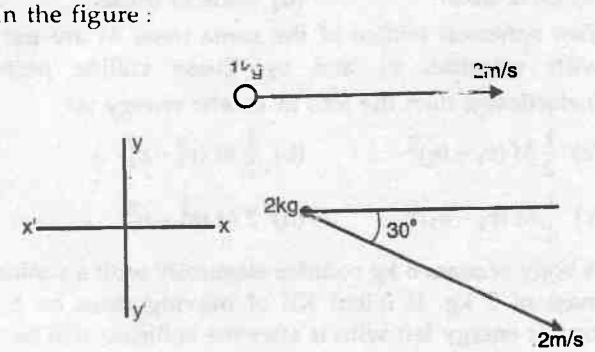
5. Centre of mass of a semicircular plate of radius R, the density of which linearly varies with distance, d at centre to a value $2d$ at circumference is :
(a) $\frac{3R}{\pi}$ from centre (b) $\frac{4R}{2\pi}$ from centre
(c) $\frac{5R}{\pi}$ from centre (d) $\frac{7R}{5\pi}$ from centre

6. Mark correct option or options :
(a) Nagpur can be said to the geographical centre of India
(b) The population centre of India may be Uttar Pradesh
(c) The population centre may be coincided with geographical centre
(d) All the above

7. Which of the following has centre of mass not situated in the material of body ?
(a) A rod bent in the form of a circle
(b) Football
(c) Handring
(d) All the above

8. In which of the following cases the centre of mass of a rod is certainly not at its geometrical centre ?
(a) The density continuously decreases from left to right
(b) The density continuously increases from left to right
(c) The density decreases from left to right upto the centre and then increases
(d) Both (a) and (b) are correct

9. Find the velocity of centre of mass of the system shown in the figure :



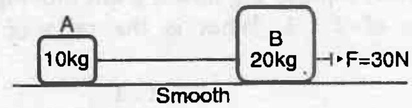
(a) $\left(\frac{2+2\sqrt{3}}{3}\right)\hat{i}-\frac{2}{3}\hat{j}$ (b) $4\hat{i}$
(c) $\left(\frac{2-2\sqrt{3}}{3}\right)\hat{i}-\frac{1}{3}\hat{j}$ (d) None of these

10. A ball kept in a closed box moves in the box making collisions with the walls. The box is kept on a smooth surface. The centre of mass :
(a) of the box remains constant
(b) of the box plus the ball system remains constant
(c) of the ball remains constant
(d) of the ball relative to the box remains constant

11. A man of mass M stands at one end of a plank of length L which lies at rest on a frictionless surface. The man walks to the other end of the plank. If the mass of plank is $M/3$, the distance that the mass moves relative to the ground is :
(a) $\frac{3L}{4}$ (b) $\frac{L}{4}$
(c) $\frac{4L}{5}$ (d) $\frac{L}{3}$

12. The centre of mass of a system cannot change its state of motion, unless there is an external force acting on it. Yet the internal force of the brakes can bring a car to rest. Then :
(a) the brakes stop the wheels
(b) the friction between the brake pads and the wheel stops the car
(c) the car is stopped by the road
(d) the car is stopped by the driver pressing the pedal

13. Two blocks A and B are connected by a massless string (shown in fig.) A force of 30 N is applied on block B. The distance travelled by centre of mass in 2 second starting from rest is :

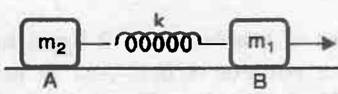


(a) 1 m (b) 2 m
(c) 3 m (d) none of these

14. The motion of the centre of mass of a system of two particles is unaffected by their internal forces :
(a) irrespective of the actual directions of the internal forces
(b) only if they are along the line joining the particles
(c) only if they are at right angles to the line joining particles
(d) only if they are obliquely inclined to the line joining the particles

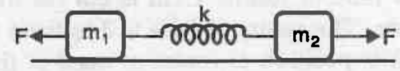
15. A loaded spring gun of mass M fires a shot of mass m with a velocity v at an angle of elevation θ. The gun is initially at rest on a horizontal frictionless surface. After firing, the centre of mass of the gun-shot system :
(a) moves with a velocity $v\frac{m}{M}$
(b) moves with a velocity $\frac{vm}{M}\cos\theta$ in the horizontal direction
(c) remains at rest
(d) moves with a velocity $\frac{v(M-m)}{(M+m)}$ in the horizontal direction

16. Two bodies A and B of masses m_1 and m_2 respectively are connected by a massless spring of force constant k. A constant force F starts acting on the body A at $t=0$. Then:



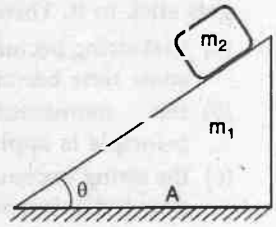
(a) at every instant, the acceleration of centre of mass is $\frac{F}{m_1+m_2}$
(b) at $t=0$, acceleration of B is zero but that of A is maximum
(c) the acceleration of A decreases continuously
(d) all the above

17. In the given figure, two bodies of masses m_1 and m_2 are connected by massless spring of force constant k and are placed on a smooth surface (shown in figure), then :



(a) the acceleration of centre of mass must be zero at every instant
(b) the acceleration of centre of mass may be zero at every instant
(c) the system always remains in rest
(d) none of the above

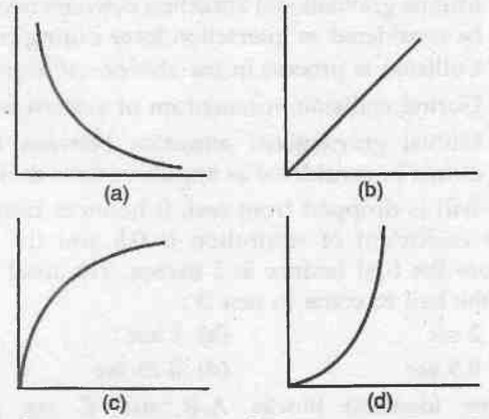
18. In the given figure the mass m_2 starts with velocity v_0 and moves with constant velocity on the surface. During motion the normal reaction between the horizontal surface and fixed triangular block m_1 is N. Then during motion :



(a) $N = (m_1 + m_2)\,g$ (b) $N = m_1 g$
(c) $N < (m_1 + m_2)\,g$ (d) $N > (m_1 + m_2)\,g$

19. If momentum of a body remains constant, then mass-speed graph of body is :
(a) circle (b) straight line
(c) rectangular hyperbola (d) parabola

20. If kinetic energy of a body remains constant, then momentum mass graph is :



21. Two bodies of masses m and $4m$ are moving with equal linear momentum. The ratio of their kinetic energies is :
(a) 1 : 4 (b) 4 : 1
(c) 1 : 1 (d) 1 : 2

22. If momentum of a given mass of body is increased by $n\%$, then :
(a) the kinetic energy of body changes by $2n\%$, when $n < 5$
(b) the kinetic energy of body changes by $2n\%$, when $n > 50$
(c) the kinetic energy may be constant
(d) the kinetic energy must be constant

23. If the momentum of a body increases by 20%, the percentage increase in its kinetic energy is equal to :
(a) 44 (b) 88
(c) 66 (d) 20

24. Mark correct option or options :
(a) The kinetic energy of a system may be changed without changing momentum
(b) The momentum of a system may be changed without changing kinetic energy
(c) If momentum of a system is zero, kinetic energy of system must be zero
(d) If different bodies have same momentum, kinetic energy of lightest body will be maximum

25. Two observers are situated in different inertial reference frames. Then :
(a) the momentum of a body by both observers may be same
(b) the momentum of a body measured by both observers must be same
(c) the kinetic energy measured by both observers must be same
(d) none of the above

26. A man is sitting in a moving train, then :
(a) his momentum must not be zero
(b) his kinetic energy is zero
(c) his kinetic energy is not zero
(d) his kinetic energy may be zero

27. When a meteorite burns in the atmosphere, then :
(a) the momentum conservation principle is applicable to the meteorite system
(b) the energy of meteorite remains constant
(c) the conservation principle of momentum is applicable to a system consisting of meteorites, earth and air molecules
(d) the meteorite momentum remains constant

28. A bomb dropped from an aeroplane explodes in air. Its total :
(a) momentum decreases
(b) momentum increases
(c) kinetic energy increases
(d) kinetic energy decreases

29. If a bullet is fired from a gun, then :
(a) the mechanical energy of bullet gun system remains constant
(b) the mechanical energy is converted into non-mechanical energy
(c) the mechanical energy may be conserved
(d) the non-mechanical energy is converted into mechanical energy

30. A nucleus moving with a velocity $\vec{u}$ emits an α-particle. Let the velocities of the α-particle and the remaining nucleus be $\vec{u}_1$ and $\vec{u}_2$ and their masses be m_1 and m_2, then :
(a) $\vec{u}$, $\vec{u}_1$ and $\vec{u}_2$ must be parallel to each other
(b) none of the two of $\vec{u}$, $\vec{u}_1$, $\vec{u}_2$ should be parallel to each other
(c) $\vec{u}_1 + \vec{u}_2$ must be parallel to $\vec{u}$
(d) $m_1\vec{u}_1 + m_2\vec{u}_2$ must be parallel to $\vec{u}$

31. A 15 gm bullet is fired horizontally into a 3 kg block of wood 10 cm above its initial level, the velocity of the bullet was :
(a) 251 m/sec
(b) 261 m/sec
(c) 271 m/sec
(d) 281 m/sec

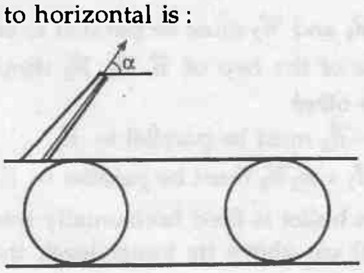
32. Two bodies of mass M and m are moving with same kinetic energy. If they are stopped by same retarding force, then :
(a) both bodies cover same distance before coming to rest
(b) if $M > m$, the time taken to come to rest for body of mass M is more than that of body of mass m
(c) if $m > M$, then body of mass m has more momentum than that of mass M
(d) all the above

33. Two blocks of mass m_1 and m_2 are connected by a massless spring and placed at smooth surface. The spring initially stretched and released. Then :
(a) the momentum of each particles remains constant separately
(b) the momentum of both bodies are same to each other
(c) the magnitude of momentum of both bodies are same to each other
(d) the mechanical energy of system remains constant
(e) both (c) and (d) are correct

34. When two blocks A and B coupled by a spring on a frictionless table are stretched and then released, then :
(a) kinetic energy of body at any instant after releasing is inversely proportional to their masses
(b) kinetic energy of body at any instant may or may not be inversely proportional to their masses
(c) $\frac{\text{K.E. of } A}{\text{K.E. of } B} = \frac{\text{mass of } B}{\text{mass of } A}$, when spring is massless
(d) both (b) and (c) are correct

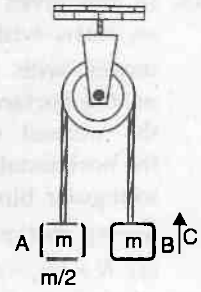
35. Two bodies are projected from roof with same speed in different directions. If air resistance is not taken into account. Then :
(a) they reach at ground with same magnitude of momenta if bodies have same masses
(b) they reach at ground with same kinetic energy
(c) they reach at ground with same speed
(d) both (a) and (c) are correct

*36. A shell of mass m is fired from a gun carriage of mass M which is initially at rest but is free to roll frictionlessly on a level track. The muzzle speed of shell is v relative to gun. Maximum range of shell if gun is inclined at α to horizontal is :



(a) $\frac{v^2 \sin 2\alpha}{g}$ (b) $\left(\frac{v^2 \sin 2\alpha}{g}\right)\left(\frac{M}{M+m}\right)$
(c) $\frac{(v \cos \alpha - v)^2}{g}$ (d) $\frac{mv^2 \sin 2\alpha}{Mg}$

37. Two identical masses A and B are hanging stationary by a light pulley (shown in the figure). A shell C moving upwards with velocity v collides with the block B and gets stick to it. Then :



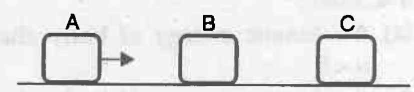
(a) first string becomes slack and after some time becomes taut
(b) the momentum conservation principle is applicable to B and C
(c) the string becomes taut only when down displacement of combined mass B and C is occured
(d) both (a) and (b) are correct

38. A bullet hits horizontally and gets embeded in a solid block resting on a frictionless surface. In this process :
(a) momentum is conserved
(b) kinetic energy is conserved
(c) both momentum and K.E. are conserved
(d) neither momentum nor K.E. is conserved

39. Mark correct option or options :
(a) Mutual gravitational attraction between two bodies can be considered as interaction force during collision
(b) Collision is process in the absence of impulsive force
(c) During collision, momentum of system may change
(d) Mutual gravitational attraction between two bodies cannot be considered as impulsive force during collision

40. If a ball is dropped from rest, it bounces from the floor. The coefficient of restitution is 0.5 and the speed just before the first bounce is 5 m/sec. The total time taken by the ball to come to rest is :
(a) 2 sec (b) 1 sec
(c) 0.5 sec (d) 0.25 sec

41. Three identical blocks A, B and C are placed on horizontal frictionless surface. The blocks B and C are at rest. But A is approaching towards B with a speed 10 m/s. The coefficient of restitution for all collision is 0.5. The speed of the block C just after collision is :



(a) 5.6 m/s
(b) 6 m/s
(c) 8 m/s
(d) 10 m/s

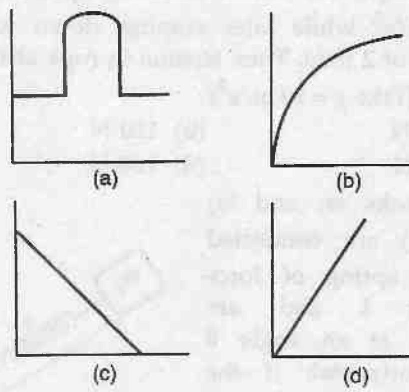
42. A thin uniform bar lies on a frictionless horizontal surface and is free to move in any way on the surface. Its mass is 0.16 kg and length is 1.7 m. Two particles each of mass 0.08 kg are moving on the same surface and towards the bar in the direction perpendicular to the bar, one with a velocity of 10 m/s and other with velocity 6 m/s. If collision between particles and bar is completely inelastic, both particles strike with the bar simultaneously. The velocity of centre of mass after collision is :
(a) 2 m/s (b) 4 m/s
(c) 10 m/s (d) 16 m/s

43. A body is dropped and observed to bounce a height greater than the dropping height. Then
(a) the collision is elastic
(b) there is additional source of energy during collision
(c) it is not possible
(d) this type of phenomenon does not occur in nature

44. When two bodies collide elastically, the force of interaction between them is :
(a) conservative
(b) non-conservative
(c) either conservative or non-conservative
(d) zero

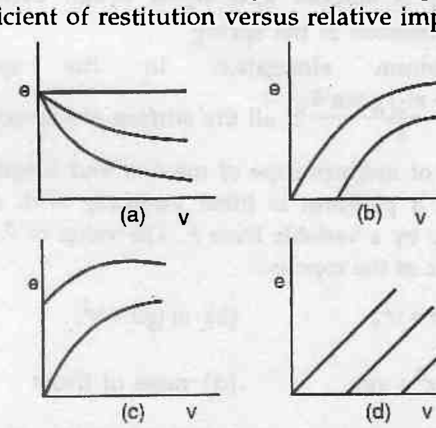
45. In the case of super elastic collision :
(a) initial K.E. of system is less than final K.E. of system
(b) initial K.E. = final K.E.
(c) initial K.E. > final K.E.
(d) initial K.E. > final K.E.

46. The graph between the fraction loss in energy in a head-on elastic collision and the ratio of the masses of the colliding bodies is :

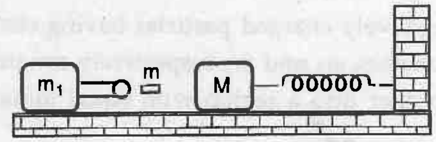


47. A body of mass M moving with a speed u has a head-on collision with a body of mass m originally at rest. If $M >> m$, the speed of the body of mass m after collision will be nearly :
(a) $\frac{um}{M}$ (b) $\frac{uM}{m}$
(c) $\frac{u}{2}$ (d) $2u$

48. Which one of the following is the best representation of coefficient of restitution versus relative impact velocity ?

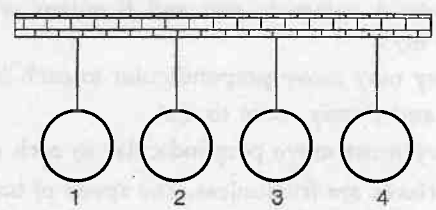


* 49. A block of mass M lying on a smooth horizontal surface is rigidly attached to a light horizontal spring of force constant k. The other end of the spring is rigidly connected to a fixed wall. A stationary gun fires bullets of mass m each in horizontal direction with speed v_0 one after other. The bullets hit the block and get embedded in it.



The first bullet hits the block at $t = 0$. The second bullet hits at $t = 2\pi\sqrt{\frac{M+m}{k}}$, the third bullet hits at $t = 2\pi\sqrt{\frac{M+m}{k}} + 2\pi\sqrt{\frac{M+2m}{k}}$ and so on. The maximum compression in the spring after the nth bullet hits is :
(a) $\frac{nmv_0\sqrt{k}}{(M+nm)^{3/2}}$ (b) $\frac{(M+nm)^{3/2}}{nmv_0\sqrt{k}}$
(c) $\frac{\sqrt{nmv_0 k}}{(M+nm)^{3/2}}$ (d) $\frac{nmv_0}{\sqrt{k(M+nm)}}$

* 50. In the given figure four identical spheres of equal mass m suspended by wires of equal length l_0 so that all spheres sre almost touching to each other. If the sphere 1 is released from the horizontal position and all collisions are elastic, the velocity of sphere 4 just after collision is :



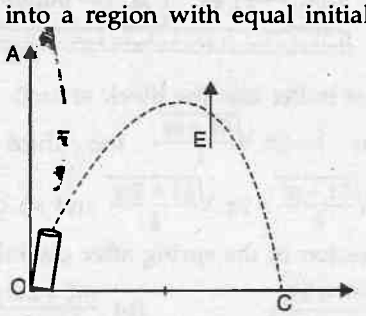
(a) $\sqrt{2gl_0}$ (b) $\sqrt{3gl_0}$
(c) $\sqrt{gl_0}$ (d) $\frac{\sqrt{gl_0}}{2}$

51. A ball moving with a certain velocity hits another identical ball at rest. If the plane is frictionless and collision is elastic, the angle between the directions in which the balls move after collision, will be :
(a) 30° (b) 60°
(c) 90° (d) 120°

52. A shell is fired from a cannon with a velocity v at an angle θ with the horizontal direction. At the highest point in its path, it explodes into two pieces, one retraces its path to the cannon and the speed of the other pieces immediately after the explo- sion is :
(a) $3v\cos\theta$ (b) $2v\cos\theta$
(c) $\left(\frac{3}{2}\right)v\cos\theta$ (d) $\frac{\sqrt{3}}{2}v\cos\theta$

53. A smooth steel ball strikes a fixed smooth steel plate at an angle θ with the vertical. If the coefficient of restitution is e, the angle at which the rebounce will take place is :
(a) θ (b) $\tan^{-1}\left[\frac{\tan\theta}{e}\right]$
(c) $e\tan\theta$ (d) $\tan^{-1}\left[\frac{e}{\tan\theta}\right]$

* **54.** Two negatively charged particles having charges e_1 and e_2 and masses m_1 and m_2 respectively are projected one after another into a region with equal initial velocities.



The electric field E is along the y-axis, while the direction of projection makes an angle α with the y-axis. If the ranges of the two particles along the x-axis are equal then one can conclude that:

(a) $e_1 = e_2$ and $m_1 = m_2$ (b) $e_1 - e_2$ only

(c) $m_1 = m_2$ only (d) $e_1 m_1 = e_2 m_2$

55. If two bodies A and B of definite shape (dimensions of bodies are not ignored) A is moving with speed of 10 m/s and B is in rest. They collide elastically. Then:

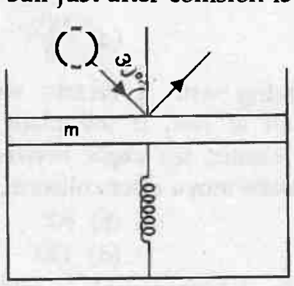
(a) body A comes to rest and B moves with speed of 10 m/s

(b) they may move perpendicular to each other

(c) A and B may come to rest

(d) they must move perpendicular to each other

56. All surfaces are frictionless. The speed of ball just before striking is 24 m/s, the coefficient of restitution $e = 0.8$. The velocity of ball just after collision is:



(a) 18 m/s (b) 12.2 m/s

(c) 17.2 m/s (d) none of these

57. In classical system:

(a) the varying mass system is not considered

(b) the varying mass system must be considered

(c) the varying mass system may be considered

(d) only varying of mass due to velocity is considered

58. A body in equilibrium may not have:

(a) momentum (b) velocity

(c) acceleration (d) kinetic energy

59. A machine gun fires 120 shots per minute. If the mass of each bullet is 10 g and the muzzle velocity is 800 m/sec, the average recoil force on the machine gun is:

(a) 120 N (b) 8 N

(c) 16 N (d) 12 N

60. A machine gun fires a steady stream of bullets at the rate of n per minute into a stationary target in which the bullets get embeded. If each bullet has a mass m and arrive at the target with a velocity v, the average force on the target is:

(a) $60mnv$ (b) $\frac{60v}{mn}$

(c) $\frac{mnv}{60}$ (d) $\frac{mv}{60n}$

61. A gun is 'aimed' at a target in line with its barrel. The target is released at the every instant the gun is fired. The bullet will:

(a) hit the target (b) pass above the target

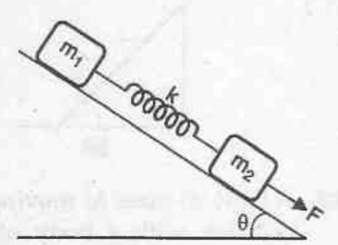
(c) pass below the target (d) certainly miss the target

62. Two boys of masses 10 kg and 8 kg are moving along a vertical rope, the former climbing up with acceleration of 2 m/s^2 while later coming down with uniform velocity of 2 m/s. Then tension in rope at fixed support will be (Take $g = 10$ m/s^2):

(a) 200 N (b) 120 N

(c) 180 N (d) 160 N

* **63.** Two blocks m_1 and m_2 ($m_2 > m_1$) are connected with a spring of force constant k and are inclined at an angle θ with horizontal. If the system is released from rest, which one of the following statements is/are correct?



(a) Maximum compression in the spring is $\frac{(m_1 - m_2) g \sin\theta}{k}$ if there is no friction any where

(b) There will be no compression or elongation in the spring if there is no friction any where

(c) If m_1 is smooth and m_2 is rough there will be compression in the spring

(d) Maximum elongation in the spring is $\frac{(m_1 - m_2) g \sin\theta}{k}$ if all the surface are smooth

64. The end of uniform rope of mass m and length L that is piled on a platform is lifted vertically with a constant velocity v by a variable force F. The value of F as a lifted position x of the rope is:

(a) $\frac{m}{L}(gx + v^2)$ (b) $m(gx + v^2)$

(c) $\frac{m}{L^2}(gx^2 + xv)$ (d) none of these

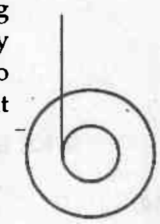
65. A truck moving on a smooth horizontal surface with a uniform speed u is carrying stone-dust. If a mass Δm of the stone-dust leaks from the truck in a time Δt, the force needed to keep the truck moving at uniform speed is:

(a) $\frac{u\,\Delta m}{\Delta t}$ (b) $\Delta m \frac{du}{dt}$

(c) $u\frac{\Delta m}{\Delta t} + (\Delta m)\frac{du}{dt}$ (d) zero

66. An athelete diving off a high spring board can perform a variety of physical moments in the air before entering the water below. Which one of the following parameters will remain constant during the fall? The athelete's :
(a) linear velocity
(b) linear momentum
(c) moment of inertia
(d) angular velocity

67. A YO-YO is a toy in which a string is wound round a central shaft as shown in figure. The string unwinds and rewinds itself alternately making the YO-YO rises and fall. The ratio of the tensions in the string during descent and ascent is :



(a) 1 : 1 (b) $r_2 : r_1$
(c) $r_1 : r_2$ (d) $r_1 : 1$

Answers

Level-1

1. (c)	2. (d)	3. (c)	4. (c)	5. (d)	6. (b)	7. (a)	8. (b)	9. (a)	10. (a)
11. (b)	12. (a)	13. (c)	14. (b)	15. (a)	16. (c)	17. (c)	18. (b)		

Level-2

1. (c)	2. (b)	3. (a)	4. (b)	5. (d)	6. (d)	7. (d)	8. (d)	9. (a)	10. (b)
11. (b)	12. (c)	13. (b)	14. (a)	15. (c)	16. (d)	17. (a)	18. (c)	19. (c)	20. (c)
21. (b)	22. (a)	23. (a)	24. (d)	25. (a)	26. (d)	27. (c)	28. (c)	29. (d)	30. (d)
31. (d)	32. (d)	33. (e)	34. (d)	35. (d)	36. (b)	37. (d)	38. (a)	39. (d)	40. (c)
41. (a)	42. (b)	43. (b)	44. (a)	45. (a)	46. (a)	47. (d)	48. (a)	49. (d)	50. (a)
51. (c)	52. (a)	53. (b)	54. (a)	55. (b)	56. (b)	57. (c)	58. (c)	59. (c)	60. (c)
61. (a)	62. (a)	63. (b)	64. (a)	65. (d)	66. (d)	67. (a)			

Solutions

Level-1

3. $$m_A v_A + m_B v_B = 0$$
$$v_B = -\frac{m_A v_A}{m_B} = -\frac{200\times10^{-3}\times 0.3}{400\times10^{-3}}$$
$$= -\frac{60}{400} = -0.15$$

4. $$mv - mv = (m+m)\,v$$
$$v = 0$$

5. $$Mv = \frac{M}{4}v_1 + \frac{3}{4}Mv_2$$
$$Mv = \frac{3}{4}Mv_2 \qquad (\because v_1 = 0)$$
$$v_2 = \frac{4v}{3}$$

7. $$mv = (m+2m)v_1$$
$$\frac{v}{3} = v_1$$

9. $$K = \frac{1}{2}mv^2 = \frac{1}{2}\times\frac{m\,(mv^2)}{m} = \frac{(mv)^2}{2m} \quad\text{or}\quad K = \frac{p^2}{2m}$$
$$\therefore\quad \frac{K_1}{K_2} = \frac{p_1^2}{2m_1}\times\frac{2m_2}{p_2^2} \quad\text{or}\quad \frac{3}{1} = \frac{p_1}{p_2}\times\frac{6}{2}$$
$$\frac{p_1}{p_2} = 1$$
$$\therefore\quad p_1 : p_2 = 1 : 1$$

10. $u_1 = 4$ m/s $\quad u_2 = 3$ m/s

$m_1 = 3$ kg $\quad m_2 = 4$ kg
$$m_1u_1 + m_2u_2 = (m_1+m_2)v$$
$$3\times4 + 4\times(-3) = (3+4)v$$
$$v = 0$$

11. $$mv - 2mv = mv_1 + mv_2$$
$$-v = v_1 + v_2 \qquad \text{...(i)}$$
and $$\frac{v_2 - v_1}{v+2v} = 1 \;\Rightarrow\; v_2 - v_1 = 3v \qquad \text{...(ii)}$$
Solving eqs. (i) and (ii),
$$v_2 - v_1 = 3v$$
$$v_2 + v_1 = -v$$
$$2v_2 = 2v$$
$\therefore\; v_2 = v$ and $-v_1 = 2v \;\therefore\; v_1 = -2v$

12. $$15m + 10m = mv_1 + mv_2$$
$$25 = v_1 + v_2 \qquad \text{...(i)}$$
and $$\frac{v_2 - v_1}{u_1 - u_2} = 1$$
$$\Rightarrow\quad \frac{v_2 - v_1}{15 - 10} = 1$$
$$\Rightarrow\quad v_2 - v_1 = 5 \qquad \text{...(ii)}$$
$$v_1 + v_2 = 25$$
$$v_2 - v_1 = 5$$
$$\therefore\quad 2v_2 = 30$$
$$\therefore\quad v_2 = 15\text{ m/s},\; v_1 = 10\text{ m/s}$$

8

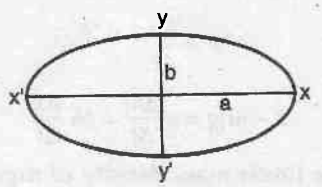
Rotation

Syllabus: General motion of a rigid body, nature of rotational motion, torque, angular momentum, conservation of angular momentum and its applications, moment of inertia and its physical significance, parallel and perpendicular axes theorem, expression for moment of inertia for ring, disc and sphere.

Review of Concepts

1. Moment of Inertia

(i) Calculation for moment of inertia by digits:



M.I. about an axis of symmetry is

$$\frac{\text{Mass} \times \text{the sum of squares of perpendicular semi axis}}{3 \text{ or } (4 \text{ or } 5)}$$

where denominator to be 3 or 4 or 5 according as the body is rectangular, elliptical (including circular) or ellipsoidal (Including spherical) *e.g.*, for ellipse,

$$I_z = \frac{M}{4}(a^2 + b^2)$$

(ii) Expression for moment of inertia of a lamina about an axis passing through origin making an angle θ with x-axis is

$$I = I_x \cos^2\theta + I_y \sin^2\theta - 2F \sin\theta \cos\theta$$

where $F = \Sigma\, mxy$ = the product of inertia.

(iii) In the case of symmetrical two dimensional bodies, the M.I. for all axes passing through centre of mass and in the plane of body will be same. Both axes need not to be perpendicular to each other.

(iv) The angular velocity of all points of a rigid body are same.

(v) The areal velocity is given by $\frac{1}{2}r^2\omega$.

(vi) If a number of coplanar forces are acting on a system, then the sum of torques of all forces about any point is equal to torque of resultant force about the same point.

(vii) Couple can not be balanced by a single force.

(viii) Friction is responsible for pure rolling motion but dissipation of energy against friction is zero.

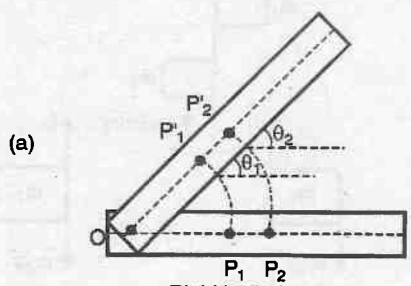
(ix) Couple is always balanced by a couple. It is not balanced by a single force.

(x) Twice the vector area of a closed plane polygon is equal to the sum of torques about any point in the plane of the polygon of forces represented by sides of polygon taken in order.

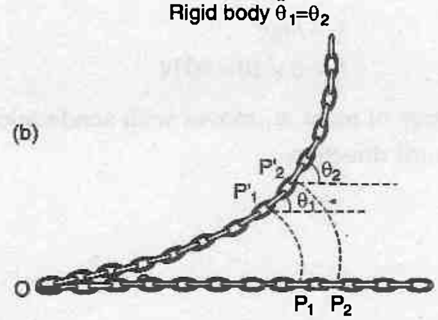
(xi) The sum of moment of masses about its centre of mass is always zero.

(xii) $\theta = 2\pi n$, where n = the number of revolutions.

(xiii) Angular displacements of all points of a rigid body are same. But in the case of non-rigid body, greater the distance of the point from the axis of rotation, greater will be its angular displacement.



Rigid body $\theta_1 = \theta_2$



Non-rigid body $\theta_1 < \theta_2$

(xiv) Rolling motion on an inclined plane:

$$\text{velocity } v = \frac{2gs \sin\theta}{\sqrt{\left(1 + \frac{K^2}{R^2}\right)}},$$

$$\text{acceleration } a = \frac{g \sin\theta}{1 + \frac{K^2}{R^2}}$$

where, s = distance of inclined plane

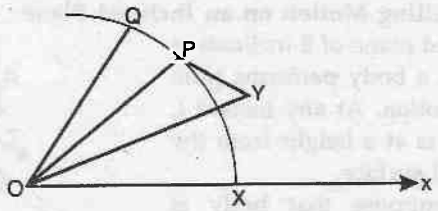
K = radius of gyration

R = radius of symmetrical body

(xv) The angular velocity depends on the point about which rotation is considered.

(xvi) Angular velocity of a point whose motion is in a plane:

Let a point P be in motion in a plane if O be a fixed point, OX is a fixed line in the plane.



$$\omega = \frac{d\theta}{dt}$$

$$\angle POQ = \Delta\theta$$

$$OP = r$$

$$OQ = r + \Delta r$$

OY is perpendicular on PQ. Let $Q\,(r + \Delta r, \theta + \Delta\theta)$ is the position of the point P after time $t + \Delta t$ where Δt is very small.

$$\therefore \quad v = \lim_{\Delta t \to 0} \frac{PQ}{\Delta t}$$

But $\quad \frac{1}{2} r\,(r + \Delta r) \sin \Delta\theta = \text{area of } OPQ = PQ \times OY$

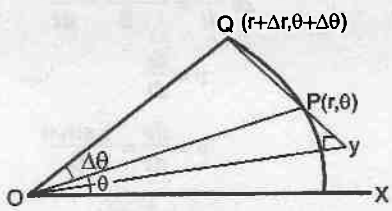
or $\quad r\,(r + \Delta r) \sin \Delta\theta = 2PQ \times OY$

or $\quad r^2 \frac{\Delta\theta}{\Delta t} = \frac{2PQ}{\Delta t} \times OY$

or $\quad r^2 \frac{d\theta}{dt} = 2v \times p$

where p = perpendicular from the point O upon tangent at P to the path of the moving particle.

(xvii) **Areal velocity:** The rate at which area XOP increases per unit time where **X** is the point in which the path of P meets OX,



$$\text{areal velocity} = \frac{dA}{dt} = \lim_{\Delta t \to 0} \frac{\text{area of } POQ}{\Delta t}$$

or $\quad \frac{dA}{dt} = \frac{\frac{1}{2}(r + \Delta r) \sin (\Delta\theta)}{\Delta t}$

$$= \frac{1}{2} r^2 \frac{\Delta\theta}{\Delta t} = \frac{1}{2} r^2 \frac{d\theta}{dt}$$

$$\therefore \quad \frac{dA}{dt} = \frac{1}{2} r^2 \omega$$

(xviii) Moment of inertia depends upon the position of the axis of rotation.

(xix) The moment of inertia of a body about a given axis depends upon mass, the shape and size and the distribution of masses from the axis of rotation.

(xx) The large moment of inertia helps keeping the motion uniform.

(xxi) If a number of torques acted on a system and the system is in rotational equilibrium, then clockwise torque = anticlockwise torque

(xxii) If a body or system is in complete equilibrium, then net force and net torque on the body or system are zero.

(xxiii) In the case of couple, the sum of moment of all forces about any point is the same.

(xxiv) Conservation principle of angular momentum

$$\vec{L} = I\,\vec{\omega}$$

where $\vec{L}$ is the component of angular momentum along the axis of rotation.

If $\quad \Sigma \tau = 0, \;$ then $\; \vec{L} = \text{constant}$

(xxv) Angular impulse $= \int \tau\, dt$

$$\vec{\tau} = \frac{d\vec{L}}{dt} \quad \text{and} \quad \vec{L} = m\,(\vec{r} \times \vec{v})$$

$$\frac{d\vec{L}}{dt} = m\left\{\vec{r} \times \frac{d\vec{v}}{dt} + \frac{d\vec{r}}{dt} \times \vec{v}\right\}$$

The angular momentum of a system about a point O is given by

$$\vec{L} = \sum_{i=1}^{n} m_i\,\vec{r_i} \times \vec{v_i}$$

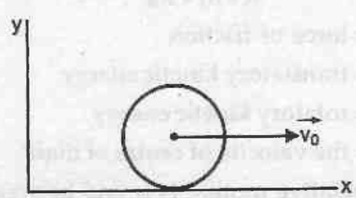
$$\vec{L} = \vec{L}_{cm} + m\,\vec{r}_o \times \vec{v}_o$$

where $\vec{L}_{cm}$ = the angular momentum as seen from the centre of mass frame, $m\,\vec{r}_o \times \vec{v}_o$ represents the angular momentum of body if it is assumed to be concentrated at the centre of mass translating with the velocity $\vec{v}_o$, *e.g.*, we consider a situation shown in the figure. In this situation a solid sphere of radius R and mass m performs pure rolling motion. If we want to calculate the angular momentum of the sphere about origin O, then we can use the formula

$$\vec{L} = \vec{L}_{cm} + m\,\vec{r}_o \times \vec{v}_o$$

In this case, $\quad \vec{L}_{cm} = I\,\vec{\omega} = \frac{2}{5} mR^2 \omega$

$$v_o = R\omega \quad \text{(for the pure rolling motion)}$$



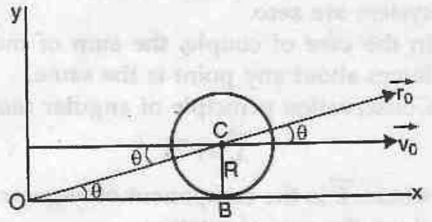
$$\therefore \quad L_{cm} = I\omega = \frac{2}{5} MR^2\,\omega = \frac{2}{5}\, mRv_o$$

In the given figure, $|\vec{r}_o \times \vec{v}_o| = r_o v_o \sin\theta = v_o r_o \sin\theta$

In $\Delta\, OCB$, $\quad \sin\theta = \frac{R}{r_o} \quad \therefore\ R = r_o \sin\theta$

$\therefore \quad |\vec{r}_o \times \vec{v}_o| = v_o R$

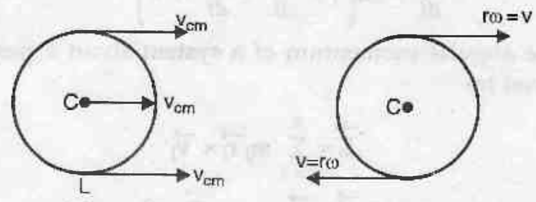
The directions of $\vec{r}_o \times \vec{v}_o$ and $\vec{L}_{cm}$ are same to each other.



$$\therefore \quad \vec{L} = \vec{L}_{cm} + m\,(\vec{r}_c \times \vec{v}_o)$$

$$|\vec{L}| = \frac{2}{5} mRv_o + mv_oR = \frac{7}{5} mRv_o$$

2. A uniform rod of mass m and length l is set rotating with the constant angular velocity. The work is minimum for setting motion when the axis is passing through the centre of mass.

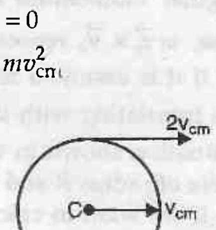


(a) Translation $\qquad$ (b) Rotation

$f_r = 0,\ \omega = 0$ $\qquad$ $K_T = 0$

$K_T = 1/2\ mv_{cm}^2$ $\qquad$ $K_R = 1/2\ I\omega^2$

$K_R = 0$



(c) Rolling

$f_r \neq 0$

$v_{cm} = R\omega$

$K = K_T + K_R$

Here, $\quad f_r$ = force of friction

K_T = translatory kinetic energy

K_R = rotatory kinetic energy

v_{cm} = the velocity of centre of mass

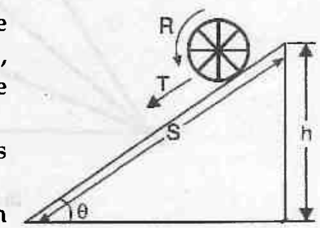
(i) If no relative motion is found between surface and the point of contact, then the motion is rolling without slipping or pure rolling motion.

(ii) The rolling motion may be treated as pure rotatory motion about an axis through the point of contact.

(iii) The velocity of instantaneous axis is same as that of the centre of mass of the body.

(iv) If a body performs pure rolling motion, then the path of any point on the surface of body is cycloid.

3. Rolling Motion on an Inclined Plane : We consider an inclined plane of θ inclination on which a body performs pure rolling motion. At any instant t, the body is at a height from the horizontal surface.



We suppose that body is released from height h.

According to conservation principle of energy,

$$mgh = \frac{1}{2} I\omega^2 + \frac{1}{2} mv_{cm}^2$$

But $\quad v_{cm} = r\omega$

$$\therefore \quad mgh = \frac{1}{2} I\omega^2 + \frac{1}{2} mr^2\omega^2$$

or $$mgh = \frac{1}{2} mv^2\left(1 + \frac{I}{mr^2}\right)$$

or $$mgh = \frac{1}{2} mv^2 \beta \qquad \ldots\text{(i)}$$

where β is a constant for a given body.

The value of β does not depend upon mass and radius of the body. It only depends upon shape of the body. The value of β is always greater or equal to one.

From the equation $\quad v = \sqrt{\frac{2gh}{\beta}}$

$$v^2 = \frac{2gh}{\beta} \qquad \text{(where } h - s\sin\theta)$$

or $$2v\frac{dv}{dt} = \frac{2g\sin\theta}{\beta}\frac{ds}{dt}$$

But $$v = \frac{ds}{dt}$$

$$\therefore \quad a = \frac{dv}{dt} = \frac{g\sin\theta}{\beta}$$

$$s = \frac{1}{2}at^2$$

$$t = \frac{1}{\sin\theta}\sqrt{\frac{2h\beta}{g}}$$

$\therefore$ Two bodies of the same shape but of different masses and radii reach the bottom at the same time.

(i) In the case of rolling, slipping and falling from the same height, the speeds of sliding and falling are equal but that of rolling is lesser, acceleration is maximum in falling and minimum in rolling.

(ii) The falling body reaches the bottom first and the rolling body reaches the bottom last.

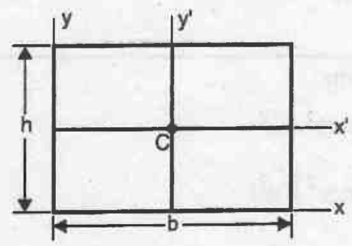
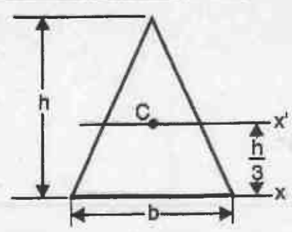
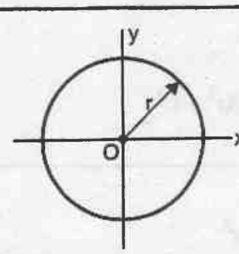
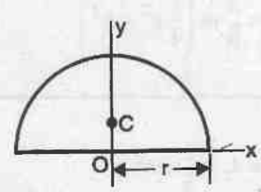
(iii) As factor $\beta = 1 + \frac{I}{mr^2}$ depends on shape of body and is independent of mass so, if a solid and hollow body of same shape are allowed to roll down an inclined plane then as $\beta_S < \beta_H$, solid body will reach the bottom first with greater velocity.

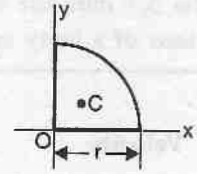
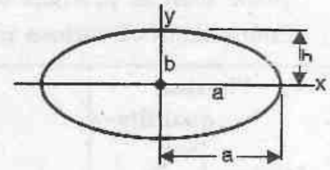
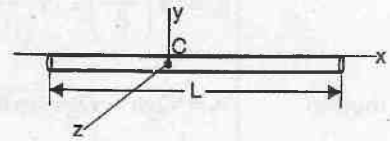
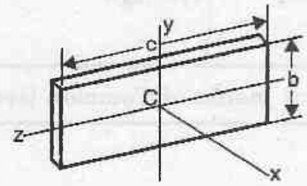
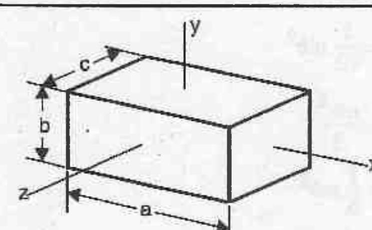
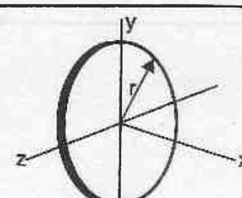
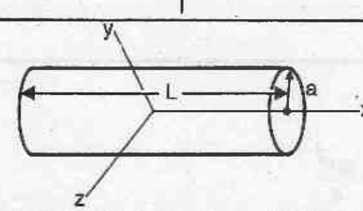
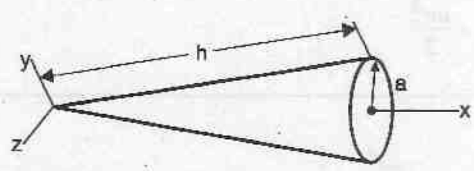
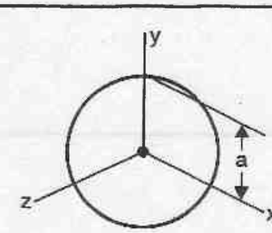
(iv) If a cylinder, ring, disc and sphere roll on inclined plane then as $\beta_r = \max$ while $\beta_s = \min$, the sphere will reach the bottom first with greater velocity while ring will reach the bottom with least velocity.

(v) **Comparison of various motions of a body on an inclined palne :**

S. No.	Physical quantity→ / Motion ↓	Velocity	Acceleration	Time of descend
1.	Rolling motion	$v_r = \sqrt{\left(\frac{2gh}{\beta}\right)} = \sqrt{\left[\frac{2gs \sin\theta}{(1+K^2/R^2)}\right]}$	$a_x = \frac{g \sin\theta}{\beta} = \frac{g \sin\theta}{\left(1+\frac{K^2}{R^2}\right)}$	$T_r = \frac{1}{\sin\theta}\sqrt{\left(\frac{2h\beta}{g}\right)} = \frac{1}{\sin\theta}\sqrt{\left[\frac{2h(1+K^2/R^2)}{g}\right]}$
2.	Sliding motion	$v_s = \sqrt{2gh} = \sqrt{2gs \sin\theta}$	$a_s = g \sin\theta$	$T_s = \frac{1}{\sin\theta}\sqrt{\left(\frac{2h}{g}\right)} = \sqrt{\left(\frac{2s}{g \sin\theta}\right)}$
3.	Falling motion	$v_f = \sqrt{2gh}$	$a_f = g$	$T_f = \sqrt{\left(\frac{2h}{g}\right)}$

4. Mass Moment of Inertia of Common Geometrical Shapes :

Rectangle $I_x' = \frac{1}{12} mh^2$ $I_y' = \frac{1}{12} mb^2$ $I_x = \frac{mh^2}{3}$ $I_y = \frac{1}{3} mb^2$ $I_c = \frac{1}{12}(b^2 + h^2)$	
Triangle $I_x' = \frac{1}{18} mh^2$ $I_x = \frac{1}{6} mh^2$	
Circle $I_x = I_y = \frac{mr^2}{4}$ $I_o = \frac{mr^2}{2}$	
Semicircle $I_x = I_y = \frac{mr^2}{4}$ $I_o = \frac{mr^2}{2}$	

Quarter circle $I_x = I_y = \frac{mr^2}{4}$ $I_y = \frac{ma^2}{4}$ $I_o = \frac{m}{4}(a^2 + b^2)$	 
Slender rod $I_y = I_x = \frac{1}{12} mL^2$	
Thin rectangular plate $I_x = \frac{1}{12} m(b^2 + c^2)$ $I_y = \frac{1}{12} mc^2$ $I_z = \frac{1}{12} mb^2$	
Rectangular prism $I_x = \frac{1}{12} m(b^2 + c^2)$ $I_y = \frac{1}{12} m(c^2 + a^2)$ $I_z = \frac{1}{12} m(a^2 + b^2)$	
Thin disc $I_x = \frac{1}{2} mr^2$ $I_y = I_z = \frac{1}{4} mr^2$	
Circular cylinder $I_x = \frac{1}{2} ma^2$ $I_y = I_z = \frac{1}{12} m(3a^2 + L^2)$	
Circular cone $I_x = \frac{3}{10} ma^2$ $I_y = I_z = \frac{3}{5} m\left(\frac{1}{4}a^2 + h^2\right)$	
Sphere $I_x = I_y = I_z = \frac{2}{5} ma^2$	

Objective Questions

Level-1

1. A sphere of mass 5 kg and radius 1 m rotates about a tangent. The moment of inertia of the sphere is :
(a) 5 kgm^2 (b) 2 kgm^2
(c) 7 kgm^2 (d) none of these

2. A solid cylinder of mass 1 kg and radius 10 cm is rotating about its natural axis. What is the moment of inertia of cylinder ?
(a) 5 kgm^2 (b) 5×10^{-3} kgm^2
(c) 10 kgm^2 (d) None of these

3. A ring of mass m and radius r is suspended from a horizontal nail in a vertical wall in a room. The moment of inertia of the ring about the nail is :
(a) MR^2 (b) $2MR^2$
(c) $4MR^2$ (d) $8MR^2$

4. The moment of inertia of a thin uniform circular disc about one of the diameters is I. Its moment of inertia about an axis perpendicular to the plane of the disc and passing through its centre is :
(a) $\sqrt{2}\, I$ (b) $2\, I$
(c) $\frac{I}{2}$ (d) $\frac{I}{\sqrt{2}}$

5. A thin uniform rod is rotating about an axis passing through its centre and perpendicular to its length, moment of inertia is I_0. M.I. of rod about an axis through one end and perpendicular to the rod will be :
(a) $\frac{1}{2} I_0$ (b) $3\, I_0$
(c) $5\, I_0$ (d) $4\, I_0$

6. Three thin uniform rods, each of mass m and length l lie along x, y, z axes with one end of each at the origin. The moment of inertia about the z-axis for the three rod system is :
(a) $\frac{2}{3} ml^2$ (b) $\frac{1}{3} ml^2$
(c) $\frac{1}{2} ml^2$ (d) ml^2

7. The moment of inertia of two bodies are I_1 and I_2. Their geometrical shapes are same, the first made of iron and the second of aluminium, then :
(a) $I_1 < I_2$
(b) $I_1 = I_2$
(c) $I_1 > I_2$
(d) relation between I_1 and I_2 depends on the actual shape of the bodies.

8. A naughty girl sits stationary at the back end of a long trolley moving uniformly with speed v on a smooth horizontal floor. If she gets up and runs forward, then the speed of the centre of mass of (trolley and girl) system :
(a) increases
(b) decreases
(c) remains the same
(d) depends on the speed of girl

9. A ball is rolling on a rough horizontal surface. It gradually slows down and stops. The force of friction tries to :
(a) decrease the linear velocity
(b) decrease the angular velocity
(c) increase the linear momentum
(d) decrease the angular velocity

10. The angular momentum of a projectile projected at angle θ with, the horizontal with speed u about the point of projection when it is at the highest point is :
(a) $\frac{mu^2 \sin^2\theta}{g}$ (b) $\frac{mu\cos\theta}{g}$
(c) $\frac{mu^3 \sin^2\theta\cos\theta}{2g}$ (d) none of these

11. Two cylinders P and Q are of equal mass and length but made of metals with densities ρ_P and ρ_Q ($\rho_P > \rho_Q$). If their moment of inertia about an axis passing through centre and normal to the circular face be I_P and I_Q, then :
(a) $I_P = I_Q$ (b) $I_P > I_Q$
(c) $I_P < I_Q$ (d) $I_P < I_Q$

12. Radius of a ring is 4 cm and its mass is 10 gm. Its moment of inertia about an axis passing through its centre and perpendicular to its plane is :
(a) 160 g-cm^2 (b) 80 g-cm^2
(c) 16 g-cm^2 (d) none of these

13. A cubical body of mass m and edge a slides down a rough inclined plane of inclination α with a uniform velocity. The torque of the normal force on the body, has magnitude :
(a) $mga\cos\alpha$ (b) $\frac{1}{2} mga\sin\alpha$
(c) mga (d) zero

14. The kinetic energy of a ring of mass m and radius r which rotates about an axis passing through its centre and perpendicular to the plane with angular velocity ω, is :
(a) $mr\omega^2$ (b) $mr^2\omega^2$
(c) $\frac{1}{2} mr^2\omega^2$ (d) $\frac{1}{2} mr\omega^2$

15. A uniform rod of length 1 m and mass 1/2 kg rotates at angular speed 6 rad s^{-1}, about one of its ends. The kinetic energy of the rod is :
(a) 1 J (b) 2 J
(c) 3 J (d) 4 J

16. The ratio of its rotational kinetic energy and translational kinetic energy of a sphere, which is rolling without slipping on a horizontal plane, will be :
(a) 5 : 2 (b) 2 : 5
(c) 7 : 5 (d) 5 : 7

17. A disc and a sphere of the same mass and radius are rolling. Their kinetic energies are equal. The ratio of their velocities is :
(a) 10 : 7 (b) 7 : 10
(c) 2 : 5 (d) 5 : 2

18. A flywheel rotating about a fixed axis has angular speed 20 rad/s^{-1} and kinetic energy 360 J. The moment of inertia of the flywheel is :
(a) 1.8 kg m^2 (b) 2.5 kg m^2
(c) 18 kg m^2 (d) none of these

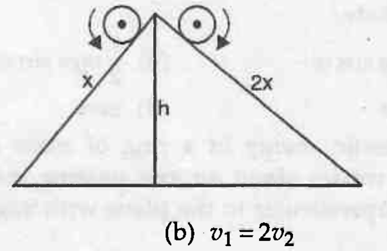
19. If the angular momentum of a body increases by 40% its kinetic energy of rotation increases by :
(a) 80% (b) 20%
(c) 96% (d) none of these

20. A solid sphere of mass 2 kg rolls on a table with the linear speed 3 m/s. Its total kinetic energy is :
(a) 15 J (b) 18 J
(c) 12.6 J (d) 11.5 J

21. A uniform ring of mass 20 kg and radius 0.2 m is making 420/22 revolutions per minute about its geometrical axis then, the rotational kinetic energy of the ring about the axis is :
(a) 22 kJ (b) 1.6 J
(c) 1.8 J (d) none of these

22. A disc at rest have angular velocity 30 rad/s in 6 sec, with a constant angular acceleration. The total angle turned during this interval is :
(a) 216 rad (b) 144 rad
(c) 108 rad (d) 90 rad

23. Two identical discs slip from top of two identical planes of slant length x and $2x$ but height h is same as shown in figure. The velocities v_1 and v_2 acquired by the discs, when they reach the bottom of the incline, are related as :



(a) $v_1 = v_2$ (b) $v_1 = 2v_2$
(c) $2v_1 = v_2$ (d) none of these

24. Two bodies A and B initially at rest, move towards each other under a mutual force of attraction. At the instant when the speed of A is v and the speed of B is $2v$, the speed of the centre of mass of the system is :
(a) zero (b) $3v$
(c) $1.5v$ (d) v

25. A disc of mass m and radius r rolls down an inclined plane without slipping, the speed of its centre of mass, when it reaches the bottom, is :
(a) $\sqrt{2gh}$ (b) $\sqrt{\left(\frac{4}{3}gh\right)}$
(c) $\sqrt{\left(\frac{3}{4}gh\right)}$ (d) $\sqrt{\left(\frac{4}{g}h\right)}$

26. The angular velocity of a body is $\vec{\omega} = 2\hat{i} + \hat{j} + 4\hat{k}$. A torque $\vec{\tau} = 2\hat{i} + 2\hat{j} + 2\hat{k}$ acts on it. The rotational power is :
(a) 14 W (b) 10 W
(c) 15 W (d) none of these

27. A rigid body is rotating with angular acceleration α and moment of inertia of the body is I. If the power supplied to the body is P, its instantaneous angular velocity is :
(a) $P I \alpha$ (b) $\frac{P}{I\alpha}$
(c) $\frac{PI}{\alpha}$ (d) $\frac{P\alpha}{I}$

28. Radius of gyration of a body about an axis at a distance of 4 cm from its centre of mass is 8 cm. The radius of gyration about a parallel axis through its centre of mass is :
(a) 7 cm (b) 3 cm
(c) 4 cm (d) none of these

29. A constant couple of 200 Nm turns a wheel of moment of inertia 50 kgm^2 about an axis through its centre. The angular velocity gained in 4 second is :
(a) 4 rad/s (b) 16 rad/s
(c) 8 rad/s (d) 2 rad/s

30. A particle of mass 20 g is moving with linear velocity $5\hat{i}$ m/s and having position vector $(3\hat{i} + 4\hat{j})$ m about origin. The angular momentum of its particle is :
(a) $4\hat{k}$ Js (b) $-4\hat{k}$ Js
(c) $-0.4\hat{k}$ Js (d) $0.4\hat{k}$ Js

31. A body of mass m is moving in a plane along a circle of radius r. Its angular momentum about the axis of rotation is L. The centripetal force acting on the particle will be :
(a) $\frac{L^2}{mr}$ (b) $\frac{L^2 m}{r}$
(c) $\frac{L^2}{mr^3}$ (d) $\frac{L^2}{mr^2}$

32. The distance between the sun and the earth be 'r' then the angular momentum of the earth around the sun is proportional to :
(a) $\sqrt{r}$ (b) $r^{3/2}$
(c) r (d) none of these

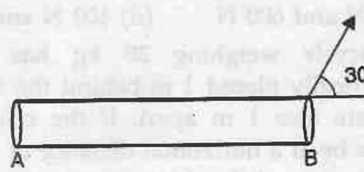
33. A ceiling fan of moment of inertia 0.6 kg m^2 is turned up to working speed $\frac{10}{\pi}$ rps. The angular momentum of the fan is :
(a) 6 kg m^2 s^{-1} (b) 12 kg m^2 s^{-1}
(c) 0.12 kg m^2 s^{-1} (d) none of these

Level-2

1. Mark correct option or options :
 (a) Radial acceleration is equal to time derivative of radial velocity
 (b) Radial acceleration is not equal to time derivative of radial velocity
 (c) Transverse acceleration is time derivative of transverse velocity
 (d) Both (b) and (c) are correct

2. A rigid body rotates with constant angular velocity ω about the line $x = \frac{y}{2} = \frac{z}{2}$, the speed of particle at the instant, it passes through the point (2, 3, 5) is :
 (a) ω (b) 2ω
 (c) 3ω (d) $\sqrt{2}\omega$

3. The instantaneous velocity of point B of the given rod of length 0.5 metre is 3 m/s in the represented direction. The angular velocity of the rod for minimum velocity of end A is :

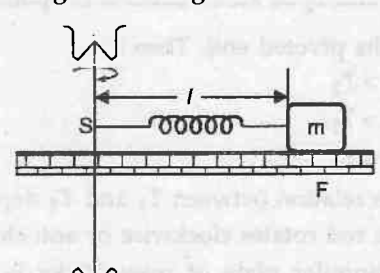


 (a) 1.5 rad/s (b) 5.2 rad/s
 (c) 2.5 rad/s (d) none of these

4. A car is moving in a circular horizontal track of radius 10 m with a constant speed of 10 m/sec. A plumb bob is suspended from the roof of the car by a light rigid rod of length 1 m. The angle made by the rod with the track is : (Take $g = 10 \text{ m/s}^2$)
 (a) zero (b) 30°
 (c) 45° (d) 60°

5. If a body completes a vertical circle, then
 (a) total energy of body remains constant
 (b) angular momentum remains constant
 (c) angular velocity remains constant
 (d) none of the above

* 6. A block of mass m having coefficient of friction μ with the floor F is placed at one end of the spring. The spring is attached to this block and a vertical shafts. The floor with the shaft is given an angular acceleration α. Then :

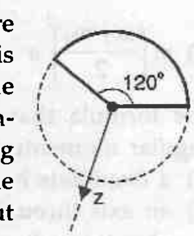


 (a) the spring cannot elongate before $t = \sqrt{\frac{\mu g}{l\alpha^2}}$
 (b) the spring elongates as soon as the rotation starts
 (c) the stored energy in the spring goes on increasing right from $t = 0$ onwards
 (d) the maximum spring force acts at $t = \sqrt{\frac{\mu g}{l\alpha^2}}$

7. Moment of inertia of a copper sphere :
 (a) depends upon temperature
 (b) depends upon angular velocity
 (c) depends upon the position of axis of rotation
 (d) both (a) and (c) are correct

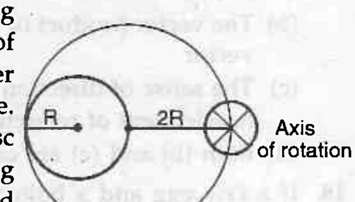
8. Let I_A and I_B be moment of inertia of a body about two axis A and B respectively. The axis of body A passes through the centre of mass of the body but B does not. Then :
 (a) $I_A < I_B$
 (b) if $I_A < I_B$, the axes are parallel
 (c) if the axes are parallel $I_A < I_B$
 (d) if the axes are not parallel $I_A > I_B$

9. An arc making 120° at the centre of ring of mass m and radius r is cut from the ring. The arc is made to rotate about z-axis perpendicular to its plane and passing through the centre of the ring. The moment of inertia of the arc about the z-axis :



 (a) mr^2 (b) $\frac{mr^2}{3}$
 (c) $\frac{mr^2}{2}$ (d) $\frac{mr^2}{4}$

10. Mass of bigger disc having radius $2R$ is M. A disc of radius R is cut from bigger disc as shown in figure. Moment of inertia of disc about an axis passing through periphery and perpendicular to plane (shown in figure) is :



 (a) $\frac{27MR^2}{8}$ (b) $\frac{29MR^2}{8}$
 (c) $3.5MR$ (d) $2MR^2$

11. The ratio of the radii of gyration of a circular disc and a circular ring of the same radii about a tangential axis in the plane is :
 (a) 1 : 2 (b) $\sqrt{5} : \sqrt{6}$
 (c) 2 : 3 (d) 2 : 1

12. The M.I. about an axis of symmetry is given by (mass × sum of square of perpendicular semi axes) × $\frac{1}{n}$. Then :

(a) if $n=3$, body is rectangular
(b) if $n=4$, body is elliptical
(c) if $n=5$, body is spherical
(d) all the above

13. The moment of inertia of a uniform solid right circular cone of mass 10 kg, height 2 m and vertical angle 90° about a diameter of its base, is :
(a) 10 kgm^2 (b) 20 kgm^2
(c) 30 kgm^2 (d) none of these

14. Ram says, "A body may be in pure rotation in the presence of a single external force." Shyam says, "This is possible only for a non rigid body", then :
(a) Ram's statement is correct
(b) both statements are correct in different situations
(c) both statements are wrong
(d) both statements are stated by physicists

15. A particle of mass m rotates in a circle of radius a with a uniform angular speed ω_0. It is viewed from a frame rotating about the z-axis with a uniform angular speed ω. The centrifugal force on the particles is :
(a) $m\omega^2 a$ (b) $m\omega_0^2 a$
(c) $m\left(\frac{\omega+\omega_0}{2}\right)^2 a$ (d) $m\omega\omega_0$

16. The formula that torque equals the rate of change of angular momentum is true in following general cases :
(a) a fixed axis in inertial space
(b) an axis through the centre of mass even though the object may be accelerating
(c) a variable axis in inertial space
(d) both (a) and (c) are correct

17. Mark correct option or options :
(a) The vector product of two polar vectors may be axial vector
(b) The vector product of two polar vectors must be axial vector
(c) The sense of direction of axial vector depends on the handedness of reference frame
(d) Both (b) and (c) are correct

18. If a raw egg and a boiled egg are spinned on the table by applying same torque, then :
(a) boiled egg will spin faster
(b) raw egg will spin faster
(c) moment of inertia of boiled egg will be lesser than that of the raw egg
(d) both (a) and (c) are correct

19. The torque $\vec{\tau}$ on a body about a given point is found to be equal to $\vec{A}\times\vec{L}$ where $\vec{A}$ is constant vector and $\vec{L}$ is the angular momentum of the body about that point. From this it follows that :
(a) $\frac{d\vec{L}}{dt}$ is perpendicular to $\vec{L}$ at all instant of time
(b) the component of $\vec{L}$ in the direction of $\vec{A}$ does not change with time
(c) the magnitude of $\vec{L}$ does not change with time
(d) all the above

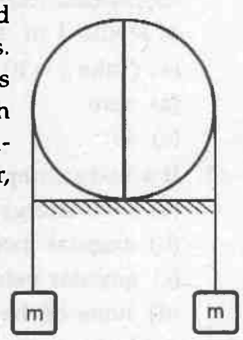
20. Mark correct option or options :
(a) For neutral equilibrium, the potential energy is constant
(b) In stable equilibrium, potential energy is minimum
(c) For unstable equilibrium, potential energy is neither constant nor minimum
(d) All the above

21. If a body is moving on a horizontal table with constant velocity, then equilibrium is :
(a) stable (b) unstable
(c) neutral (d) none of these

22. A portmanteau of length 1.5 m and height 1 m is carried up stairs by two men, who hold it by the front and back edges of its lower face. If the portmanteau is inclined at 30° to the horizontal and weighs 100 kg, how much of the weight each man support ?
(a) 6925 N and 30.75 N (b) 6.925 N and 3075 N
(c) 500 N and 600 N (d) 400 N and 600 N

***23.** The tricycle weighing 20 kg has a small wheel symmetrically placed 1 m behind the two large wheels, which are also 1 m apart. If the centre of gravity of machine be at a horizontal distance of 25 cm behind the front wheels and the rider whose weight is 40 kg, be 10 cm behind the front wheels. The thrust on each front wheel is :
(a) 255 N (b) 90 N
(c) 200 N (d) 400 N

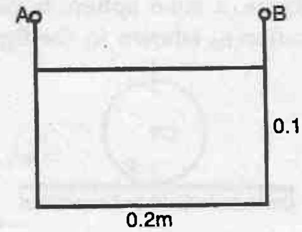
24. Two halves of a round homogeneous cylinder are held together by a thread wrapped round the cylinder with two equal weights. The complete cylinder weighs 31.4 kg. The plane of contact of both of its halves is vertical. For equilibrium of both halves of the cylinder, the minimum value of m is :



(a) $\frac{2}{3}$ g (b) 3.14 g
(c) $\frac{2}{3}$ kg (d) 31.4 g

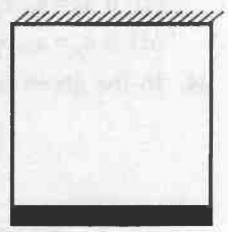
25. A rod of length L is pivoted at one end and is rotated with a uniform angular velocity in a horizontal plane. Let T_1 and T_2 be the tensions at the points $\frac{L}{4}$ and $\frac{3L}{4}$ away from the pivoted end. Then :
(a) $T_1 > T_2$
(b) $T_2 > T_1$
(c) $T_1 = T_2$
(d) the relation between T_1 and T_2 depends on whether the rod rotates clockwise or anti-clockwise

26. A rectangular plate of mass 20 kg is suspended from points A and B as shown. If the pin B is suddenly removed, determine the angular acceleration (in rad/sec^2) of the plate :



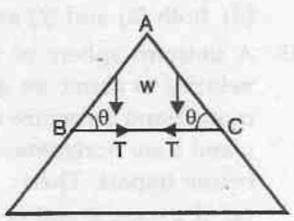
(a) 48 (b) 19.6
(c) 29.4 (d) 23.6

27. A uniform rod of length l and mass m is suspended by two vertical inextensible string as shown in figure. Then tension in the left string when right string snaps, is :



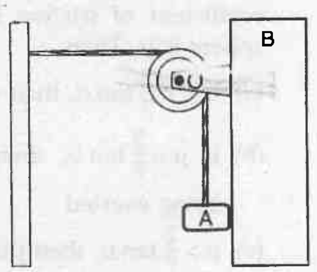
(a) $\frac{3mg}{4}$ (b) $\frac{mg}{4}$
(c) $\frac{mg}{2}$ (d) $\frac{mg}{8}$

* 28. Two uniform equal ladders AB and AC, each of weight 'w' lean against each other and a string is tied between B and C. They stand on a smooth horizontal surface. Then :



(a) the force exerted by one rod on the other at A is equal to the extension T in the string
(b) tension $T = \left(\frac{w}{2}\right)\cot\theta$
(c) the normal reaction at B and C are equal
(d) both (a) and (b) are correct

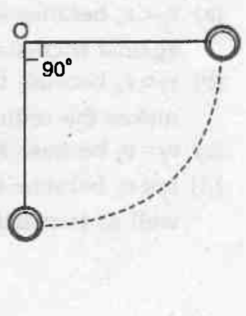
* 29. In the given figure, the mass of blocks A and B are m_1 and m_2 respectively, the pulley is circular disc of mass m and radius r. The pulley is free to rotate about O. No friction exists between A and B and the floor. The magnitude of acceleration of block B is a_0. Then the magnitude of acceleration of A is :



(a) a_0 (b) $2a_0$
(c) $\sqrt{2}a_0$ (d) g

30. A simple pendulum is vibrating with an angular amplitude of 90° as shown in the figure. For what value of α, the acceleration is directed horizontally ?

(a) 0
(b) 90°
(c) $\cos^{-1}\left(\frac{1}{\sqrt{3}}\right)$
(d) $\sin^{-1}\left(\frac{1}{\sqrt{3}}\right)$

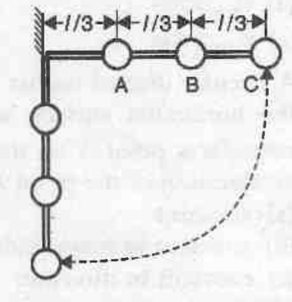


31. A rod of length L is hinged from one end. It is brought to a horizontal position and released. The angular velocity of the rod when it is in vertical position, is :

(a) $\sqrt{\frac{2g}{L}}$ (b) $\sqrt{\frac{3g}{L}}$
(c) $\sqrt{\frac{g}{2L}}$ (d) $\sqrt{\frac{g}{L}}$

32. A light rod carries three equal masses A, B and C as shown in figure. The velocity of B in vertical position of rod if it is released from horizontal position as shown in figure is :

(a) $\sqrt{2gl}$
(b) $\sqrt{\frac{18gl}{7}}$
(c) $\sqrt{\frac{4gl}{3}}$
(d) $\sqrt{\frac{8gl}{7}}$



33. The kinetic energy of a lamina moving in its plane is :

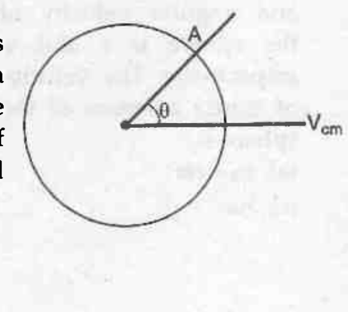
(a) $M(v_{cm}^2 + k^2\omega^2)$ (b) $\frac{1}{2}M(v_{cm}^2 + k^2\omega^2)$
(c) $\frac{1}{2}I\omega^2$ (d) none of these

34. Mark correct option or options :
(a) The centre of gravity may be coincided with centre of mass
(b) Due to movement of body, centre of gravity changes but centre of mass does not change
(c) The centre of gravity must not be coincided with the centre of gravity
(d) The centre of gravity is always above the centre of mass

35. At any instant, a rolling body may be considered to be in pure rotation about an axis through the point of contact. This axis is translating forward with speed :
(a) equal to centre of mass
(b) zero
(c) twice of centre of mass
(d) no sufficient data

36. In the case of falling, rolling and sliding from same height :
(a) the falling body reaches bottom first and rolling at last
(b) the acceleration is maximum in falling and minimum in rolling
(c) the velocity of sliding is greater than that of rolling
(d) all the above

37. A sphere of radius R is rolling on a rough horizontal surface. The magnitude of velocity of A with respect to ground will be :



(a) $\sqrt{2}v_{cm}$

(b) $2v_{cm}\sin\theta$

(c) $\sqrt{2}v_{cm}\sqrt{1+\sin\theta}$

(d) no sufficient information

38. When a wheel moves a distance shorter than $2\pi R$ while making one rotation, then :

(a) $v_{cm} < R\omega$ (b) $v_{cm} \le R\omega$

(c) $v_{cm} > R\omega$ (d) $v_{cm} > R\omega$

39. If a body moves through a distance greater than $2\pi R$ in one full rotation. Then :

(a) $v_{cm} > R\omega$ (b) $v_{cm} < R\omega$

(c) $v_{cm} > R\omega$ (d) $v_{cm} < R\omega$

40. A circular disc of radius R rolls without slipping along the horizontal surface with constant velocity v_0. We consider a point A on the surface of the disc. Then the acceleration of the point A is :

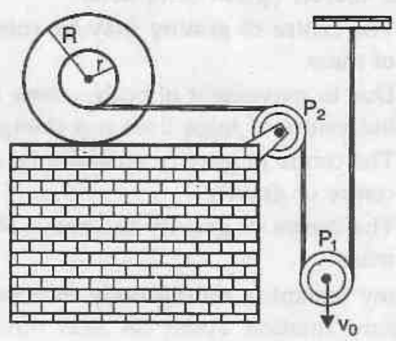
(a) constant

(b) constant in magnitude

(c) constant in direction

(d) constant in magnitude as well as direction

***41.** The bobbin with thread around it lies on a horizontal floor and can roll along it without slipping. Both pulleys P_1 and P_2 are light and frictionless. The pulley P_1 moves downwards with constant velocity v_0. The velocity of centre of mass of bobbin is :



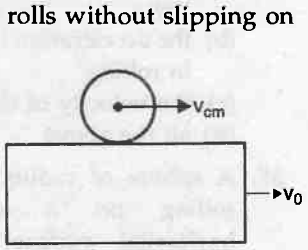
(a) $\dfrac{v_0R}{R-r}$ in forward direction

(b) $\dfrac{2v_0R}{R-r}$ in backward direction

(c) $\dfrac{v_0R}{R-r}$ in backward direction

(d) $\dfrac{2v_0R}{R-r}$ in forward direction

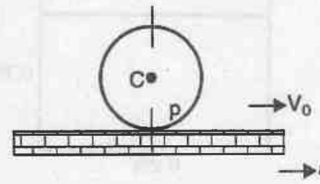
42. In the given figure, the sphere rolls without slipping on the plank which is moving with constant velocity v_0. The radius and angular velocity of the sphere is r and ω respectively. The velocity of centre of mass of the sphere is :



(a) $v_0 + r\omega$ (b) $v_0 - r\omega$

(c) $r\omega$ (d) v_0

43. In the given figure, a solid sphere is placed on a plank having acceleration a_0 (shown in the figure). Then :



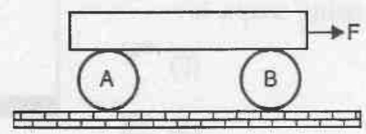
(a) if $a_p = a_0$, pure rolling takes place

(b) if $v_p = v_0$, pure rolling takes place

(c) if $a_p = a_0$, $v_p \ne v_0$ pure rolling takes place

(d) if $a_p = a_0$, $v_p = v_0$, pure rolling takes place

44. In the given figure, for pure rolling of spheres :



(a) friction on B is in forward direction

(b) friction on A is in backward direction

(c) friction on A and B are in forward direction

(d) both (a) and (c) are correct

45. A uniform sphere of radius a rotating with an angular velocity ω about an axis perpendicular to the plane of motion and its centre impinges on a horizontal plane, let u and v are horizontal and vertical component of velocity before impact. Then :

(a) if $u - a\omega$, u and ω are unaltered

(b) if $u = a\omega$, surface is frictionless

(c) if $u > a\omega$, angular velocity increases

(d) all the above

*** 46.** An imperfectly rough sphere moves from rest down a plane inclined at an angle α to the horizontal. The coefficient of friction between the inclined plane and sphere is μ. Then

(a) if $\mu < \frac{2}{7}\tan\alpha$, then the sphere never rolls

(b) if $\mu = \frac{2}{7}\tan\alpha$, then the maximum friction always being exerted

(c) $\mu > \frac{2}{7}\tan\alpha$, then pure rolling takes place

(d) all the above

*** 47.** A ball rolls down an inclined groove acquiring a velocity v_f as it reaches the bottom. If the same ball slides without friction rather than rolled from the same height down a similar track to acquire a velocity v_s, which of the following statements is true ?

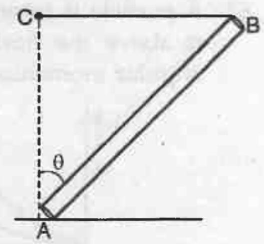
(a) $v_f < v_s$ because work must be done by the rolling ball against frictional forces

(b) $v_f > v_s$ because the rotational kinetic energy acquired makes the rolling ball travel faster

(c) $v_f = v_s$ because K.E. must be conserved

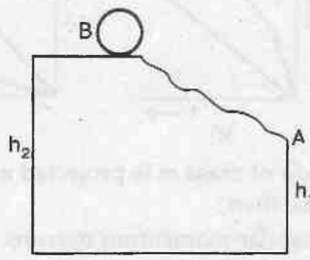
(d) $v_f < v_s$ because the rolling ball acquires rotational as well as translational K.E.

48. A rod AB of mass 10 kg tied with a string at C such that $AC = AB$. At $\theta = 30°$:



(a) rod is in equilibrium
(b) the force of friction on the rod by ground is 25 N
(c) the force of friction acts in the forward direction
(d) all the above

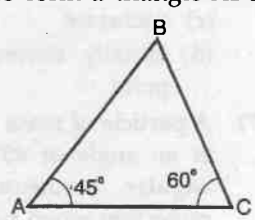
49. In the given figure :



(a) if ball performs pure rolling then friction in surface is absent
(b) if air resistance is absent, after point A, angular momentum of ball remains constant
(c) after A, path of centre of mass is parabolic
(d) both (b) and (c) are correct

50. A uniform rod is placed vertically on a smooth surface and then released. Then :
(a) the centre of mass of rod follows straight line path
(b) the centre of mass of rod follows circular path
(c) the instantaneous axis is passing through the contact point
(d) all the above

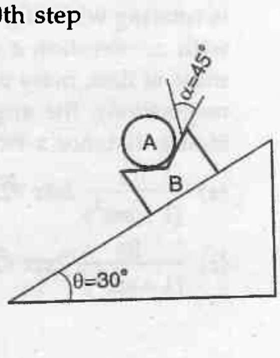
51. Three links are hinged together to form a triangle ABC as shown in the figure. At a certain instant, the point A is moving towards the mid point of BC with a velocity of 5 m/s and B is moving at a perpendicular direction to AC. The velocity of point C is :



(a) 5 m/s (b) 10.4 m/s
(c) 10.8 m/s (d) 1.8 m/s

52. A ball rolls off the top of a step ladder with a horizontal velocity of 10 m/s. If the steps are 1 m high and 1 m wide, the ball will just hit :
(a) 3rd step (b) 20th step
(c) 12th step (d) 10th step

53. A cylinder of mass m rests in a carriage shown. The maximum acceleration of carriage so that the cylinder does not loose contact at B is :



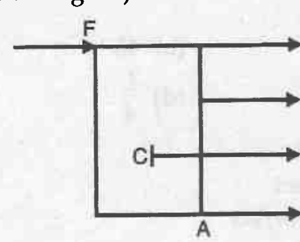
(a) 3.66 m/s^2
(b) 10 m/s^2
(c) 45 m/s^2
(d) 8 m/s^2

54. Mark correct option or options :
(a) Rolling friction always oppose the motion of centre of mass of rolling body
(b) Sliding friction always oppose the motion of centre of mass of rolling body
(c) Rolling friction depends upon hardness of the surface
(d) Rolling friction does not depend upon roughness of the surface
(e) (a), (c) and (d) are correct

55. Mark correct option or options :
(a) A uniform cube has minimum moment of inertia about an axis passing through centre and is passing through opposite corners
(b) The moment of inertia of a complicated shape bodies can be determined by using inertia of table
(c) Displacing of axial vectors is meaningless
(d) All the above

56. A uniform cube of mass m and edge a moves on a horizontal surface along the positive x-axis, with initial velocity v_0 :
(a) during motion, $N > mg$
(b) during motion, normal reaction acts on the centre of mass
(c) during motion, the normal reaction shifts towards positive x-axis from the centre of mass
(d) during motion, normal reaction shifts in the direction of the forces of friction

57. In the case of toppling of the body about the point A. (Shown in the figure) :

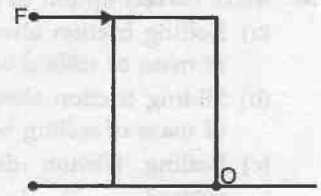


(a) $v_C > v_2 > v_1 > v_A$ (b) $v_1 > v_2 > v_C > v_A$
(c) $v_A > 0$ (d) $v_C < v_1 < v_2 < v_A$

58. In the above problem, acceleration of the point A is :
(a) > 0 (b) $\ngtr 0$
(c) < 0 (d) $= 0$

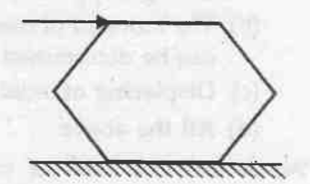
59. Two cubes A and B of same shape, size and mass are placed on a rough surface in the same manner. Equal forces are applied on both the cubes. But at the cube A, the force is applied at the top in horizontal direction. But at the cube B just above the centre of mass of the cube in the same manner. Then :
(a) A will topple first
(b) B will topple first
(c) both will topple at the same time
(d) none of the above

*60. A cube of side a is placed on rough surface (shown in the figure). Then :



(a) if $f < \frac{Mg}{2}$, then the body will move in pure rotation and will not topple
(b) if $F > \frac{Mg}{2}$, the body will topple
(c) if $\mu > 0.5$, the body will move by toppling
(d) all the above

61. For the toppling of the shown regular hexagon, the coefficient of friction must be :



(a) > 0.21
(b) < 0.21
(c) $= 0.21$
(d) < 0.21

62. A regular polygon of n sides is placed on a rough surface vertically as such one of the side of regular polygon touches the surface. A force is applied horizontally at the top. The chosen value of n are 3, 5 and 8. For which value of n, the polygon first is likely to topple ?
(a) 3 (b) 5
(c) 8 (d) all the above

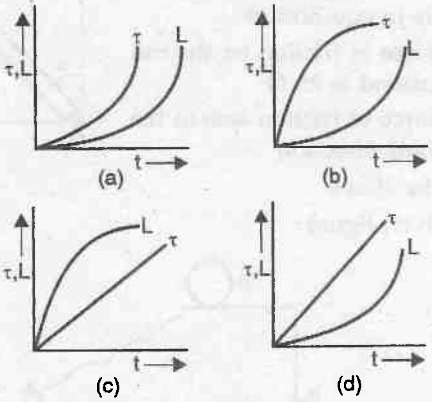
63. A particle performs uniform circular motion with an angular momentum L. If the frequency of particle motion is doubled and its K.E. is halved, the angular momentum becomes :
(a) $2L$ (b) $4L$
(c) $\frac{L}{2}$ (d) $\frac{L}{4}$

64. $L = I\omega$ formula is :
(a) always correct
(b) sometimes correct
(c) always wrong
(d) physically correct but dimensionally wrong

65. A person can balance easily a moving bicycle, but cannot balance a stationary bicycle. This statement is based upon :
(a) conservation principle of linear momentum
(b) conservation principle of angular momentum
(c) conservation principle of energy
(d) all of the above principle

66. Mark correct option or options
(a) The angular momentum of a rotating body must be parallel to the angular velocity
(b) The angular momentum may or may not be parallel to angular velocity
(c) The kinetic energy of rotational body is half of product of angular momentum and angular velocity
(d) Both (b) and (c) are correct

67. A particle is projected with initial velocity u at an angle α above the horizontal, then variation of torque and angular momentum with time will be :



68. If a particle of mass m is projected at an angle α with the horizontal, then :
(a) the angular momentum remains constant
(b) the linear momentum of particle remains constant
(c) total mechanical energy remains constant in the absence of air resistance
(d) all the above

69. A mass m is moving with a constant velocity along a line parallel to the x-axis, away from the origin. Its angular momentum with respect to the origin :
(a) is zero (b) remains constant
(c) goes on increasing (d) goes on decreasing

70. When a body is projected at an angle with the horizontal in the uniform gravitational field of the earth, the angular momentum of the body about the point of projection, as it proceeds along its path :
(a) remains constant (b) increases
(c) decreases
(d) initially decreases and increases after its highest point

71. A particle of mass m is projected with velocity v moving at an angle of 45° with horizontal. The magnitude of angular momentum of projectile about point of projection when particle is at maximum height, is :
(a) zero (b) $\frac{mv^3}{4\sqrt{2}g}$
(c) $\frac{mv^3}{\sqrt{2}g}$ (d) $m\sqrt{2gh^3}$

72. A man is standing at the centre of a big flat disc which is rotating with angular speed ω. The man starts running with acceleration a with respect to disc. If M, m, I, R are mass of disc, mass of man, M.I. of disc and radius of disc respectively, the angular acceleration of disc when man is at a distance x from centre is :
(a) $\frac{I\omega}{(1+mx^2)}2mx\sqrt{2ax}$ (b) $\frac{I\omega}{(1+mx^2)^2}\sqrt{2ax}$
(c) $\frac{I\omega}{(1+mx^2)^2}2mx\sqrt{2ax}$ (d) none of these

73. A lady dancer is dancing on a turn table. During dancing, she stretches her hands. Then :
(a) the angular velocity increases
(b) the angular velocity decreases
(c) the angular velocity first increases, then decreases
(d) the angular velocity remains constant

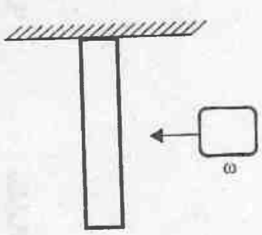
74. Two particles, each of mass m and moving with speed v in opposite directions along parallel lines are separated by a distance d. The vector angular momentum of this system of the particles will be :
(a) maximum when the origin is taken beyond the two parallel lines on either sides
(b) maximum when the origin is taken beyond the two parallel lines on either sides
(c) maximum when the origin is taken beyond the two parallel lines on either sides
(d) same, no point is taken as the origin

75. A uniform rod of length $2a$ is held with one end resulting on a smooth horizontal table making an angle α with the vertical. When the rod is released :
(a) its centre of mass moves vertically downwards on a straight line
(b) its centre of mass remains in rest
(c) the rod rotates about a vertical axis
(d) both (a) and (c) are correct

76. A 70 kg man standing on ice throws a 3 kg body horizontally at 8 m/s. The friction coefficient between the ice and his feet is 0.02. The distance, the man slips is :
(a) 0.3 m (b) 2 m
(c) 1 m (d) ∞

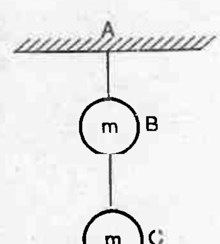
77. In a radioactive decay, a number of fragments are found. If parent nucleus is initially at rest then after decay centre of mass will :
(a) move on a straight line
(b) move in a circle
(c) remain in rest
(d) move in parabolic path

78. A particle of mass m strikes elastically, a rod of mass M and length L suspended from a fixed support, then :



(a) conservation of linear momentum can be applied
(b) conservation of angular momentum can be applied
(c) both the above
(d) none of the above

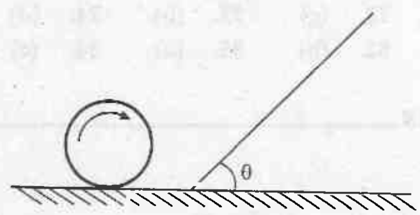
79. A weightless rod of length l carries two equal masses m one fixed at the end and other in the middle of the rod. The rod can revolve in a vertical plane about A. Then horizontal velocity which must be imparted to end C of rod to deflect it to horizontal position is :



(a) $\sqrt{\frac{12}{5} gl}$ (b) $\sqrt{3gl}$
(c) $\sqrt{\frac{16}{5} gl}$ (d) $\sqrt{2gl}$

80. Two balls A and B of angular velocities ω_A and ω_B collide with each other. Then after collision :
(a) both have same angular velocities
(b) $\omega_A > \omega_B$
(c) $\omega_A = \omega_B$, when balls are smooth
(d) $\omega_A > \omega_B$ when balls are smooth

81. A uniform solid cylinder rolling without slipping along a horizontal plane suddenly encounters a plane inclined at angle θ as shown in figure. The value of θ which could bring the cylinder immediately to rest after impact, is :



(a) 90° (b) 60°
(c) 120° (d) 30°

82. A body whose mass is m_1 is acted upon at a given point P by a blow of impulse x. If v and v' be the velocities of P in the direction of x just before and just after the action of x, the change in kinetic energy is :
(a) $\left(\frac{v+v'}{2x}\right)$ (b) $\frac{(v+v')\,x}{2}$
(c) $\frac{1}{4}(v'+v)\,x$ (d) all of these

83. A uniform rod OA of mass M and length $2a$ rests on a smooth table and is free to turn about a smooth pivot at its end O, in contact with it at a distance b from O is an inelastic particle of mass m, a horizontal blow of impulse p is given to rod at a distance x from O in a direction perpendicular to the rod. The resultant instantaneous angular velocity of the rod is :
(a) $\frac{px}{\frac{4Ma^2}{3}+mb^2}$ (b) $\frac{px}{M}$
(c) $\frac{px}{ma^2+mb^2}$ (d) none of these

84. A uniform rod AB of mass m and length l is at rest on a smooth horizontal surface. An impulse p is applied to the end B. The time taken by the rod to turn through a right angle is :
(a) $2\pi\frac{ml}{p}$ (b) $2\pi\frac{p}{ml}$
(c) $\frac{\pi ml}{12p}$ (d) $\frac{\pi p}{ml}$

Answers

Level-1

1. (c)	2. (b)	3. (b)	4. (b)	5. (d)	6. (a)	7. (a)	8. (c)	9. (a)	10. (c)
11. (c)	12. (a)	13. (b)	14. (c)	15. (c)	16. (b)	17. (b)	18. (a)	19. (c)	20. (c)
21. (b)	22. (d)	23. (a)	24. (a)	25. (b)	26. (a)	27. (b)	28. (a)	29. (b)	30. (c)
31. (c)	32. (a)	33. (b)							

Level-2

1. (d)	2. (d)	3. (b)	4. (c)	5. (a)	6. (a)	7. (d)	8. (c)	9. (b)	10. (b)
11. (b)	12. (d)	13. (a)	14. (c)	15. (b)	16. (d)	17. (d)	18. (d)	19. (d)	20. (d)
21. (c)	22. (b)	23. (a)	24. (c)	25. (a)	26. (a)	27. (b)	28. (d)	29. (c)	30. (c)
31. (b)	32. (d)	33. (b)	34. (a)	35. (a)	36. (d)	37. (c)	38. (a)	39. (a)	40. (b)
41. (d)	42. (a)	43. (d)	44. (d)	45. (d)	46. (d)	47. (a)	48. (c)	49. (d)	50. (a)
51. (b)	52. (b)	53. (a)	54. (e)	55. (d)	56. (c)	57. (b)	58. (d)	59. (a)	60. (d)
61. (a)	62. (c)	63. (d)	64. (b)	65. (b)	66. (d)	67. (d)	68. (c)	69. (b)	70. (b)
71. (b)	72. (c)	73. (b)	74. (d)	75. (d)	76. (a)	77. (c)	78. (b)	79. (a)	80. (c)
81. (c)	82. (b)	83. (a)	84. (c)						

Solutions

Level-1

1. $$I_{\text{tangent}} = \frac{2}{5}mr^2 + mr^2 = \frac{7}{5}mr^2$$
$$= \frac{7}{5} \times 5 \times (1)^2 = 7 \text{ kg m}^2$$

2. $$I = \frac{1}{2}mr^2 = \frac{1}{2} \times 1 \times (0.1)^2$$
$$= \frac{0.01}{2} = 5 \times 10^{-3} \text{ kg m}^2$$

5. $$I = \frac{Ml^2}{3} \times \frac{4}{4} = 4\frac{Ml^2}{12} = 4I_0$$

8. Since, the system is isolated, no external force is acting therefore, the speed of the C.M. does not change.

10. Height of the projectile is,
$$H = \frac{u^2 \sin^2 \theta}{2g}$$
Velocity at highest point $= u \cos \theta$
$$\therefore \quad L = mvH = \frac{m\,(u^2 \sin^2 \theta)}{2g} u \cos \theta$$
$$= \frac{mu^3 \sin^2 \theta \cos \theta}{2g}$$

11. Mass of cylinder $M = \pi R^2 l \rho$
$$\therefore \quad R^2 \propto \frac{1}{\rho}$$
$$\frac{I_P}{I_Q} = \frac{\frac{1}{2}MR_P^2}{\frac{1}{2}MR_Q^2}$$
or
$$\frac{I_P}{I_Q} = \frac{\rho_Q}{\rho_P}$$
or
$$\rho_P > \rho_Q$$
$$\therefore \quad I_P < I_Q$$

14. $$\text{KE} = \frac{1}{2}I\omega^2 = \frac{1}{2}mr^2\omega^2$$

16. $$\frac{\text{Rotational kinetic energy}}{\text{Translational kinetic energy}} = \frac{\frac{1}{2} \cdot \frac{2}{5}Mr^2 \cdot \omega^2}{\frac{1}{2}Mv^2} = \frac{2}{5}$$

17. $$\text{Total KE} = \frac{1}{2}Mv^2 + \frac{1}{2}I\omega^2 = \frac{1}{2}\left(Mv^2 + MK^2\frac{v^2}{R^2}\right)$$
$$\text{KE} = \frac{1}{2}Mv^2\left(1 + \frac{K^2}{R^2}\right)$$
$$v^2 \propto \frac{1}{\left(1 + \frac{K^2}{R^2}\right)}$$ (∵ KE are equal masses are also equal.)
$$\therefore \quad \frac{v_d^2}{v_s^2} = \frac{\dfrac{1}{\left(1 + \frac{R^2}{R^2}\right)}}{\dfrac{1}{\left(1 + \frac{2R^2}{5R^2}\right)}}$$
$$\frac{v_d^2}{v_r^2} = \frac{7}{10}$$

9

Gravitation

Syllabus: Acceleration due to gravity, one and two dimensional motion under gravity. Universal law of gravitation, variation in the acceleration due to gravity of the earth. Planetary motion, artificial satellite, geostationary satellite, gravitational potential energy near surface of earth, gravitational potential and escape velocity.

Review of Concepts

1. Newton's law of Gravitation :

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

where G is a gravitational constant. Its value does not depend upon medium.

$$G = 6.67 \times 10^{-11}\ \text{Nm}^2/\text{kg}^2 = 6.7 \times 10^{-\text{[illegible]}}\ \text{dyne cm}^2/\text{gm}^2$$

(a) Gravitational force is central force and conservative in nature.

(b) The value of G is determined by Cavendish method in 1798.

(c) Gravitational force is always attractive in nature.

(d) Relation between g and G:

$$g = \frac{GM}{R^2}$$

where M = mass of earth, R = radius of earth

2. The variation of g :

(a) The value of g falls with height:

$$g_h = g\left(\frac{R}{R+h}\right)^2 = g\left(1+\frac{h}{R}\right)^{-2}$$

where g_h = gravitational acceleration at height h from the surface of earth.

If $h << R$, $\quad g_h = g\left(1-\frac{2h}{R}\right)$

(b) The variation of g with depth d from the surface of earth:

$$g_d = g\left(1-\frac{d}{R}\right)$$

(c) The value of g at the centre of earth is zero.

(d) Due to rotation of earth, the value of g decreases as the speed of rotation of earth increases. The value of acceleration due to gravity at a latitude λ is

$$g_\lambda = g - R\omega^2 \cos^2 \lambda$$

At equator, $\lambda = 0$ and at the pole, $\lambda = 90°$

(i) At the equator, $g_E = g - R\omega^2$

(ii) At the pole, $g_{pole} = g$

(iii) If the earth stops spinning, then the value of g is same as everywhere.

(iv) The earth has a bulge at the equator because of the spinning motion.

(v) Isogram is defined as the line joining the places have same gravitational acceleration.

(vi) For flying off the object situated at equator, the angular speed about its own axis should be larger than seventeen times the present value.

(vii) If a planet moves around sun, work done by gravitational force is zero. So, total mechanical energy of planet remains constant.

3. Escape Velocity: It is defined as minimum speed of projection with which if a body is projected upwards, then it does not return back to earth.

Mathematically, $\quad v_{es} = \sqrt{\left(\frac{2GM}{R}\right)} = \sqrt{2gR}$

where M = mass of planet

(a) Escape velocity is independent of the mass of projectile, but it depends on the mass of planet.

(b) Escape velocity does not depend on angle of projection.

(c) The trajectory of a projectile projected from a very tall tower parallel to the surface of earth depends upon its velocity v as follows :

Velocity of Projectile	Trajectory
$v < \frac{v_e}{\sqrt{2}} = v_o$	Projectile does not revolve around earth. It fall back on the surface of earth.
$v = \frac{v_e}{\sqrt{2}} = v_o$	Projectile revolves around the earth in circular orbit.
$\frac{v_e}{\sqrt{2}} < v < v_e$	Projectile moves around earth in elliptical path.
$v = v_e$	It escapes from the gravitational field of earth in parabolic path.
$v > v_e$	It escapes from the gravitational field of earth in a hyperbolic path.

(d) If a particle of mass m is dropped from the end of tunnel along diameter of earth, then the motion of the particle is S.H.M. having angular frequency of

$$\omega = \sqrt{\left(\frac{g}{R}\right)}$$

(e) The time period of longest pendulum on the surface of earth is given by $T = 2\pi\sqrt{\left(\frac{R}{g}\right)}$

where $R = 6400$ km, $g = 9.8$ m/s²

4. Intensity and Potential:

(a) Gravitational field at a point distance r from a point mass m is $E = \frac{Gm}{r^2}$ towards the point mass and gravitational potential is

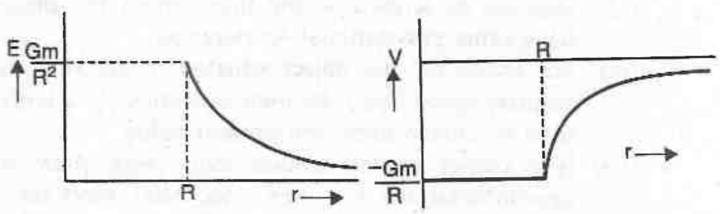
$$V = -\frac{Gm}{r}$$

(b) Spherical shell or hollow sphere

Case I: $\longrightarrow r \geq R$, where R is radius of spherical shell.

$$E = \frac{Gm}{r^2} \quad \text{and} \quad V = -\frac{Gm}{r}$$

Case II: $\longrightarrow r < R$, $E = 0$, $V = -\frac{Gm}{R}$

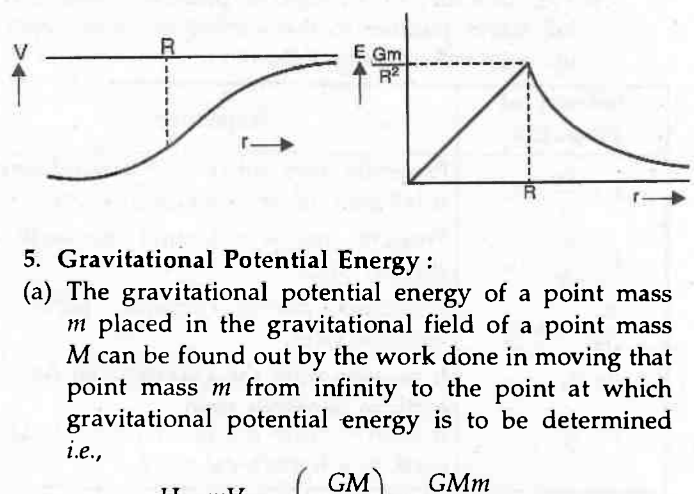


(c) A uniform solid sphere of mass m:

Case I: $\longrightarrow r > R$, $E = \frac{Gm}{r^2}$ and $V = -\frac{Gm}{r}$

Case II: $\longrightarrow r < R$, $E = \frac{Gm}{R^3} r$

and $\quad V = -\frac{Gm}{2R^3}(3R^2 - r^2)$



5. Gravitational Potential Energy:

(a) The gravitational potential energy of a point mass m placed in the gravitational field of a point mass M can be found out by the work done in moving that point mass m from infinity to the point at which gravitational potential energy is to be determined *i.e.*,

$$U = mV = m\left(-\frac{GM}{r}\right) = -\frac{GMm}{r}$$

r, being the distance between masses.

Or the gravitational potential energy or self energy for a system of n masses is given by

$$U = -\sum_{i=1}^{n}\sum_{j=1}^{n}\frac{GM_i m_j}{r_{ij}} \qquad (i > j)$$

(b) The change occurred in potential energy when a point mass m is moved vertically upwards through a height h from earth's surface.

$$\Delta U = \frac{mgRh}{(R+h)}$$

Case I: $\longrightarrow h << R$, $\Delta U = \frac{mgh}{1 + \frac{h}{R}} \approx mgh$

Case II: $\longrightarrow h >> R$, $\Delta U = \frac{mgR}{1 + \frac{R}{h}} \approx mgR$

6. Satellite:

(a) **Orbital velocity:**

(i) Orbital velocity of a satellite revolving around the earth in a circular orbit at a height h is

$$v_o = \sqrt{\left[\frac{gR^2}{(R+h)^2}\right]} = \sqrt{\left[\frac{GM}{(R+h)^2}\right]}$$

where, R = radius of earth, M = mass of earth

(ii) If satellite is revolving near the earth *i.e*, $h << R$, then

$$v_o = \sqrt{gR} \sim 8 \text{ km/sec}$$

(b) **Time period:**

(i) The period of revolution is

$$T = \frac{2\pi(R+h)}{v_o} = 2\pi\sqrt{\left[\frac{(R+h)^3}{gR^2}\right]}$$

(ii) If $h << R$, then $T = 2\pi\sqrt{\left(\frac{R}{g}\right)} = 84.6$ min

(c) **Kinetic energy:**

$$\text{K.E.} = \frac{1}{2}mv_o^2 = \frac{GMm}{2(R+h)}$$

(d) **Potential energy:**

$$\text{P.E.} = -\frac{GMm}{(R+h)} = -2\,\text{K.E.}$$

So, total energy $E = \text{K.E.} + \text{P.E.} = \text{K.E.} - 2\text{K.E.}$

$$= -\text{K.E.} = -\frac{GMm}{2(R+h)}$$

Some Important Points:

(a) The total energy of a satellite in the orbit is always negative *i.e.*, the body is bound to the earth.

(b) If we place a satellite in an orbit with a velocity v, then the velocity v_o for which the satellite revolves around the earth in an orbit of radius r is $v_o = \sqrt{\frac{GM}{r}}$.

(i) When $v < v_o$; the satellite does not revolve around the earth and spirals inwards till it falls on earth.

(ii) When $v_o > v < v_{es}$; the satellite revolves in elliptical orbit.

(iii) When $v > v_{es}$; the satellite escapes following hyperbolic orbit.

(c) The total energy of satellite when it is thrown with a velocity v, is:

(i) positive, if $v > v_{es}$

(ii) zero, if $v = v_{es}$

(iii) negative, if $v < v_{es}$

Objective Questions

Level-1

1. The radius of the earth shrinks by 1%. The acceleration due to gravity on the earth's surface would (mass remaining constant):
   (a) increase by 2% (b) increase by 1%
   (c) decrease by 1% (d) decrease by 0.5%
2. If F_1 is the magnitude of the force exerted on earth by moon and F_2 is the magnitude of force exerted on moon by earth then:
   (a) $F_1 > F_2$ (b) $F_1 = F_2$
   (c) $F_1 < F_2$ (d) none of these
3. The gravitational force of attraction between two spherical bodies, each of mass 100 kg, if the distance between their centres is 100 m, is:
   $(G = 6.67 \times 10^{-11}\ \text{Nm}^2\ \text{kg}^{-2})$
   (a) 6.67×10^{-11} N (b) 6.67×10^{-9} N
   (c) 6.67 N (d) none of these
4. A particle is fired vertically upwards with a speed of $v = \sqrt{0.8}\ v_e$. If the radius of the earth is R_e then the maximum height attained by the particle will be:
   (a) R_e (b) $2R_e$
   (c) $3R_e$ (d) $4R_e$
5. A planet has radius and mass, both half of those of the earth, then the value of g on that planet will be:
   (a) 4.9 m/s^2 (b) 9.8 m/s^2
   (c) 19.6 m/s^2 (d) 13.8 m/s^2
6. A body is projected vertically from the earth's surface with velocity equal to half of the escape velocity. Maximum height reached by the body is:
   (a) $\frac{5R}{3}$ (b) $\frac{R}{3}$
   (c) $\frac{2R}{3}$ (d) $\frac{R}{2}$
7. If the radius of the earth reduces by 4% density remaining the same, then the escape velocity will:
   (a) increase by 4% (b) increase by 2%
   (c) decrease by 4% (d) decrease by 2%
8. The time period of artificial satellite in a circular orbit of radius R is T. The radius of the orbit in which time period is $8T$ is:
   (a) $2R$ (b) $3R$
   (c) $4R$ (d) $5R$
9. A satellite is orbiting very close to planet. Its time period depends only upon:
   (a) density of the planet (b) mass of the planet
   (c) radius of the planet (d) mass of the satellite
10. A body is projected with escape velocity 11.2 km/s from earth's surface. If the body is projected in a direction 30° angle to the vertical, its escape velocity in this case will be:
    (a) 11.2 km/s (b) $11.2 \times \frac{1}{2}$ km/s
    (c) $11.2\left(\frac{\sqrt{3}}{2}\right)$ km/s (d) none of these
11. A planet is moving in an elliptical orbit. If T, V, E and L are respectively the kinetic energy, potential energy, total energy and the magnitude of the angular momentum of the planet then the true statement out of the following is:
    (a) T is conserved
    (b) V is always positive
    (c) E is always negative
    (d) L is conserved but the direction vector $\vec{L}$ continuously changes
12. The gravitational field in a region is given by $E = (5\hat{i} + 12\hat{j})$ N/kg then the magnitude of the gravitational force acting on a particle of mass 2 kg placed at the origin, will be:
    (a) zero (b) 13 N
    (c) 26 N (d) 75 N
13. The minimum energy required to launch a 'm' kg satellite from earth's surface in a circular orbit at an altitude of $2R$ which is the radius of each, will be;
    (a) $3mgR$ (b) $\frac{5}{6}mgR$
    (c) $2mgR$ (d) $\frac{1}{5}mgR$
14. The gravitational potential difference between the surface of a planet and a point 20 m above it is 16 J /kg. Then the work done in moving a 2 kg mass by 8 m on a slope 60° from the horizontal, is:
    (a) 11.1 J (b) 5.55 J
    (c) 16 J (d) 27.7 J
15. Three particles, each of mass 10^{-2} kg are brought from infinity to the vertices of an equilateral triangle of side 0.1 m, the work done is:
    (a) 2×10^{-8} J (b) 2×10^{-11} J
    (c) 2×10^{-12} J (d) 2×10^{-13} J

Level-2

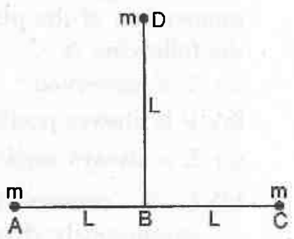
1. The gravitational force of attraction between two spherical bodies, each of mass 1 kg placed at 10 m apart $(G = 6.67 \times 10^{-11}\ \text{Nm}^2/\text{kg}^2)$ is:
   (a) 6.67×10^{-13} N (b) 6.67×10^{-11} N
   (c) 6.67×10^{-7} N (d) none of these

2. If the distance between the two particles is increased by 2%, then the force of attraction between them will :
(a) decrease 6% (b) decrease 4%
(c) increase 4% (d) increase 6%

3. How the gravitational constant will change if a brass plate is introduced between two bodies?
(a) No change (b) Decreases
(c) Increases (d) No sufficient data

4. Six particles each of mass m are placed at the corners of a regular hexagon of edge length a. If a point mass m_0 is placed at the centre of the hexagon, then the net gravitational force on the point mass m_0 is :
(a) $\frac{6Gm^2}{a^2}$ (b) $\frac{6Gmm_0}{a^2}$
(c) zero (d) none of these

5. Two particles each of mass m are placed at A and C as such $AB = BC = L$. The gravitational force on the third particle placed at D at a distance L metre on the perpendicular bisector of the line AC, is :



(a) $\frac{Gm^2}{\sqrt{2}L^2}$ along BD (b) $\frac{Gm^2}{\sqrt{2}\,L^2}$ along DB
(c) $\frac{Gm^2}{L^2}$ along AC (d) none of these

6. In a hypothetical concept, electron of mass m_e revolves around nucleus due to gravita- tional force of attraction between electron and proton of mass m_p. If the radius of circular path of electron is r then the speed of electron is :
(a) $\sqrt{\frac{Gm_pm_e}{4r}}$ (b) $\sqrt{\frac{Gm_pm_e}{r}}$
(c) $\sqrt{\frac{Gm_p}{r}}$ (d) none of these

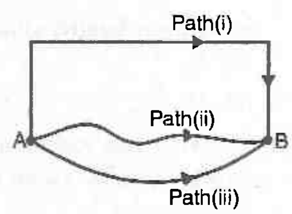
7. Three point masses each of mass m rotate in a circle of radius r with constant angular velocity ω due to their mutual gravitational attraction. If at any instant, the masses are on the vertex of an equilateral triangle of side a, then the value of ω is :
(a) $\sqrt{\frac{Gm}{a^3}}$ (b) $\sqrt{\frac{3Gm}{a^3}}$
(c) $\sqrt{\frac{Gm}{3a^3}}$ (d) none

8. A spherical mass of radius $r = \frac{R}{2}$ is taken out from a uniform sphere of radius R and mass density ρ. The force which this sphere having a cavity will exert on a mass m placed at a distance of x from its centre x $(x > R)$ is :
(a) $\frac{4\pi}{3}\frac{\rho GmR^3}{x^2}$
(b) $\frac{4\pi}{3}\rho GmR^3\left[\frac{1}{x^2} - \frac{1}{2\,(2x-R)^2}\right]$
(c) $\frac{4Gm\rho}{3\,(R^2+x^2)^{3/2}}$
(d) none of the above

9. Suppose the gravitational force varies inversely as the n^{th} power of the distance. Then the time period of a planet in circular orbit of radius R around the sun will be proportional to :
(a) R^n (b) $R^{(n+1)/2}$
(c) $R^{(n-1)/2}$ (d) R^{-n}

10. A straight rod of length L extends from $x = a$ to $x = L + a$. The gravitational force exerted by it on a point mass m at $x = 0$ if the linear density of rod is $\mu = A + Bx^2$, is :
(a) $Gm\left[\frac{A}{a} + BL\right]$ (b) $Gm\left[A\left(\frac{1}{a} - \frac{1}{a+L}\right) + BL\right]$
(c) $Gm\left[BL + \frac{A}{a+L}\right]$ (d) $Gm\left[BL - \frac{A}{a}\right]$

11. A gravitational field is present in a region. A point mass is shifted from A to B, from different paths shown in the figure. If W_1, W_2 and W_3 represent work done by gravitational force for respective paths, then :



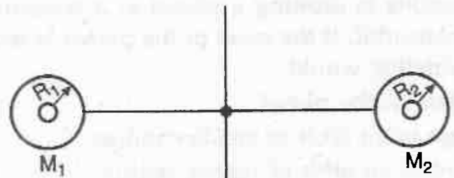
(a) $W_1 = W_2 = W_3$ (b) $W_1 > W_2 > W_3$
(c) $W_1 > W_3 > W_2$ (d) none of these

12. The mass of the moon is about 1.2% of the mass of the earth. The gravitational force exerted by moon on earth as compared to the gravitational force exerted by earth on moon :
(a) is the same (b) is smaller
(c) is greater (d) varies with its phase

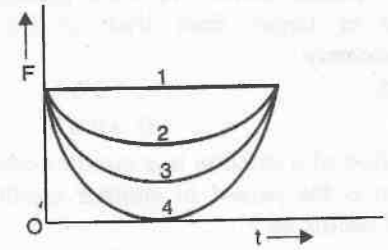
13. A point mass m_0 is placed at distance $R/3$ from the centre of a spherical shell of mass m and radius R. The gravitational force on the point mass m_0 is :
(a) $\frac{4Gmm_0}{R^2}$ (b) zero
(c) $\frac{9Gmm_0}{R^2}$ (d) none of these

14. n-particles each of mass m_0 are placed on different corners of a regular polygon of edge length a. The distance between vertex and centre of polygon is r_0. The gravitational potential at the centre of the polygon is :
(a) $-\frac{Gnm_0}{r_0}$ (b) $-\frac{Gm_0}{r_0}$
(c) $\frac{nGm_0}{r_0}$ (d) none of these

* 15. Suppose that in a region only gravitational field due to masses M_1 and M_2 are present. A particle of mass m goes from surface of M_1 to the surface of M_2 in a spaceship moving with constant velocity. Neglect all other objects besides M_1, M_2 and m.

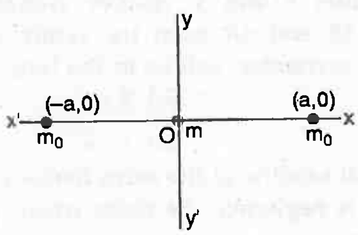


Which part of figure 15 (B) best represents the net gravitational force on the particle as a function of time?



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

16. In the given figure, for small displacement of particle of mass m along y-axis, the motion of the particle is:



(a) simple harmonic
(b) motion with constant acceleration
(c) non-oscillatory
(d) none of the above

17. In previous problem, the acceleration of the particle of mass m at origin is:
(a) zero (b) greater than zero
(c) less than zero (d) none of these

18. A point mass of 10 kg is placed at the centre of earth. The weight of the point mass is:
(a) zero (b) 98 N
(c) 49 N (d) none of these

19. The time period of a simple pendulum at the centre of earth is:
(a) zero (b) infinite
(c) less than zero (d) none of these

20. A particle hanging from a massless spring stretches it by 2 cm at earth's surface. How much will the same particle stretch the spring at height 2624 km from the surface of earth? (Radius of earth = 6400 km)
(a) 1 cm (b) 2 cm
(c) 3 cm (d) 4 cm

21. At the surface of a certain planet acceleration due to gravity is one-quarter of that on the earth. If a brass ball is transported to this planet, then which one of the following statements is not correct?
(a) The mass of the brass ball on this planet is quarter of its mass as measured on the earth
(b) The brass ball has same mass on the other planet as on the earth
(c) The brass ball has same volume on the other planet as on the earth
(d) None of the above

22. If the radius of earth decreases by 10%, the mass remaining unchanged, what will happen to the acceleration due to gravity?
(a) Decreases by 19%
(b) Increases by 19%
(c) Decreases by more than 19%
(d) Increases by more than 19%

23. A man covers 60 metre distance in one minute on the surface of earth. The distance he will cover on the surface of moon per minute is: (assuming $g_{moon} = \frac{g_{earth}}{6}$)
(a) 60 m (b) 60×6 m
(c) $\frac{60}{6}$ m (d) $\sqrt{60}$ m

24. A body is suspended on a spring balance in a ship sailing along the equator with a speed v'. If ω is the angular speed of the earth and w_0 is the scale reading when the ship is at rest, the scale reading when the ship is sailing, will be very close to:
(a) w_0 (b) $w_0\left(1+\frac{2\omega v'}{g}\right)$
(c) $w_0\left(1 \mp \frac{2\omega v'}{g}\right)$ (d) none of these

25. If earth were to rotate faster than its present speed, the weight of an object will:
(a) increase at the equator but remain unchanged at poles
(b) decrease at the equator but remain unchanged at the poles
(c) remain unchanged at the equator but decrease at the poles
(d) remain unchanged at the equator but increase at the poles

26. If the earth stops rotating about its axis, the acceleration due to gravity will remain unchanged at:
(a) equator (b) latitude 45°
(c) latitude 60° (d) poles

27. The gravitational field in a region is 10 N/kg $(\hat{i} - \hat{j})$. The work done by gravitational force to shift slowly a particle of mass 1 kg from point (1 m, 1 m) to a point (2 m, – 2 m) is:
(a) 10 joule (b) – 10 joule
(c) – 40 joule (d) + 40 joule

28. In previous problem, the work done by external agent is :
(a) 40 joule (b) – 40 joule
(c) zero (d) + 10 joule

29. The gravitational force in a region is given by
$$\vec{E} = ay\hat{i} + ax\hat{j}$$
The work done by gravitational force to shift a point mass m from (0, 0, 0) to (x_0, y_0, z_0) is :
(a) $ma\,x_0y_0z_0$ (b) $ma\,x_0y_0$
(c) $-ma\,x_0y_0$ (d) zero

30. Let V and E be the gravitational potential and gravitational field at a distance r from the centre of a hollow sphere. Consider the following statements :
(A) the V-r graph is continuous
(B) the E-r graph is discontinuous
(a) both A and B are wrong
(b) both A and B are correct
(c) A is correct but B is wrong
(d) A is wrong but B is correct

31. The work done by an external agent to shift a point mass from infinity to the centre of earth is :
(a) $= 0$ (b) > 0
(c) < 0 (d) < 0

32. The work done in shifting a particle of mass m from centre of earth to the surface of earth is :
(a) $-mgR$ (b) $+\dfrac{mgR}{2}$
(c) zero (d) none of these

33. If a rocket is fired with a speed $v = 2\sqrt{gR}$ near the earth's surface and coasts upwards, its speed in the inter-steller space is :
(a) $4\sqrt{gR}$ (b) $\sqrt{2gR}$
(c) $\sqrt{gR}$ (d) $\sqrt{4gR}$

34. In the above question, if the satellite is stopped suddenly in its orbit and allowed to fall freely onto the earth, the speed with which it hits the surface of the earth is : (Assume $g = 10\ \text{m/sec}^2$ and $R = 6400$ km)
(a) 4 km/sec (b) 8 km/sec
(c) 2 km/sec (d) 6 km/sec

35. A projectile is fired vertically upwards from the surface of the earth with a velocity kv_e, where v_e is the escape velocity and $k < 1$. If R is the radius of the earth, the maximum height to which it will rise measured from the centre of earth will be : (neglect air resistance)
(a) $\dfrac{1-k^2}{R}$ (b) $\dfrac{R}{1-k^2}$
(c) $R(1-k^2)$ (d) $\dfrac{R}{1+k^2}$

36. A satellite is moving on a circular path of radius r around earth has a time period T. If its radius slightly increases by Δr, the change in its time period is :
(a) $\dfrac{3}{2}\left(\dfrac{T}{r}\right)\Delta r$ (b) $\left(\dfrac{T}{r}\right)\Delta r$
(c) $\dfrac{3}{2}\left(\dfrac{T^2}{r^2}\right)\Delta r$ (d) none of these

37. A satellite is orbiting a planet at a constant height in a circular orbit. If the mass of the planet is reduced to half, the satellite would :
(a) fall on the planet
(b) go to an orbit of smaller radius
(c) go to an orbit of higher radius
(d) escape from the planet

38. A satellite is launched into a circular orbit of radius R around the earth. A second satellite is launched into an orbit of radius $1.01R$. The time period of the second satellite is larger than that of the first one by approximately :
(a) 0.5% (b) 1.5%
(c) 1% (d) 3.0%

39. The period of a satellite in a circular orbit of radius R is T. What is the period of another satellite in a circular orbit of radius $4R$?
(a) $4T$ (b) $\dfrac{T}{8}$
(c) $\dfrac{T}{4}$ (d) $8T$

40. Two satellites S and S' revolve around the earth at distances $3R$ and $6R$ from the centre of earth. Their periods of revolution will be in the ratio :
(a) 1 : 2 (b) 2 : 1
(c) $1 : 2^{1.5}$ (d) $1 : 2^{0.67}$

41. An artificial satellite of the earth releases a packet. If air resistance is neglected, the point where the packet will hit, will be :
(a) ahead
(b) exactly below
(c) behind
(d) it will never reach the earth

42. If the universal constant of gravitation is decreasing uniformly with time, then a satellite in orbit would still maintain its :
(a) radius
(b) tangential speed
(c) angular momentum
(d) period of revolution

43. A satellite of mass m_s revolving in a circular orbit of radius r_s around the earth of mass M has a total energy E. Then its angular momentum will be :
(a) $\sqrt{\dfrac{E}{m_s r_s^2}}$ (b) $\dfrac{E}{2m_s r_s^2}$
(c) $\sqrt{2Em_s r_s^2}$ (d) $\sqrt{2Em_s r_s}$

44. A satellite S is moving in an elliptical orbit around the earth. The mass of the satellite is very small compared to the mass of the earth :

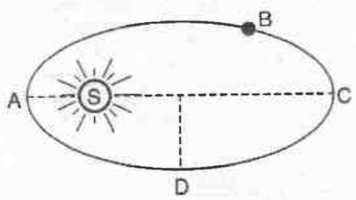
(a) the acceleration of S is always directed towards the centre of the earth

(b) the angular momentum of S about the centre of the earth changes in direction but its magnitude remains constant

(c) the total mechanical energy of S varies periodically with time

(d) the linear momentum of S remains constant in the magnitude

45. A planet revolves in elliptical orbit around the sun. (see fig.) The linear speed of the planet will be maximum at :



(a) A (b) B
(c) C (d) D

46. Mark correct option or options :

(a) Only equatorial orbits are stable for a satellite

(b) Escape velocity does not depend upon angle of projection

(c) A communication satellite rotates in a direction from west to east

(d) All the above

47. Two bodies each of mass 1 kg are at a distance of 1 m. The escape velocity of a body of mass 1 kg which is midway between them is :

(a) 8×10^{-5} m/s (b) 2.31×10^{-5} m/s
(c) 4.2×10^{-5} m/s (d) zero

48. If an artificial satellite is moving in a circular orbit around the earth with a speed equal to half the magnitude of the escape velocity from the earth, the height of the satellite above the surface of the earth is :

(a) $2R$ (b) $\frac{R}{2}$
(c) R (d) $\frac{R}{4}$

49. A particle of mass m is projected from the surface of earth with a speed v_0 ($v_0 <$ escape velocity). The speed of particle at height $h - R$ (radius of earth) is: (Here $R = 6400$ km and $g = 9.8$ m/s^2)

(a) $\sqrt{gR}$ (b) $\sqrt{v_0^2 - 2gR}$
(c) $\sqrt{v_0^2 - gR}$ (d) none of these

50. The ratio of the radii of the planets P_1 and P_2 is k. The ratio of acceleration due to gravity is r. The ratio of the escape velocities from them will be :

(a) kr (b) $\sqrt{kr}$
(c) $\sqrt{\left(\frac{k}{r}\right)}$ (d) $\sqrt{\left(\frac{r}{k}\right)}$

51. The escape velocity on the surface of the earth is 11.2 km/sec. If mass and radius of a planet are 4 and 2 times respectively than that of earth. The escape velocity from the planet will be :

(a) 11.2 km/sec (b) 1.112 km/sec
(c) 15.8 km/sec (d) 22.4 km/sec

52. The escape velocity of a body on the surface of the earth is 11.2 km/sec. If the earth's mass increases to twice its present value and radius of the earth becomes half, the escape velocity becomes :

(a) 5.6 km/sec (b) 11.2 km/sec
(c) 22.4 km/sec (d) 44.8 km/sec

Answers

Level-1

1. (a)	**2.** (b)	**3.** (a)	**4.** (d)	**5.** (c)	**6.** (b)	**7.** (c)	**8.** (c)	**9.** (a)	**10.** (a)
11. (c)	**12.** (c)	**13.** (b)	**14.** (a)	**15.** (d)					

Level-2

1. (a)	**2.** (b)	**3.** (a)	**4.** (c)	**5.** (b)	**6.** (c)	**7.** (b)	**8.** (b)	**9.** (b)	**10.** (b)
11. (a)	**12.** (a)	**13.** (b)	**14.** (a)	**15.** (d)	**16.** (a)	**17.** (a)	**18.** (a)	**19.** (b)	**20.** (a)
21. (a)	**22.** (d)	**23.** (a)	**24.** (c)	**25.** (b)	**26.** (d)	**27.** (d)	**28.** (b)	**29.** (b)	**30.** (b)
31. (c)	**32.** (b)	**33.** (b)	**34.** (b)	**35.** (b)	**36.** (a)	**37.** (d)	**38.** (b)	**39.** (d)	**40.** (c)
41. (d)	**42.** (c)	**43.** (c)	**44.** (a)	**45.** (a)	**46.** (d)	**47.** (b)	**48.** (c)	**49.** (c)	**50.** (b)
51. (c)	**52.** (c)								

10

Simple Harmonic Motion

Syllabus: Periodic motion, simple harmonic motion and its equation of motion, energy in S.H.M., oscillations of a spring and simple pendulum.

Review of Concepts

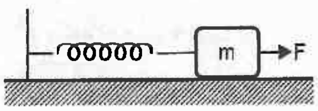
1. To prove S.H.M., prove that the acceleration on the body is proportional to the displacement and directed opposite to it throughout the motion.

General Method

Situation: A block of mass m is connected by a massless spring of constant k as shown in figure. Prove that motion of the block is S.H.M.

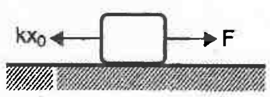
Step-I: Determine the equilibrium position of the block.

At equilibrium position of block, acceleration is zero. Hence, net force is zero.



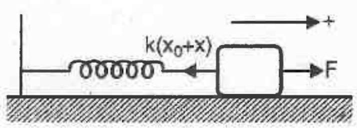
From force diagram, $F = kx_0$ at equilibrium position.

Step-II: Displace the block for small displacement x from equilibrium position. Let the block is displaced a small displacement x in rightward direction.



For solving the problem, the direction of displacement is taken as positive and mean position is taken as origin.

Step-III: Determine the acceleration at the displaced position of block.

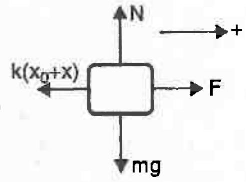


From the force diagram shown in figure

$$F - k(x_0 + x) = ma$$

or $$F - kx_0 - kx = ma$$

or $$-kx = ma \quad (\because kx_0 = F)$$



$\therefore$ $$a = -\frac{k}{m}x$$

$\therefore$ $$a \propto -x$$

Step-IV: Compare the acceleration: In the case of S.H.M.,

$$a = -\omega^2 x$$

$\therefore$ $$-\frac{k}{m}x = -\omega^2 x$$

$\therefore$ $$\omega = \sqrt{\left(\frac{k}{m}\right)}$$

$\therefore$ $$\frac{2\pi}{T} = \sqrt{\left(\frac{k}{m}\right)}$$

$\therefore$ $$T = 2\pi\sqrt{\left(\frac{m}{k}\right)}$$

(i) In the case of S.H.M., total energy of the system remains constant at every instant.

(ii) In the case of S.H.M., particle is in stable equilibrium at the mean position.

2. Displacement: Displacement of particle in the case of S.H.M. is always measured from mean position.

(a) If particle is at mean position at $t = 0$, then displacement $x = A \sin \omega t$

where A = amplitude, ω = angular frequency $= \frac{2\pi}{T} = 2\pi f$

where f = frequency and T = time period.

(b) If particle is at extreme position at $t = 0$, then $x = A \cos \omega t$.

(c) In general $x = A \sin(\omega t + \phi)$, where ϕ is initial phase or epoch.

3. Velocity:

$\because$ $$x = A \sin(\omega t + \phi)$$

$\therefore$ $$v = \frac{dx}{dt} = A\omega \cos(\omega t + \phi)$$

$$= A\omega\,[1 - \sin^2(\omega t + \phi)]^{1/2}$$

$$= A\omega\left[1 - \frac{x^2}{A^2}\right]^{1/2} = \omega\sqrt{A^2 - x^2}$$

(a) At mean position, velocity is maximum, *i.e.*, $v_{max} = A\omega$ at $x = 0$.

(b) At extreme position, velocity is zero. *i.e.*, $v = 0$ at $x = \pm A$.

4. Acceleration: Acceleration is

$$a = \frac{dv}{dt} = -A\omega^2 \sin(\omega t + \phi) = -\omega^2 x$$

(a) Acceleration is zero at mean position, *i.e.*, $a = 0$, at $x = 0$.

(b) Acceleration is maximum at extreme position, *i.e.*, $a_{max} = -\omega^2 A$ at $x = A$.

5. Energy:

(a) Potential energy $U = \frac{1}{2} m\omega^2 x^2$

$\therefore \quad U \propto x^2$

(b) Kinetic energy $= \frac{1}{2} m\omega^2 (A^2 - x^2)$

$$\text{Total energy} = \text{P.E.} + \text{K.E.} = \frac{1}{2} mA^2\omega^2 = \text{constant.}$$

6. Phase:

(a) The phase of SHM is the sine function of $(\omega t + \phi)$.

(b) If the phase is zero at a certain instant then from the equation of SHM, *i.e.*, $y = A \sin(\omega t + \phi)$,

$$y = 0 \quad \text{and} \quad v = \left(\frac{dy}{dt}\right) = A\omega$$

i.e., particle is crossing the equilibrium position.

If $(\omega t + \phi) = \frac{\pi}{2}$, $y = A$ and so, $v = \frac{dy}{dt} = 0$

i.e., particle is at extreme position.

7. Time period:

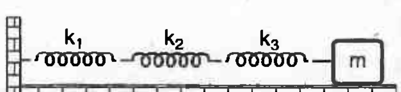
(a) Spring mass system:

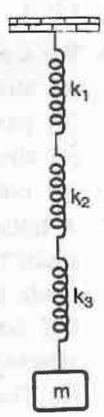
(i) If the spring is massless, $T = 2\pi\sqrt{\left(\frac{m}{k}\right)}$

(ii) If the spring is massive of mass m_s,

$$T = 2\pi\sqrt{\left(\frac{m + \frac{m_s}{3}}{k}\right)}$$

(iii) Series combination of springs:





Here, $\frac{1}{k} = \frac{1}{k_1} + \frac{1}{k_2} + \frac{1}{k_3} + \ldots$

where k is equivalent spring constant.

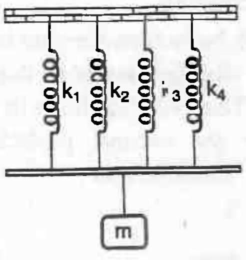
$$\therefore \quad T = 2\pi\sqrt{\left(\frac{m}{k}\right)}$$

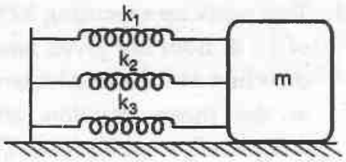
$$= 2\pi\sqrt{\left[m \Big/ \left(\frac{1}{k_1} + \frac{1}{k_2} + \frac{1}{k_3} + \ldots\right)\right]}$$

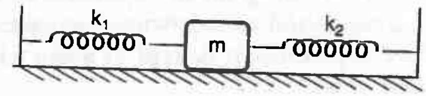
(iv) Parallel combination of springs:

Here, $k = k_1 + k_2 + k_3 \ldots$

$$T = 2\pi\sqrt{\left(\frac{m}{k}\right)} = 2\pi\sqrt{\left[\frac{m}{(k_1 + k_2 + k_3 + \ldots)}\right]}$$

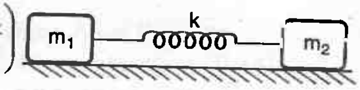






(v) If two masses m_1 and m_2 are connected by a massless spring:

Here, $T = 2\pi\sqrt{\left(\frac{\mu}{k}\right)}$



where, $\mu = \frac{m_1 m_2}{m_1 + m_2}$ = reduced mass

(b) Simple pendulum: $T = 2\pi\sqrt{\left(\frac{l}{g_{eff}}\right)}$

Here, $g_{eff} = \frac{\text{tension in the string of stationary pendulum}}{\text{mass of the bob}}$

l = length of pendulum

(c) Physical or compound pendulum:

$$T = 2\pi\sqrt{\left(\frac{l + \frac{K^2}{l}}{g}\right)}$$

where l = distance of centre of gravity from point of suspension and

K = radius of gyration about an axis passing through centre of gravity.

Some Important Points:

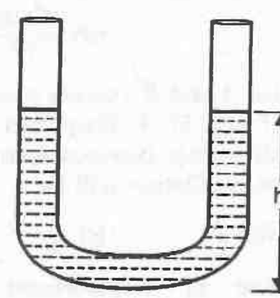
(a) Motion which repeats itself after a fixed interval of time is called periodic motion.

(b) For periodic function $\sin(\theta + 2\pi) = \sin\theta$.

(c) In the case of water oscillating in a U-tube,

$$T = 2\pi\sqrt{\left(\frac{h}{g}\right)}$$

where h is the height of liquid column in each limb.



(d) In the case of a balanced wheel or torsional pendulum,

$$T = 2\pi\sqrt{\left(\frac{I}{C}\right)}$$

where, I = moment of inertia

C = torsional constant

= restoring torque per unit twist.

(e) When a ball of mass m is made to oscillate in the neck of an air chamber having volume V and neck area A, then

$$T = 2\pi\sqrt{\left(\frac{mV}{PA^2}\right)}$$

(f) If a person sitting on an oscillating swing stands up, the time period of the swing decreases.

(g) When a pendulum is kept in a car which is sliding down, then

$$T = 2\pi\sqrt{\left(\frac{l}{g\cos\theta}\right)}$$

where θ is an angle of inclination.

(h) If a simple pendulum oscillates in a non-viscous liquid of density σ, then its time period is

$$T = 2\pi\sqrt{\left[\frac{L}{\left(1-\frac{\sigma}{\rho}\right)g}\right]}$$

(i) If the mass m attached to a spring oscillates in a non-viscous liquid of density σ, then its time period is

$$T = 2\pi\left[\frac{m}{k}\left(1-\frac{\sigma}{\rho}\right)\right]^{1/2}$$

where k = force constant

ρ = density of suspended mass

(j) If time period of one spring is T_1 and that of second spring is T_2 and if they are connected in series, then $T_{series} = \sqrt{T_1^2 + T_2^2}$. If they are connected in parallel,

$$T_{parallel} = \frac{T_1 T_2}{\sqrt{T_1^2 + T_2^2}}$$

(k) The time period of a simple pendulum having long length is

$$T = 2\pi\sqrt{\left[\frac{lR}{(l+R)g}\right]}$$

where, R = radius of earth

If length is infinite, then $T = 2\pi\sqrt{\left(\frac{R}{g}\right)}$

Objective Questions

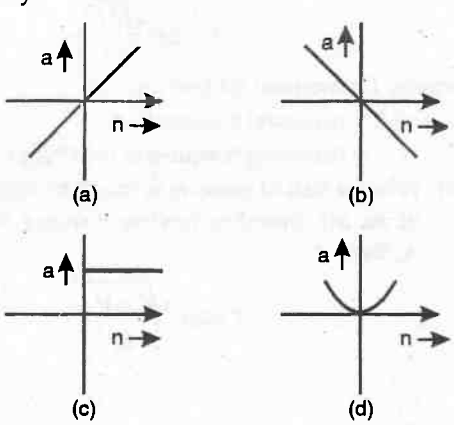
Level-1

1. In the case of S.H.M., at the time of maximum kinetic energy :
(a) potential energy must be zero
(b) potential energy is minimum
(c) potential energy must not be zero
(d) potential energy is maximum

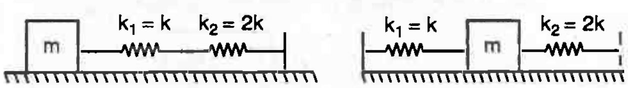
2. A particle of mass m is executing S.H.M. of time period T, and amplitude a_0. The force on particle at the mean position is :
(a) $\frac{4\pi^2 m}{T^2} a_0$ (b) $\frac{2\pi^2 m}{T^2} a_0$
(c) zero (d) $\frac{\pi^2 m a_0}{T^2}$

3. Two particles A and B execute simple harmonic motion of periods T and $5T/4$. They start from mean position. The phase difference between them when the particle A completes an oscillation will be :
(a) 0 (b) $\frac{\pi}{2}$ (c) $\frac{\pi}{4}$ (d) $\frac{2\pi}{5}$

4. The equation of displacement of a particle is $x = A\sin\omega t$, x is displacement as a function of time, the correction variation of acceleration a with displacement x is given by :



5. The ratio of time periods of oscillations of situations shown in figures (i) and (ii) is :



(a) 2 : 3
(b) 3 : $\sqrt{2}$
(c) 4 : 3
(d) 1 : 1

6. For a simple pendulum, the graph between T^2 and L is :
(a) straight line passing through origin
(b) parabolic
(c) circle
(d) none of the above

7. A hollow metal sphere is filled with water through a small hole in it. It is hanging by a long thread and is made to oscillate. Water slowly flows out of the hole at the bottom. How will the period of oscillation be affected ?
(a) The period will go on decreasing
(b) the period will not be affected
(c) The period will first increase then decrease till the sphere is empty
(d) The period will go on increasing

8. Two particles executing S.H.M. have time periods in ratio of 1 : 4. Both are given small displacements in the same direction at the same instant. They will again be in phase at the mean position after the second particle has completed n oscillations. The value of n is :
(a) 4 (b) 2
(c) $\frac{1}{2}$ (d) zero

9. If a particle is acted by two simple harmonic motions simultaneously, the path of particle is :
(a) stream line motion
(b) Lissajous figure
(c) just like motion of a particle under gravity
(d) none of the above

10. For a particle executing S.H.M., the potential energy is given by $U = U_0 \sin^2 \omega t$. The maximum kinetic energy of the particle is :
(a) U_0 (b) $\frac{U_0}{\sqrt{2}}$
(c) $\frac{U_0}{3}$ (d) none of these

11. The time period of particle executing S.H.M. is doubled, then :
(a) angular frequency becomes half
(b) frequency becomes half
(c) frequency becomes double
(d) none of the above

12. A particle of mass 10 kg is executing S.H.M. of time period 2 second and amplitude 0.25 m. The magnitude of maximum force on the particle is :
(a) 5 N (b) 24.65 N
(c) zero (d) 40.6 N

13. Two S.H.M.'s $x = a \sin \omega t$ and $y = b \cos \omega t$ directed along y-axis respectively are acted on particle. The path of the particle is :
(a) circle (b) straight line
(c) ellipse (d) parabola

14. The minimum phase difference between two S.H.M.'s

$$y_1 = \sin \frac{\pi}{6} \sin \omega t + \sin \frac{\pi}{3} \cos \omega t$$

$$y_2 = \cos \frac{\pi}{6} \sin \omega t + \cos \frac{\pi}{3} \cos \omega t \text{ is :}$$

(a) $\pi/3$ (b) $\pi/6$
(c) $\pi/12$ (d) 0

15. If the mass of bob of simple pendulum is increased by 50%, the time period of the pendulum :
(a) does not change (b) increases
(c) decreases (d) none of these

16. The equations of two linear S.H.M.'s are

$$x = a \sin \omega t \quad \text{along } x\text{-axis}$$

$$y = a \sin 2\omega t \quad \text{along } y\text{-axis}$$

If they act on a particle simultaneously, the trajectory of the particle is :
(a) $\frac{y^2}{a^2} + \frac{x^2}{4a^2} = 1$ (b) $y^2 = \frac{4x^2}{a^2}(a^2 - x^2)$
(c) $y^2 = 2ax$ (d) none of these

17. In the case of S.H.M., if the particle is at the mean position, then the particle is in :
(a) stable equilibrium (b) unstable equilibrium
(c) neutral equilibrium (d) none of these

18. The equation of acceleration of a particle is $a = -k(x + b)$, where x is distance along x-axis and k is a positive constant. The motion of particle is :
(a) oscillatory (b) periodic
(c) S.H.M. (d) all of these

19. In previous problem, the mean position of the particle with respect to origin is at distance :
(a) $-b$ (b) $+b$
(c) 0 (d) none of these

20. A particle executes S.H.M., its time period is 16 s. If it passes through the centre of oscillation then its velocity is 2 m/s at time 2 sec. The amplitude will be :
(a) 7.2 m (b) 4 cm
(c) 6 cm (d) 0.72 m

21. A body executing S.H.M. has its velocity 10 cm/s and 7 cm/s, when its displacements from the mean position are 3 cm and 4 cm respectively. The length of path is :
(a) 10 cm (b) 9.5 cm
(c) 4 cm (d) 11.36 cm

22. A pendulum clock is observed to give correct time at the equator. What will happen if the same pendulum clock is taken to the pole of the earth ?
(a) It will gain time (b) It will loss time
(c) Unchanged (d) None of these

Level-2

1. A particle executing simple harmonic motion has amplitude of 1 metre and time period 2 second. At $t = 0$, net force on the particle is zero. The equation of displacement of particle is :
(a) $x = \sin \pi t$ (b) $x = \cos \pi t$
(c) $x = \sin 2\pi t$ (d) $x = \cos 2\pi t$

2. In previous question, maximum velocity and maximum acceleration are respectively :
(a) 1 m/s, π m/s^2
(b) π m/s and π^2 m/s^2
(c) π m/s and π m/s^2
(d) none of these

3. A particle executes simple harmonic motion. The amplitude of vibration of particle is 2 cm. The displacement of particle in one time period is :
(a) 1 cm (b) 2 cm
(c) 4 cm (d) zero

4. In previous problem, the distance travelled by the particle is :
(a) 8 cm
(b) 2 cm
(c) 4 cm
(d) zero

5. Ram say's, "The average value of displacement, velocity and acceleration for one time period in the case of S.H.M. is zero."
Shyam say's "The acceleration of particle is maximum at extreme position."
(a) Ram's statement is correct
(b) Shyam's statement is correct
(c) Both statements are wrong
(d) Both (a) and (b) are correct

6. A particle moves along y-axis according to equation $y = 3 + 4\cos\omega t$. The motion of particle is :
(a) not S.H.M.
(b) oscillatory but not S.H.M.
(c) S.H.M.
(d) none of the above

7. In previous problem, the amplitude of vibration is :
(a) 3 unit (b) 4 unit
(c) 5 unit (d) none of these

8. A body with speed 'v' is moving along a straight line. At the same time it is at distance x from a fixed point on the line, the speed is given by $v^2 = 144 - 9x^2$. Then :
(a) displacement of the body < distance moved by body
(b) the magnitude of acceleration at a distance 3 m from the fixed point is 27 m/s^2
(c) the motion is S.H.M. with $T = \frac{2\pi}{3}$ unit
(d) the maximum displacement from the fixed point is 4 unit
(e) all the above

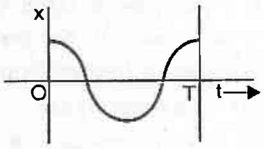
9. If $\vec{s} = a\sin\omega t\,\hat{i} + b\cos\omega t\,\hat{j}$, the equation of path of particle is :
(a) $x^2 + y^2 = \sqrt{a^2 + b^2}$ (b) $\frac{x^2}{b^2} + \frac{y^2}{a^2} = 1$
(c) $\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$ (d) none of these

10. The motion of a particle is given by
$$y = 4\sin\omega t + 8\sin\left(\omega t + \frac{\pi}{3}\right)$$
The motion of particle is :
(a) S.H.M.
(b) not S.H.M.
(c) periodic but not S.H.M.
(d) none of the above

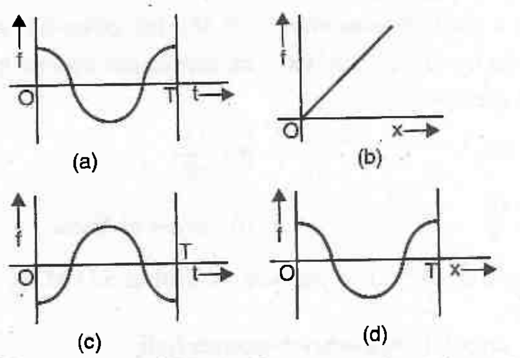
11. In previous problem, the amplitude of vibration is :
(a) 4 unit (b) 8 unit
(c) 10.58 unit (d) none of these

12. The motion of a particle varies with time according to the relation $y = a\sin\omega t + a\cos\omega t$. Then :
(a) the motion is oscillatory but not S.H.M.
(b) the motion is S.H.M. with amplitude a
(c) the motion is S.H.M. with amplitude $\sqrt{2}a$
(d) none of the above

13. A body is doing S.H.M. having amplitude a and time period T. The figure shows position-time graph. At any time 't', acceleration of body is 'f'.



Which of the following graphs is/are appropriate ?



14. A particle executes S.H.M. along a straight line so that its period is 12 second. The time it takes in traversing a distance equal to half its amplitude from its equilibrium position is :
(a) 6 second (b) 4 second
(c) 2 second (d) 1 second

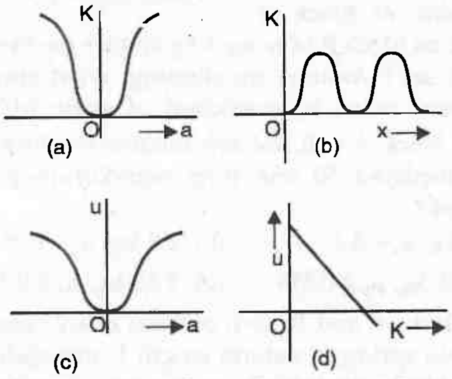
15. A particle executes S.H.M. with an amplitude of 10 cm and frequency 2 Hz. At $t = 0$, the particle is at a point where potential energy and kinetic energy are same. The equation of displacement of particle is :
(a) $0.1\sin\left(4\pi t + \frac{\pi}{4}\right)$ (b) $0.1\sin 4\pi t$
(c) $0.1\cos\left(4\pi t + \frac{\pi}{4}\right)$ (d) none of these

16. A particle executes simple harmonic motion with a frequency f. The frequency with which the potential energy oscillates is :
(a) f (b) $f/2$
(c) $2f$ (d) zero

17. A particle of mass m is executing oscillation about the origin on the X-axis. Its potential energy is $U(x) = k|x|^3$, where k is a positive constant. If the amplitude of oscillation is a, then its time period T is :
(a) proportional to $\frac{1}{\sqrt{a}}$ (b) independent of a
(c) proportional to $\sqrt{a}$ (d) proportional to $a^{3/2}$

* 18. A particle of mass m is free to move along the x-axis and has potential energy given by
$$U(x) = k[1 - e^{-x^2}]$$
for $-\infty \le x \le \infty$, where k is positive constant of appropriate dimensions. Then :
(a) at points away from the origin, the particle is in unstable equilibrium
(b) for any finite non-zero value of x, there is a force directed away from the origin
(c) if its total mechanical energy is $k/2$, it has its minimum kinetic energy at origin
(d) for small displacement from $x = 0$, motion is S.H.M.

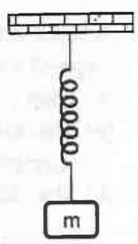
19. During S.H.M., a particle has displacement x from mean position. If acceleration, kinetic energy and excess potential energy are represented by a, K and U respectively, then choose the appropriate graph :



20. A simple harmonic oscillator has amplitude A, angular velocity ω, and mass 'm'. Then average energy in one time period will be :

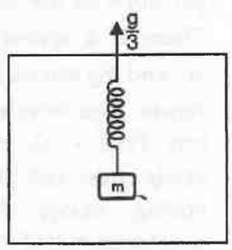
(a) $\frac{1}{4}m\omega^2A^2$ (b) $\frac{1}{2}m\omega^2A^2$
(c) $m\omega^2A^2$ (d) zero

21. A point mass $m = 20$ kg, is suspended by a massless spring of constant 2000 N/m. The point mass is released when elongation in the spring is 15 cm. The equation of displacement of particle as function of time is : (Take $g = 10\ m/s^2$)



(a) $y = 10 \sin 10t$ (b) $y = 10 \cos 10t$
(c) $y = 10 \sin\left(10t + \frac{\pi}{6}\right)$ (d) none of these

22. A spring of spring constant 200 N/m has a block of mass 1 kg hanging at its one end and of other end spring is attached to a ceiling of an elevator. The elevator rising upwards with an acceleration of $g/3$. When acceleration is suddenly cease, then what should be the angular frequency and elongation during the time when the elevator is accelerating ?



(a) 14.14 rad/s, 0.07 m (b) 13 rad/s, 0.1 m
(c) 14 rad/s, 0.05 m (d) 10 rad/s, 0.07 m

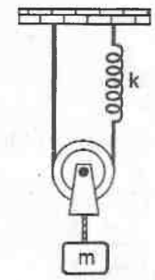
23. A spring of force constant k is cut into two pieces such that one piece is double the length of the other. Then the long piece will have a force constant of :

(a) $\frac{2}{3}k$ (b) $\frac{3}{2}k$
(c) $3k$ (d) $6k$

24. A solid copper sphere is suspended from a massless spring. The time period of oscillation of the system is 4 second. The sphere is now completely immersed in a liquid whose density is 1/8th that of brass. The sphere remains in liquid during oscillation. Now the time period is :

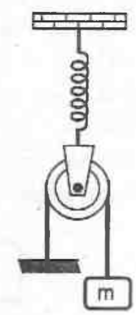
(a) 4 second (b) 2 second
(c) 3 second (d) none of these

25. A system shown in figure. consists of a massless pulley, a spring of force constant k and a block of mass m. If block is just slightly displaced vertically down from its equilibrium position and released then the period of vertical oscillations is :



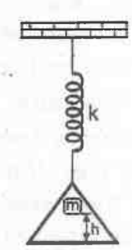
(a) $T = \pi\sqrt{\left(\frac{m}{4k}\right)}$
(b) $T = 2\pi\sqrt{\left(\frac{m}{4k}\right)}$
(c) $T = 2\pi\sqrt{\left(\frac{m}{2k}\right)}$
(d) $T = 2\pi\sqrt{\left(\frac{m}{3k}\right)}$

26. In figure, the spring has a force constant k. The pulley is light and smooth, the spring and the string are light. The suspended block has a mass m. If the block is slightly displaced from its equilibrium position and then released, the period of its vertical oscillation is :



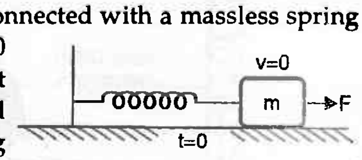
(a) $2\pi\sqrt{\left(\frac{m}{k}\right)}$
(b) $4\pi\sqrt{\left(\frac{m}{k}\right)}$
(c) $2\pi\sqrt{\left(\frac{k}{m}\right)}$
(d) $4\pi\sqrt{\left(\frac{k}{m}\right)}$

27. A load of mass m falls from a height h on to the scale pan hung from a spring as shown in the adjoining figure. If the spring constant is k and mass of the scale pan is zero and the mass m does not bounce relative to the pan, then the amplitude of vibration is :



(a) $\frac{mg}{k}$
(b) $\frac{mg}{k}\sqrt{\left(1+\frac{2hk}{mg}\right)}$
(c) $\frac{mg}{k}+\frac{mg}{k}\sqrt{\left(\frac{1+2hk}{mg}\right)}$
(d) $\frac{mg}{k}\sqrt{\left(\frac{1+2hk}{mg}-\frac{mg}{k}\right)}$

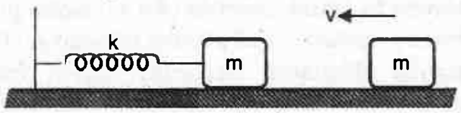
28. A block of mass 1 kg is connected with a massless spring of force constant 100 N/m. At $t = 0$, a constant force $F = 10$ N is applied on the block. The spring is in its natural length at $t = 0$.



The speed of particle at $x = 6$ cm from mean position is :

(a) 4 cm/s (b) 10 cm/s
(c) 80 cm/s (d) 50 cm/s

29. The collision between both blocks shown in figure is completely inelastic. The total energy of oscillation after collision is :



(a) $\frac{1}{2}mv^2$ (b) $\frac{mv^2}{8}$

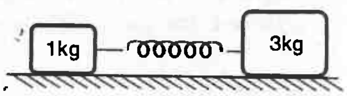
(c) $\frac{mv^2}{4}$ (d) none of these

30. In previous problem, the amplitude of vibration is :

(a) $\sqrt{\left(\frac{mv^2}{k}\right)}$ (b) $\sqrt{\left(\frac{mv^2}{2k}\right)}$

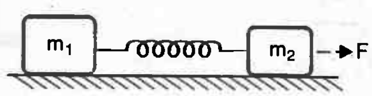
(c) $\sqrt{\left(\frac{mv^2}{4k}\right)}$ (d) none of these

31. Two point masses of 3 kg and 1 kg are attached to opposite ends of a horizontal spring whose spring constant is 300 N/m as shown in figure. The natural vibrational frequency of the system is of order :



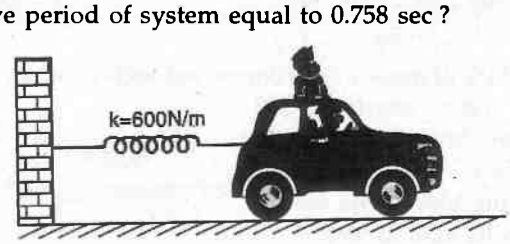
(a) 4 Hz (b) 3 Hz
(c) 2 Hz (d) 1 Hz

32. Two blocks connected by a spring rest on a smooth horizontal plane as shown in figure.



A constant force F starts acting on the block m_2, then
(a) length of spring increases continuously if $m_1 > m_2$
(b) blocks start performing S.H.M. about centre of mass of the system with increasing amplitude
(c) blocks start performing S.H.M. about centre of mass of the system which moves rectilinearly with constant acceleration
(d) acceleration of m_2 is maximum at initial moment of time only

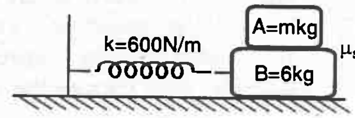
* 33. A naughty boy is sitting on the roof of a flat toy car of mass 6 kg. If no slipping takes place between car and the boy then what should be the mass of the child in order to have period of system equal to 0.758 sec ?



(a) 2.74 kg (b) 6 kg
(c) 3 kg (d) None of these

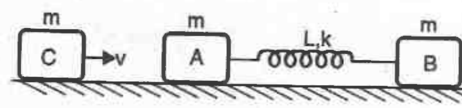
34. In the previous problem, if car is displaced 5 cm from the equilibrium position and released, the minimum value of coefficient of friction for not slipping the boy is :
(a) 0.8 (b) 0.35
(c) 0.6 (d) 0.83

* 35. Two blocks lie on each other and connected to a spring as shown in figure. What should be the mass of block A placed on block B of mass 6 kg so that the system period is 0.75 sec ? Assume no slipping, what should be the minimum value of coefficient of static friction μ_s for which block A will not slip relative to block B, if block B is displaced 50 mm from equilibrium position and released ?



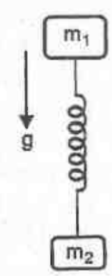
(a) 2 kg, $\mu_s = 0.4$ (b) 4.2 kg, $\mu_s = 0.358$
(c) 2.56 kg, $\mu_s > 0.358$ (d) 2.55 kg, $\mu_s < 0.358$

* 36. Two blocks A and B, each of mass m are connected by a massless spring of natural length L and spring constant k. The blocks are initially resting on a smooth horizontal floor with the spring at its natural length, as shown in figure.



A third block C, also of mass m, moves on the floor with a speed v along the line joining A and B and collides with A. Then :
(a) the kinetic energy of the $A + B$ system at maximum compression of the spring is zero
(b) the kinetic energy of $A + B$ system, at maximum compression of the spring is $\frac{mv^2}{4}$
(c) the maximum compression of the spring is $v\sqrt{\left(\frac{m}{k}\right)}$
(d) none of the above

37. There is a spring with natural length L_0. Two masses m_1 and m_2 are connected to both of its ends as shown in figure. The whole system is held at rest. At any time $t = 0$, m_2 is released and system starts free fall. Initial stretched length of spring before fall is L. What is the displacement of centre of mass as a function of time ?



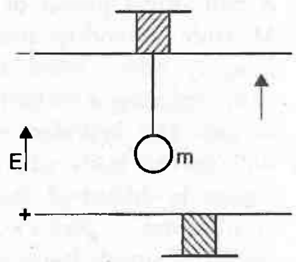
(a) gt^2 (b) $\frac{1}{2}gt^2$
(c) $\frac{g}{k}t^2$ (d) $\frac{m_1 + m_2}{m_1 m_2} \times t$

38. A second's pendulum has time period 2 sec. The spherical bob which is empty has mass of 50 g. This is replaced by another solid bob of same radius but having mass of 100 g. The new time period will be :
(a) 4 sec (b) 1 sec
(c) 2 sec (d) 8 sec

39. A clock pendulum is adjusted for giving correct time in Patna. This clock pendulum also gives correct time in :
(a) Delhi (b) Kota
(c) Hyderabad (d) none of these

40. A simple pendulum of length L and mass M is oscillating in a plane about a vertical line between angular limits $-\phi$ and $+\phi$. For an angular displacement, the tension in the string and the velocity of the bob are T and v respectively. The following relation holds good under the above conditions :
(a) $T = Mg\cos\theta$ (b) $T\cos\theta = Mg$
(c) $T - Mg\cos\theta = \frac{Mv^2}{L}$ (d) none of these

41. Between the plates of the capacitor with potential difference V across its plate such that upper plate is – ve, a ball with positive charge 'q' and mass 'm' is suspended by a thread of length 'l'. If the electrostatic force acting on a ball is less than the gravitational force, what should be the period of the ball?



(a) $T = 2\pi\sqrt{\left(\frac{l}{g}\right)}$ (b) $2\pi\sqrt{\left[\frac{l}{\left(g + \frac{qE}{m}\right)}\right]}$
(c) $T = 2\pi\sqrt{\left[\frac{l}{\left(g - \frac{qE}{m}\right)}\right]}$ (d) $2\pi\sqrt{\left(\frac{lm}{gE}\right)}$

42. From the ceiling of a train a pendulum of length 'l' is suspended. The train is moving with an acceleration a_0 on horizontal surface. What must be the period of oscillation of pendulum?
(a) $T = 2\pi\sqrt{\left(\frac{l}{g}\right)}$ (b) $T = 2\pi\sqrt{\left(\frac{l}{\sqrt{a_0^2 + g^2}}\right)}$
(c) $T = \pi\sqrt{\left(\frac{l}{\sqrt{a_0^2 + g^2}}\right)}$ (d) $T = 2\pi\sqrt{\left(\frac{l}{\sqrt{a_0^2 - g^2}}\right)}$

43. A simple pendulum has a time period T_1 when on the earth's surface, and T_2 when taken to a height R above the earth's surface, where R is the radius of earth. The value of $\frac{T_2}{T_1}$ is :
(a) 1 (b) $\sqrt{2}$
(c) 4 (d) 2

44. The period of oscillation of a simple pendulum of length L, suspended from the roof of a vehicle which moves without friction down an inclined plane of inclination α, is given by :
(a) $2\pi\sqrt{\left(\frac{L}{g\cos\alpha}\right)}$ (b) $2\pi\sqrt{\left(\frac{L}{g\sin\alpha}\right)}$
(c) $2\pi\sqrt{\left(\frac{L}{g}\right)}$ (d) $2\pi\sqrt{\left(\frac{L}{g\tan\alpha}\right)}$

45. There is a clock which gives correct time at 20°C is subjected to 40°C. The coefficient of linear expansion of the pendulum is 12×10^{-6} per °C, how much is gain or loss in time ?
(a) 10.3 sec/day (b) 19 sec/day
(c) 5.5 sec/day (d) 6.8 sec/day

46. There are two pendulums of length l_1 and l_2 whcih start vibrating. At some instant, the both pendulum are in mean position in the same phase. After how many vibrations of shorter pendulum, the both pendulum will be in phase in the mean position ?
[$(l_1 > l_2)$, $l_1 = 121$ cm, $l_2 = 100$ cm]
(a) 11 (b) 10
(c) 9 (d) 8

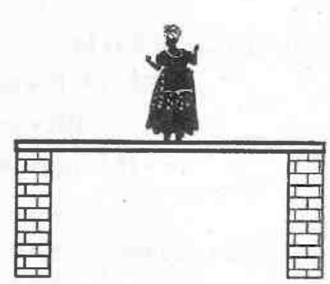
47. A block is performing S.H.M. along a vertical line with amplitude of 40 cm on a horizontal plank. The block just lose the contact with plank when plank is momentarily at rest. Then : (Take $g = 10\ \text{m/s}^2$)
(a) the period of its oscillation is $\frac{2\pi}{5}$ sec
(b) the period of its oscillation is $\frac{2\pi}{6}$ sec
(c) the period of its oscillation is $\frac{\pi}{5}$ sec
(d) none of the above

48. An elastic ball of density d is released and it falls through a height h before striking the surface of liquid of density ρ $(d < \rho)$. The motion of ball is :
(a) periodic (b) S.H.M.
(c) circular (d) parabolic

49. A ring of mass m and radius R is pivoted at a point O on its periphery. It is free to rotate about an axis perpendicular to its plane. What is the period of ring ?
(a) $T = 2\pi\sqrt{\left(\frac{R}{g}\right)}$ (b) $T = 2\pi\sqrt{\left(\frac{2R}{g}\right)}$
(c) $T = \pi\sqrt{\left(\frac{2R}{g}\right)}$ (d) $T = 2\pi\sqrt{\left(\frac{3R}{g}\right)}$

50. There is a rod of length 'l' and mass 'm'. It is hinged at one end to the ceiling. The period of small oscillation is :
(a) $T = 2\pi\sqrt{\left(\frac{2l}{3g}\right)}$ (b) $T = \pi\sqrt{\left(\frac{l}{3g}\right)}$
(c) $T = 2\pi\sqrt{\left(\frac{l}{3g}\right)}$ (d) $T = 2\pi\sqrt{\left(\frac{l}{g}\right)}$

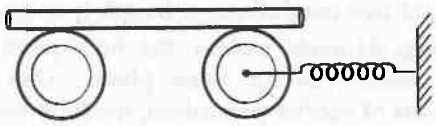
51. A lady dancer of 55 kg stands at the middle of end supported plank and causes a midspan deflection of 2.2 cm. If she flexes her knees slightly for performing a vertical vibration, the period of vibration is nearly equal to :



(a) 0.3 sec (b) 0.8 sec
(c) 0.7 sec (d) 0.9 sec

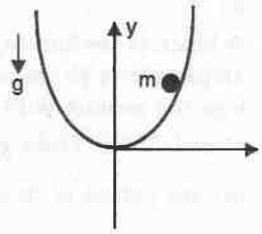
52. A 15 kg rod is supported by two uniform discs, each of mass 8 kg and radius 8 cm. Discs roll without slipping. The spring constant of the spring is 300 N/m. If the rod

is displaced right and released then the period of oscillation is :



(a) 8 sec (b) 3.32 sec
(c) 10 sec (d) none of these

53. A particle of mass m is allowed to oscillate near the minimum of a vertical parabolic path having the equation $x^2 = 4ay$. The angular frequency of small oscillations is given by :

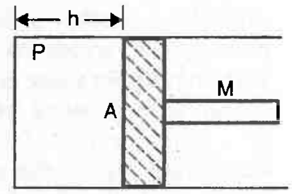


(a) $\sqrt{gh}$
(b) $\sqrt{2gh}$
(c) $\sqrt{\left(\frac{g}{2a}\right)}$ (d) $\sqrt{\left(\frac{g}{a}\right)}$

54. A highly rigid cubical block of mass m and side L is fixed rigidly on to another cubical block B of the same dimensions and of low modulus of rigidily η such that the lower face of A completely covers the upper face of B. The lower face of B is rigidly held on a horizontal surface. A small force F is applied perpendicular to one of the side faces of A. After the force is withdrawn, block A executes small oscillation, the period is :

(a) $2\pi\sqrt{\eta mL}$ (b) $2\pi\sqrt{\left(m\frac{\eta}{L}\right)}$
(c) $2\pi\sqrt{\left(\frac{mL}{\eta}\right)}$ (d) $2\pi\sqrt{\left(\frac{m}{\eta L}\right)}$

55. A cylindrical piston of mass M slide smoothly inside a long cylinder closed at one end, enclosing a certain mass of gas. The cylinder is kept with its axis horizontal. If the piston is disturbed from its equilibrium position, it oscillates simple harmonically. Its period is :



(a) $T = 2\pi\sqrt{\left(\frac{Mh}{PA}\right)}$ (b) $T = 2\pi\sqrt{\left(\frac{MA}{Ph}\right)}$
(c) $T = 2\pi\sqrt{\left(\frac{M}{PAh}\right)}$ (d) $T = 2\pi\sqrt{MPhA}$

Answers

Level-1

1. (b)	2. (c)	3. (d)	4. (b)	5. (b)	6. (a)	7. (c)	8. (a)	9. (b)	10. (a)
11. (b)	12. (b)	13. (c)	14. (b)	15. (a)	16. (b)	17. (a)	18. (d)	19. (a)	20. (a)
21. (d)	22. (a)								

Level-2

1. (a)	2. (b)	3. (d)	4. (a)	5. (d)	6. (c)	7. (b)	8. (e)	9. (c)	10. (a)
11. (c)	12. (c)	13. (c)	14. (d)	15. (a)	16. (c)	17. (a)	18. (d)	19. (c,d)	20. (a)
21. (c)	22. (a)	23. (b)	24. (a)	25. (b)	26. (b)	27. (b)	28. (c)	29. (c)	30. (b)
31. (b)	32. (c)	33. (a)	34. (b)	35. (c)	36. (b)	37. (b)	38. (c)	39. (d)	40. (c)
41. (c)	42. (b)	43. (d)	44. (a)	45. (a)	46. (a)	47. (a)	48. (a)	49. (b)	50. (a)
51. (a)	52. (b)	53. (c)	54. (d)	55. (a)					

Solutions

Level-1

1. In the case of S.H.M.

$$\text{P.E.} + \text{K.E.} = \text{constant}$$

$$\therefore \quad \text{P.E.} = \text{constant} - \text{K.E.}$$

$$\therefore \quad (\text{P.E.})_{min} = \text{constant} - (\text{K.E.})_{max}$$

2. $$F = -m\omega^2 x$$

At mean position, $x = 0$

$$\therefore \quad F = 0$$

3. $$y_1 = a_1 \sin \omega_1 t$$

$$y_2 = a_2 \sin \omega_2 t$$

$$\therefore \quad \Delta\phi = |\omega_1 t - \omega_2 t|$$

$$= |\omega_1 - \omega_2| t$$

$$= \left|\frac{2\pi}{T} - \frac{2\pi}{5T/4}\right| t$$

For one compiete vibration, $t = T$

$$\therefore \quad \Delta\phi = \frac{2\pi}{T} \times T \left|1 - \frac{4}{5}\right|$$

$$= 2\pi\left(\frac{1}{5}\right) = \frac{2\pi}{5}$$

11

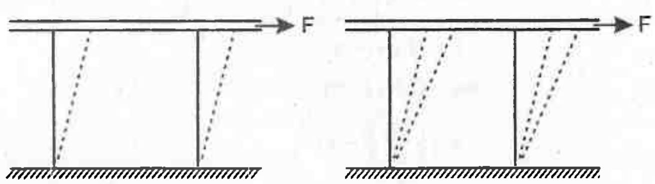
Fluid Mechanics

Syllabus: Flow of fluids, Bernoulli's theorem and its applications.

Review of Concepts

1. Definition of a fluid : Fluid mechanics deals with the behaviour of fluid at rest. A fluid is a substance that deforms continuously under the application of a shear (tangential) stress no matter how small the shear stress may be.

The distinction between a fluid and the solid state of matter is clear if you compare fluid and solid behaviour. A solid deforms when a shear stress is applied but it does not continue to increase with time. However, if a shear stress is applied to a fluid, the deformation continues to increase as long as the stress is applied.



(a) Solid (b) Fluid

Fig. : Behaviour of solid and a fluid, under the action of a constant shear force.

2. Density : In a fluid (which includes both liquid and gas), density ρ of a point mass is defined as

$$\rho = \lim_{\Delta V \to 0} \frac{\Delta m}{\Delta V} = \frac{dm}{dV}$$

(a) It is a scalar quantity.

(b) **Unit :** $kg/m^3 \longrightarrow$ S.I.

$g/cc \longrightarrow$ C.G.S.

(c) **Relative density or specific gravity** is defined as the the ratio of density of substance to density of water at 4°C. Hence,

$$\text{R.D.} = \frac{\text{Density of substance}}{\text{Density of water at } 4°\text{C}}$$

(d) **Density of a mixture of two or more liquids :**

Case I : Suppose two liquids of densities ρ_1 and ρ_2 having masses m_1 and m_2 are mixed together. Then density of mixture

$$\rho = \frac{\text{Total mass}}{\text{Total volume}} = \frac{(m_1 + m_2)}{(V_1 + V_2)}$$

$$= \frac{(m_1 + m_2)}{\left(\frac{m_1}{\rho_1} + \frac{m_2}{\rho_2}\right)}$$

If $\quad m_1 = m_2$

then $\quad \rho = \dfrac{2\rho_1\rho_2}{\rho_1 + \rho_2}$

Case II : If two liquids of densities ρ_1 and ρ_2 having volumes V_1 and V_2 are mixed, then the density of mixture

$$\rho = \frac{\text{Total mass}}{\text{Total volume}} = \frac{m_1 + m_2}{V_1 + V_2}$$

$$= \frac{\rho_1 V_1 + \rho_2 V_2}{V_1 + V_2}$$

If $\quad V_1 = V_2,$

then $\quad \rho = \dfrac{\rho_1 + \rho_2}{2}$

(e) **Effect of temperature on density :** As the temperature of liquid is increased, the mass remains same while the volume is increased and hence, the density of liquid decreases (as $\rho = \frac{1}{V}$). Thus,

$$\frac{\rho'}{\rho} = \frac{V}{V'} = \frac{V}{V + dV} = \frac{V}{V + V\gamma\theta}$$

or $\quad \rho' = \dfrac{\rho}{1 + \gamma\theta}$

where γ = thermal coefficient of volume expansion

$\Delta\theta$ = rise in temperature

(f) **Effect of pressure on density :** As pressure is increased, volume decreases and hence, density will decrease. Thus,

$$\frac{\rho'}{\rho} = \frac{V}{V'} = \frac{V}{V + dV}$$

$$= \frac{V}{V - \left(\frac{dP}{B}\right)V}$$

or $\quad \dfrac{\rho'}{\rho} = \dfrac{1}{1 - \dfrac{dP}{B}}$

or $\quad \rho' = \dfrac{\rho}{1 - \dfrac{dP}{B}}$

where dP = change in pressure

B = Bulk modulus of elasticity of liquid

3. Pressure: It is defined as normal force per unit area.

$$P = \frac{F}{A}$$

(a) It is scalar quantity.

(b) Unit: dyne/cm^2 $\longrightarrow$ C.G.S.

N/m^2 or pascal $\longrightarrow$ S.I.

(c) If we consider a point at a depth h below the surface of a liquid of density ρ, hydrostatic pressure P is given by,

$$P = P_0 + h\rho g$$

where P_0 represents the atmospheric pressure. The pressure difference between hydrostatic pressure and atmospheric pressure is called **gauge** pressure which is

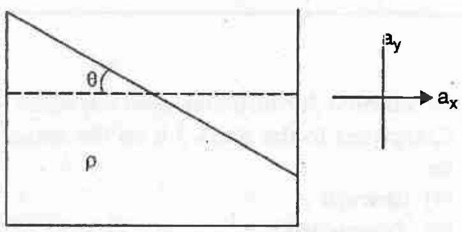
$$P - P_0 = h\rho g$$

(d) One atmospheric pressure $= 1.013 \times 10^5$ N/m^2

(e) One bar $= 10^5$ N/m^2

(f) One torr $= 1$ mm of Hg.

4. If a container is accelerated: $\tan\theta = \dfrac{a_x}{a_y + g}$



Here, a_x = horizontal component of acceleration of container

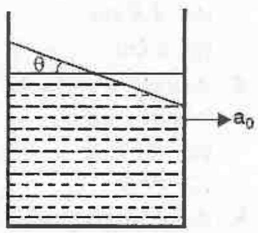
a_y = vertical component of acceleration of container

θ = the angle of inclination of free surface of the liquid with horizontal

(a) If container is accelerated horizontally:

Here $a_y = 0$, $a_x = a_0$

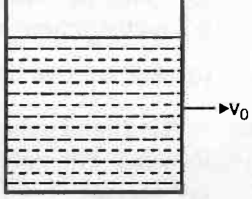
$$\therefore \quad \tan\theta = \frac{a_0}{g}$$



(b) If container is moving with constant velocity:

Here $a_x = 0$, $a_y = 0$

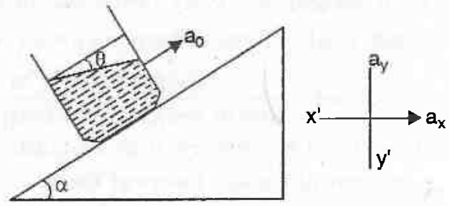
$$\therefore \quad \tan\theta = 0 \quad \Rightarrow \quad \theta = 0$$



(c) If fluid container is subjected to an acceleration along inclined plane:

Here $\quad a_x = a_0 \cos\alpha, \quad a_y = a_0 \sin\alpha$

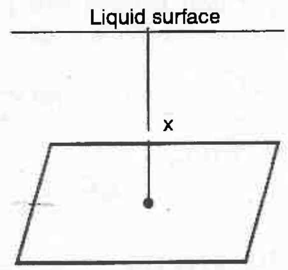
$$\therefore \quad \tan\theta = \frac{a_x}{a_y + g} = \frac{a_0 \cos\alpha}{a_0 \sin\alpha + g}$$



Here θ = angle which the liquid surface makes with the horizontal.

5. Pascal's law: When the excess pressure is exerted on a confined liquid at any point, then it is transmitted equally in all directions.

6. (a) Expression for total thrust on a horizontally immersed surface:



$$F = w A \bar{x}$$

where w = specific weight = weight per unit volume

A = the area of immersed surface

$\bar{x}$ = the depth of the horizontal surface from the liquid level

(b) The total thrust on a vertically immersed surface is

$$F = w \int x\, dx$$

$= w \times$ moment of surface area about the liquid level

$= wA\bar{x}$

where, $\bar{x}$ = the depth of centre of gravity of the immersed surface from the liquid surface

(c) Upthrust or Buoyant force is independent of all the factors of the body such as its mass, size, density, etc. except the volume of the body inside the liquid, *i.e.*,

$$F \propto V_{in} \quad \text{(Volume of body inside the liquid)}$$

This is the reason that two bodies of different masses shapes and sizes may experience same thrust when their volumes inside a fluid are equal.

(d) The centre of buoyancy is the point through which the force of buoyancy is supposed to act. The centre of buoyancy is the centre of area of the immersed section.

(e) When the metacentre is higher than the centre of gravity of the floating body, then the floating body is in stable equilibrium.

(f) When the metacentre is lower than the centre of gravity of the floating body, then the floating body is in unstable equilibrium.

(g) When the metacentre coincides with the centre of gravity of the floating body, then the floating body is in neutral equilibrium.

(h) Apparent weight of a body immersed in a liquid

$$= \text{weight in air} - \text{force of buoyancy} = mg - \rho V g.$$

(i) Specific gravity $= \dfrac{\text{weight of body in air}}{\text{loss in weight of the body in water}}$

(j) Condition for a body to float in a liquid:

weight of body = buoyant force

7. **Continuity equation:**

$$\rho_1 A_1 v_1 = \rho_2 A_2 v_2$$

when fluid is incompressible, then $\rho_1 = \rho_2$

$$\therefore \quad A_1 v_1 = A_2 v_2$$

8. **Bernoulli's theorem:** For an ideal fluid under steady state condition, the sum of kinetic energy per unit volume, potential energy per unit volume and pressure energy per unit volume is constant. Mathematically,

$$\frac{\rho v^2}{2} + \rho g h + P = \text{constant}$$

9. (a) Velocity of efflux:

$$v = \sqrt{2gh}$$

where h is the distance of orifice from the level of liquid in the container.

(b) The time of emptying a square or rectangular or circular tank through an orifice at its bottom.

$$T = \frac{2A(\sqrt{H_1} - \sqrt{H_2})}{a\sqrt{2g}}$$

where, A = the surface area of the tank

H_1 = the initial height of the liquid

H_2 = the final height of the liquid

a = the area of the orifice

(c) The time of making empty a hemispherical tank through an orifice at its bottom. Initially tank is full of water and finally tank is completely made empty.

$$T = 14\pi \frac{R^{5/2}}{15a\sqrt{2g}}$$

where, R = the radius of the hemispherical tank

a = cross-sectional area of the orifice

Objective Questions

Level-1

1. Equal masses of water and liquid are mixed together, then the mixture has a density of :
(a) 2/3 (b) 4/3
(c) 3/2 (d) 3

2. Two stretched membranes of area 2 cm^2 and 3 cm^2 are placed in a liquid at the same depth. The ratio of the pressures on them are :
(a) 1 : 1 (b) 2 : 3
(c) 3 : 2 (d) $2^2 : 3^2$

3. A cylindrical vessel containing a liquid is closed by a smooth piston of mass m. If A is the cross-sectional area of the piston and P_0 is the atmospheric pressure, then the pressure of the liquid just below the piston is :
(a) P_0 (b) $P_0 + \dfrac{mg}{A}$
(c) $\dfrac{mg}{A}$ (d) none of these

4. An iceberg is floating partially immersed in sea water. If the density of sea water is 1.03 g/cc and that of ice is 0.92 g/cc, the fraction of the total volume of iceberg above the level of sea water is :
(a) 8% (b) 11%
(c) 34% (d) 89%

5. A piece of solid weighs 120 g in air, 80 g in water and 60 g in a liquid, then the relative density of the solid and that of liquid are respectively :
(a) 3, 2 (b) 2, $\dfrac{3}{4}$
(c) 3, $\dfrac{3}{2}$ (d) 4, 3

6. A common hydrometer reads specific gravity of liquid. Compared to the mark 1.6 on the stem, the mark 1.5 will be :
(a) upward
(b) downward
(c) in the same plane
(d) may be upward or downward depending on hydrometer

7. The weight of wooden block of size 8 cm × 8 cm × 8 cm is 307.2 g. When it is floating in water, the height of the wooden block above water level is :
(a) 4.8 cm (b) 3.2 cm
(c) 4 cm (d) 6 cm

8. A body weighs 40 g in air. If its volume is 10 cc in water it will weigh :
(a) 30 g (b) 40 g
(c) 50 g (d) none of these

9. A hydrogen balloon released on the moon would :
(a) climb up with an acceleration of 9.8 m/s^2
(b) climb up with an acceleration of $9.8 \times 6\text{ m/s}^2$
(c) neither climb nor fall
(d) fall with an acceleration of $\dfrac{9.8}{6}\text{ m/s}^2$

10. A 700 g solid cube having an edge of length 10 cm floats in water. The volume of cube outside water is :
(a) 2.4 cm^3 (b) 4.8 cm^3
(c) 300 cm^3 (d) 500 cm^3

11. A body weighs 150 g in air, 120 g in water and [illegible] g in a liquid. The density of liquid in g cm^{-3} is :
(a) 2/3 (b) 4/5
(c) 13/15 (d) 15/13

12. A boy carries a fish in one hand and a bucket of water in the other hand; if he places the fish in the bucket, the weight now carried by him :
(a) is less than before
(b) is more than before
(c) is the same as before
(d) depends upon his speed

13. When a large bubble rises from the bottom of a lake to the surface, its radius doubles. The atmospheric pressure is equal to that of column of water of height H. The depth of the lake is :
(a) H (b) $2H$
(c) $7H$ (d) $8H$

14. A boat full of scrap iron is floating on water in a lake. If all the iron is dropped into water the level of water will :
(a) go up (b) remain the same
(c) rise very high (d) go very deep

15. A piece of material weighing 50 g is coated with 6.3 g of wax of relative density 0.9. If the coated piece weighs 16.3 g in water, the density of the material is :
(a) 1.515 (b) 2.3
(c) 4.8 (d) 6.2

16. An inverted bell lying at the bottom of lake 47.6 m deep has 50 cm^3 of air trapped in it. The bell is brought to the surface of the lake. The volume of the trapped air will be (atmospheric pressure = 70 cm of Hg and density of Hg = 13.6 g/cm^3)
(a) 350 cm^3 (b) 300 cm^3
(c) 250 cm^3 (d) 22 cm^3

17. A diver is 10 m below the surface of water, the approximate pressure experienced by the water is :
(a) 10^5 Pa (b) 2×10^5 Pa
(c) 3×10^5 Pa (d) 4×10^5 Pa

18. An object of density 12 g cm^{-3} is weighed with brass weights of density 8 g cm^{-3} by a physical balance. If the density of air is $12. \times 10^{-3}$ g cm^{-3} then the percentage error in weighing is :
(a) 0.005% (b) 0.001%
(c) 0.05% (d) 0.01%

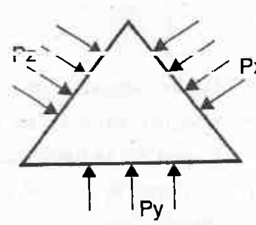
19. Bernoulli's principle is based on the law of conservation of :
(a) mass (b) momentum
(c) energy (d) none of these

20. Action of paint gun is based on :
(a) Bernoulli's principle
(b) Boyle's law
(c) Faraday's law
(d) Archimedee's principle

Level-2

1. Which of the following is/are correct about pressure ?
(a) Pressure at a point acts equally in all directions
(b) Liquid at rest exerts lateral pressure which decreases with depth
(c) Pressure acts normally on any area whatever orientation the area may be held
(d) Both (a) and (c) are correct

2. A triangular element of the liquid is shown in the figure. P_x, P_y and P_z represent the pressure on the element of the liquid. Then :



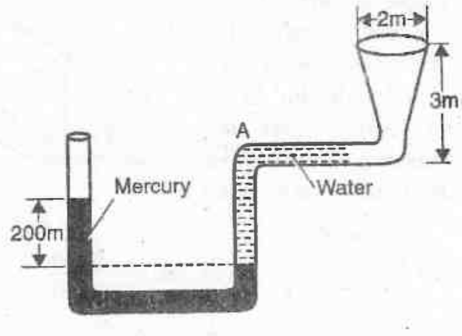
(a) $P_x = P_y \neq P_z$
(b) $P_x = P_y = P_z$
(c) $P_x \neq P_y \neq P_z$
(d) $P_x^2 + P_y^2 + P_z^2 =$ constant

3. The pressure at the bottom of a tank of liquid is not proportional to :
(a) the density of the liquid
(b) the area of the liquid surface
(c) the height of the liquid
(d) the acceleration

4. If a vessel containing a fluid of density ρ upto height h is accelerated vertically downwards with acceleration a_0 then the pressure by fluid at the bottom of vessel is :
(a) $P = P_0 + \rho gh + \rho h a_0$ (b) $P = P_0 + \rho gh$
(c) $P = P_0 + \rho h (g - a_0)$ (d) $P = P_0 - \rho gh$

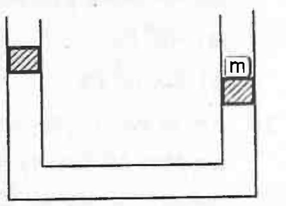
5. If a vessel contains n types of fluid of densities $\rho_1, \rho_2, \dots \rho_n$ at depth $h_1, h_2 \dots h_n$ respectively, then guage pressure at bottom is :
(a) $g \sum_{i=1}^{n} \rho_i h_i$ (b) $P_0 + g \sum_{i=1}^{n} \rho_i h_i$
(c) $\sum_{i=1}^{n} \rho_i h_i$ (d) $P_0 + \sum_{i=1}^{n} \rho_i h_i$

* 6. The figure shows a conical vessel having its outlet at A to which U-tube manometer is connected. The reading of



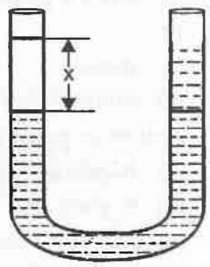
the manometer given in the figure shows when the vessel is empty. Find the reading at manometer when the vessel is completely filled with water :
(a) 400 mm (b) 300 mm
(c) 430 mm (d) 330 mm

7. The hydraulic press shown in the figure is used to raise the mass m through a height of 0.05 cm by performing 500 J of work on the small piston. The diameter of the large piston is 10 cm while that of the smaller one is 2 cm. The mass m is :



(a) 100 kg (b) 10^4 kg
(c) 10^3 kg (d) 10^5 kg

8. One end of a U-tube of uniform bore (area A) containing mercury is connected to a sanction pump. Because of it the level of liquid of density ρ falls in one limb. When the pump is removed, the restoring force in the other limb is :

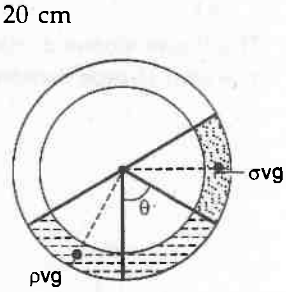


(a) $2x\rho Ag$ (b) $x\rho g$
(c) $A\rho g$ (d) $x\rho Ag$

*9. A U-tube of uniform cross-section is partially filled with a liquid (i) and another liquid (ii) , which does not mixed with liquid (i) , is poured into one side. It is found that the liquid levels of the two sides of the tube are the same while the level of liquid (i) has risen by 2 cm. If the specific gravity of liquid (i) is 1.1 then specific gravity of liquid (ii) must be :
(a) 1.12 (b) 1.1
(c) 1 : 05 (d) 1.2

10. A U-tube is partially filled with water. Oil which does not mix with water, is next poured into one side until water rises by 2.5 cm on the other side. If the density of oil be 0.8, the oil level will stand higher the water level by :
(a) 6.25 cm (b) 12.5 cm
(c) 31.35 cm (d) 20 cm

*11. A small uniform tube is bent into a circle of radius r whose plane is vertical. The equal volumes of two fluids whose densities are ρ and σ ($\rho > \sigma$), fill half the circle. Find the angle that the radius passing through the interface makes with the vertical :



(a) $\cot\theta = \dfrac{\rho - \sigma}{\rho + \sigma}$ (b) $\tan\theta = \dfrac{\rho - \sigma}{\rho + \sigma}$
(c) $\sin\theta = \dfrac{\rho + \sigma}{\rho - \sigma}$ (d) $\sin\theta = \dfrac{\rho}{\sigma}$

12. In each heart beat, a heart pumps 80 ml of blood at an average pressure of 100 mm of Hg. What will the power output of the heart ? (Assume 60 heart beat per minute)
(a) 1 W (b) 2.75 W
(c) 1.06 W (d) 0.5 W

13. A liquid is contained in a vertical U-tube. The total length of the liquid column inside the tube is l. When the liquid is in equilibrium, the liquid is just pushed down slightly. If one of the arms of U-tube are released, the entire liquid column will start a periodic motion. Then :
(a) the motion is not S.H.M.
(b) the motion is S.H.M.
(c) if it undergoes S.H.M., the time period will be $2\pi\sqrt{\left(\dfrac{l}{g}\right)}$
(d) if it undergoes S.H.M., the time period will be $2\pi\sqrt{\left(\dfrac{l}{2g}\right)}$

14. A cylindrical vessel of radius r containing a liquid is rotating about a vertical axis through the centre of circular base. If the vessel is rotating with angular velocity ω, then what is the difference of the heights of liquid at centre of vessel and edge ?
(a) $\dfrac{r\omega}{2g}$ (b) $\dfrac{r^2\omega^2}{2g}$
(c) $\sqrt{2g}\, r\omega$ (d) $\dfrac{\omega^2}{2gr^2}$

15. When n fluids of masses $m_1, m_2, \ldots, m_n$ and densities $\rho_1, \rho_2, \ldots, \rho_n$ respectively are mixed together then resultant density of mixture is :
(a) $\dfrac{\sum_{i=1}^{n} m_i}{\sum_{i=1}^{n} \rho_i}$ (b) $\dfrac{\sum_{i=1}^{n} m_i \rho_i}{\sum_{i=1}^{n} m_i}$
(c) $\dfrac{\sum_{i=1}^{n} m_i}{\sum_{i=1}^{n} \dfrac{m_i}{\rho_i}}$ (d) infinity

16. When equal volumes of two substances are mixed, the specific gravity of mixture is 4. When equal weights of the same substances are mixed, the specific gravity of the mixture is 3. The specific gravity of the two substances would be :
(a) 6 and 2 (b) 3 and 4
(c) 2.5 and 3.5 (d) 5 and 3

17. If the weight of a body in vacuum is w and w_1 and w_2 are weights when it is immersed in a liquid of specific gravity ρ_1 and ρ_2 respectively, then the relation among w, w_1 and w_2 is :
(a) $w = \dfrac{w_1\rho_2 + w_2\rho_1}{w_1 + w_2}$ (b) $w = \dfrac{w_1\rho_2 - w_2\rho_1}{\rho_2 - \rho_1}$
(c) $w = \dfrac{w_1\rho_1 + w_2\rho_2}{\rho_1 + \rho_2}$ (d) $w = \dfrac{w_1\rho_2 + w_2\rho_1}{\rho_1 + \rho_2}$

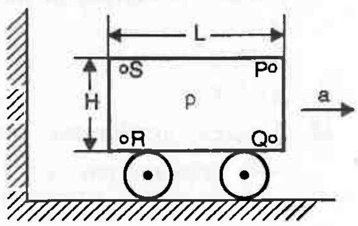
18. An alloy is prepared by mixing equal volume of two metals. The specific gravity of alloy is 4. But when equal masses of two same metals are mixed together, the specific gravity of alloy is 3. The specific gravity of each metal is :

(a) 2, 4 (b) 6, 4
(c) 6, 2 (d) 4, 8

19. If a liquid is subjected to a horizontal acceleration then :

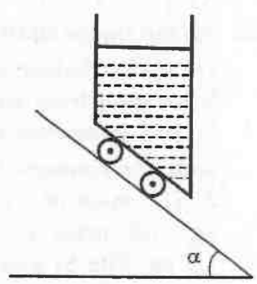
(a) slope of the liquid is inversely proportional to the horizontal acceleration
(b) slope of the liquid is directly proportional to the horizontal acceleration
(c) there is no direct relation between acceleration and inclination
(d) none of above

*** 20.** A liquid of density ρ is completely filled in a rectangular box. The box is accelerating horizontally with acceleration 'a'. What should be the gauge pressure at four points P, Q, R, S ?



(a) $P_P = 0, P_Q = 0, P_R = \rho gh, P_S = 0$
(b) $P_P = \rho gh, P_Q = 0, P_R = \rho ga, P_S = \rho aL$
(c) $P_P = 0, P_Q = \rho gh, P_R = \rho gh + \rho aL, P_S = \rho aL$
(d) $P_P = \rho gh, P_Q = 0, P_S = \rho gh - \rho aL, P_S = \rho gL$

21. On a smooth inclined plane, making an angle α with horizontal, a trolley containing a liquid of density ρ slides down. What is the angle of inclination θ of free surface with horizontal ?

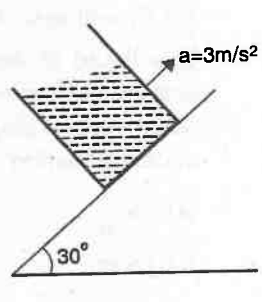


(a) $\theta = -\alpha$
(b) $\theta = \frac{\alpha}{3}$
(c) $\theta = \frac{\alpha}{9}$
(d) $\theta = \alpha$

22. On a horizontal surface, an open vessel containing water is given a constant acceleration 'a'. Due to accelerated motion, the free surface of water gets sloped with horizontal at an angle θ given by :

(a) $\theta = \tan^{-1}\left(\frac{a}{g}\right)$ (b) $\theta = \tan^{-1}\left(\frac{g}{a}\right)$
(c) $\theta = \sin^{-1}\left(\frac{a}{g}\right)$ (d) $\theta = \cos^{-1}\left(\frac{g}{a}\right)$

23. A rectangular box containing water is accelerated upwards at $3\ \text{m/s}^2$ on an inclined plane making 30° to the horizontal. The slope of the free liquid surface is :



(a) 0.23 (b) $\frac{1}{\sqrt{3}}$
(c) $\sqrt{3}$ (d) 0.32

24. A closed rectangular tank 10 m long, 5 m wide and 3 m deep is completely filled with an oil of specific gravity 0.92. The pressure difference between the rear and front corners of the tank, if it is moving with an acceleration of $3\ \text{m/s}^2$ in the horizontal direction, is :

(a) 27.6 kPa (b) 50 kPa
(c) 60 kPa (d) 70 kPa

25. The force of buoyancy on an immersed body is :

(a) due to weight of the body
(b) due to the pressure difference between upper surface and lower surface of the body
(c) due to atmospheric pressure
(d) both (a) and (c) are correct

26. A body weighs 5 N in air and 2 N when immersed in a liquid. The buoyant force is :

(a) 2 N (b) 3 N
(c) 5 N (d) 7 N

27. A neckless weighing 50 g in air, but it weighs 46 g in water. Assume copper is mixed with gold to prepare the neckless. How much copper is present in it ? (Specific gravity of gold is 20 and that of copper is 10)

(a) $m = 25$ g (b) $m = 30$ g
(c) $m = 35$ g (d) $m = 20$ g

28. If air of weight w is filled in a empty balloon which weighs w_1, the weight of balloon will become w_2. Suppose the density of air inside and outside the balloon is same, then :

(a) $w_2 = w_1 + w$ (b) $w_2 = \sqrt{w_1 w}$
(c) $w_2 = w_1$ (d) $w_2 = w_1 - w$

29. In air, a metallic sphere with an internal cavity weighs 40 g and in water it weighs 20 g. What is the volume of cavity if the density of material with cavity be 8 g/cm^3 ?

(a) zero (b) 15 cm^3
(c) 5 cm^3 (d) 20 cm^3

30. A soft plastic bag of weight w_0 is filled with air at S.T.P. Now weight of the bag is w in air. Then :

(a) $w > w_0$ (b) $w = w_0$
(c) $w > w_0$ (d) $w < w_0$

31. A block of ice of area A and thickness 0.5 m is floating in the fresh water. In order to just support a man of 100 kg, the area A should be : (the specific gravity of ice is 0.917 and density of water = 1000 kg/m^3)

(a) 1.24 m^2 (b) 4.21 m^2
(c) 2.41 m^2 (d) 7.23 m^2

32. A dog is sitting in a boat which is floating in a pond. If the dog drinks some water from the pond then :

(a) the level of water in the pond decreases
(b) the level of water in the pond increases
(c) the level of water in the pond first increases, then decreases
(d) the level of water in the pond remains unchanged

33. A glass bulb is balanced by a brass weight in a sensitive beam balance. Now the balance is covered by a glass-jar which is then evacuated. Then :
(a) the beam will remain horizontal
(b) the pan containing the bulb will go down
(c) the pan containing the bulb will go up
(d) none of the above

34. A piece of ice is floating in water. The fraction of volume of the piece of ice outside the water is :
(Given: density of ice = 900 kg/m^3 and density of water = 1000 kg/m^3)
(a) 0.21 (b) 0.01
(c) 0.1 (d) 0.9

35. A block of wood floats with 1/4 of its volume under water. What is the density of the wood ? (Density of water = 1000 kg/m^3)
(a) 750 kg/m^3 (b) 250 kg/m^3
(c) 300 kg/m^3 (d) 260 kg/m^3

36. A boat is floating on the surface of water in a tank carrying steel balls. If the balls are thrown into the tank one by one, how will it affect the level of water ?
(a) It will rise
(b) It will fall
(c) It will remain unchanged
(d) First it will rise and then fall

37. A solid floats in a liquid in the partially submerged position :
(a) the solid exerts a force equal to its weight on the liquid
(b) the liquid exerts a force of buoyancy on the solid which is equal to the weight of the solid
(c) the weight of the displaced liquid equals the weight of the solid
(d) all the above

38. A solid is completely immersed in a liquid. The force exerted by the liquid on the solid will :
(a) increase if it pushed deeper inside the liquid
(b) change if its orientation is changed
(c) decrease if it is taken partially out of the liquid
(d) none of the above

39. A block weighs 15 N and 12 N in air and water respectively. When it is immersed in another liquid, it weighs 13 N, then the relative density of the block is :
(a) 5 (b) 6
(c) 10 (d) 2

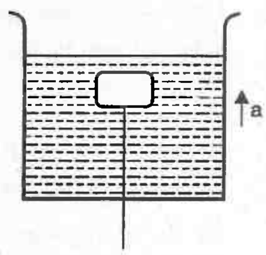
40. In a beaker containing liquid, an ice cube is floating. When ice melts completely, the level of liquid rises. Then the density of the liquid is :
(a) more than the density of ice
(b) less than the density of ice
(c) same as the density of ice
(d) none of the above

41. A metal ball immersed in alcohol weighs w_1 at 0°C and w_2 at 50°C. The co-efficient of cubical expansion of the metal is less than that of alcohol, assuming that the density of the metal is large compared to that of alcohol. It can be shown that :
(a) $w_1 > w_2$ (b) $w_1 = w_2$
(c) $w_1 < w_2$ (d) none of these

42. In English, the phrase 'tip of the iceberg' is used to mean a small visible fraction of something that is mostly hidden. For a real iceberg, what is this fraction if the density of sea water is 1.03 g/cc and that of ice is 0.92 g/cc ?
(a) 0.106 (b) 10.6
(c) 0.901 (d) 0.801

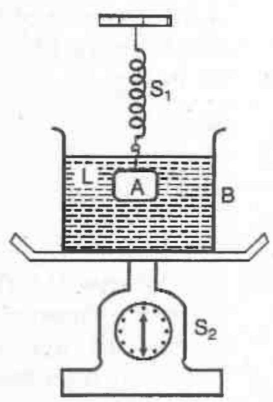
43. A vessel contains oil (density 0.8 g/cc) over mercury (density 13.6 g/cc). A homogeneous sphere floats with half its volume immersed in mercury and the other half in oil. The density of the material of the sphere in g/cc is :
(a) 3.3 (b) 6.4
(c) 7.2 (d) 12. 8

44. A tank accelerates upwards with acceleration $a = 1$ m/s^2 contains water. A block of mass 1 kg and density 0.8 g/cm^3 is held stationary inside the tank with the help of the string as shown in figure. The tension in the string is : (density of water = 1000 kg/m^3)



(a) $T = 2.2$ N (b) $T = 2.75$ N
(c) $T = 3$ N (d) $T = 2.4$ N

* 45. As the figure shows, S_1 and S_2 are spring balances. A block A is hanging from spring balance S_1 and immersed in a liquid L which is contained in a beaker B. The mass of a beaker B is 1 kg and mass of liquid L is 1.5 kg. The S_1 and S_2 balances reads 2.5 kg and 7.5 kg respectively. What will be the readings of S_1 and S_2 when block A is pulled up out of the liquid :



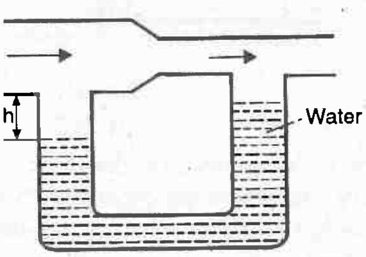
(a) S_1 will read 5 kg and S_2 will read 5 kg
(b) S_1 will read 7.5 kg and S_2 will read 2.5 kg
(c) S_1 will read 2.5 kg and S_2 will read 7.5 kg
(d) S_1 will read 10 kg and S_2 will read 2.5 kg

46. In a liquid of density σ, a rectangular block of mass m and area of cross-section a, floats. If the block is given a small vertical displacement from equilibrium position, it starts oscillation with frequency f. Then :
(a) $f \propto \frac{1}{\sigma}$ (b) $f \propto \sigma$
(c) $f \propto m$ (d) $f \propto \sqrt{a}$

47. A liquid of density ρ_0 is filled in a wide tank to a height h. A solid rod of length L, corss-section area A and density ρ is suspended freely in the tank. The lower end of the rod touches the base of the tank and $h = \frac{L}{\eta}$ (where $\eta > 1$). Then what should be angle of inclination of the rod with the horizontal in the equilibrium position
(a) $\theta = \sin^{-1}\left(\frac{1}{\eta}\sqrt{\left(\frac{\rho_0}{\rho}\right)}\right)$ (b) $\theta = \sin^{-1}\left(\frac{1}{\eta}\sqrt{\left(\frac{\rho}{\rho}\right)}\right)$
(c) $\theta = \sin^{-1}\left(\eta\sqrt{\left(\frac{\rho_0}{\rho}\right)}\right)$ (d) $\theta = \sin^{-1}\left(\sqrt{\left(\frac{\rho_0}{\rho}\right)}\right)$

48. In a steady incompressible flow of a liquid :
(a) the speed does not change if the area of cross-section changes
(b) the speed increases if the area of cross-section increases
(c) the speed decreases if the area of cross-section increases
(d) bubbles are produced when the area of the cross-section increases

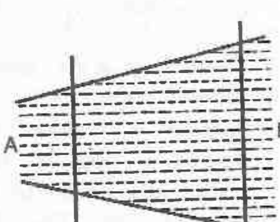
49. Air is blown through a pipe AB at a rate of 15 litre per minute. The cross-sectional area of the wide portion of the pipe AB is 2 cm^2 and that of the narrow portion is 0.5 cm^2. The difference in water lavel h is : ($\rho_{air} = 1.3$ kg/m^3)



(a) 16 mm (b) 1.55 mm
(c) 10 mm (d) 3.2 mm

50. Water from a tap emerges vertically downward with an initial speed of 1 m/s. The cross-sectional area of the tap is 10^{-4} m^2. Assume that the pressure is constant throughout the stream of water and that the flow is steady. The cross-sectional area of the stream 0.15 m below the tap is :
(a) 5×10^{-4} m^2 (b) 1×10^{-5} m^2
(c) 5.83×10^{-5} m^2 (d) 2×10^{-5} m^2

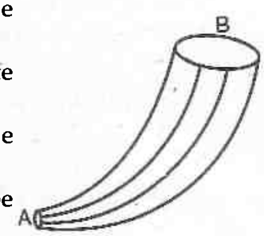
51. Through a non-uniform pipe, a non-viscous liquid is flowing from section A to B as shown in figure. Which of following is correct ?



(a) Since, liquid is flowing from A to B, therefore, pressure at A is greater than at B
(b) Velocity at B, greater than that at A
(c) Total energy per unit volume of the liquid is greater at A than that at B
(d) Axis of pipe can be horizontal

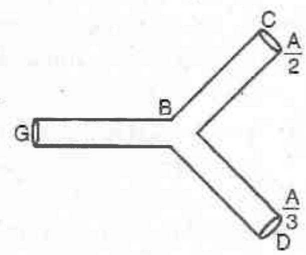
52. For compressible fluid, continuity equation is :
(a) $\rho_1 A_1 v_1 = \rho_2 A_2 v_2$ (b) $\rho_2 A_1 v_1 = \rho_1 A_2 v_2$
(c) $A_1 v_1 = A_2 v_2$ (d) $\frac{\rho_1}{\rho_2} - \frac{A_1}{A_2} - \frac{v_1}{v_2}$

53. A tube of flow is shown in the figure :



(a) the fluid particles must be accelerated from A to B
(b) fluid particles may accelerate from A to B
(c) the fluid particles must be decelerated from A to B
(d) the fluid particles may be decelerated from B to A

54. A pipe GB is fitted with two pipes C and D as shown in the figure. The pipe has area $A = 24$ m^2 at G and velocity of water at G is 10 m/s, and at C is 6 m/s. The velocity of water at D is :



(a) 21 m/s
(b) 3.3 m/s
(c) 30 m/s
(d) none of the above

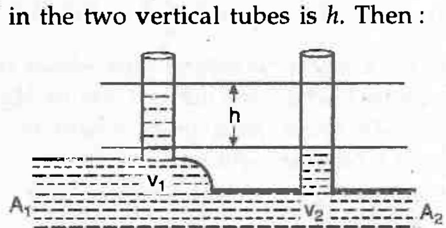
55. Bernoulli's equation is applicable to points :
(a) in a steadily flowing liquid
(b) in a stream line
(c) in a straight line perpendicular to a stream line
(d) in any non-viscous liquid

56. Bernoulli's equation is based upon :
(a) isochoric process (b) isobaric process
(c) isothermal process (d) adiabatic process

57. The horizontal flow of fluid depends upon
(a) pressure difference (b) amount of fluid
(c) density of fluid (d) all the above

58. In steady horizontal flow :
(a) the pressure is greatest where the speed is least
(b) the pressure is independent of speed
(c) the pressure is least where the speed is least
(d) (a) and (c) are correct

59. In a horizontal tube with area of cross-section A_1 and A_2 as shown in fig, liquid is flowing with velocities v_1 and v_2 respectively. The difference in the level of the liquid in the two vertical tubes is h. Then :



(a) the volume of the liquid flowing through the tube in unit time is $A_1 v_1$

(b) $v_2 - v_1 = \sqrt{2gh}$

(c) $v_2^2 - v_1^2 = 2gh$

(d) the energy per unit mass of the liquid is the same in both sections of the tube

60. A vessel is filled with water and kerosene oil. The vessel has a small hole in the bottom. Neglecting viscosity if the thickness of water layer is h_1 and kerosene layer is h_2, then the velocity v of flow of water will be : (density of water is ρ_1 g/cc and that of kerosene is ρ_2 g/cc)

(a) $v = \sqrt{2g(h_1 + h_2)}$ (b) $v = \sqrt{2g\left(h_1 + h_2 \dfrac{\rho_2}{\rho_1}\right)}$

(c) $v = \sqrt{2g(h_1\rho_1 + h_2\rho_2)}$ (d) $v = \sqrt{2g\left(h_1 \dfrac{\rho_1}{\rho_2} + h_2\right)}$

61. Mark correct option(s) :

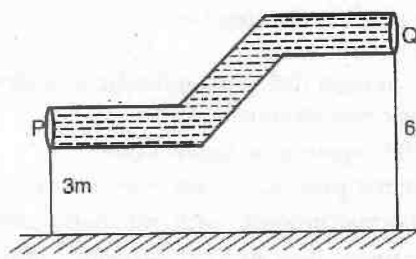
(a) two stream lines may cross each other

(b) two stream lines must cross each other

(c) two stream lines never cross each other

(d) none of above

62. A non viscous liquid of constant density 500 kg/m^3 flows in a variable cross-sectional tube. The area of cross-section of the tube at two points P and Q at heights of 3 m and 6 m are 2×10^{-3} m^3 and 4×10^{-3} m^3 respectively. The work done per unit volume by the forces of gravity as the fluid flows from point P to Q, is :



(a) 29.4 J/m^3 (b) -1.47×10^4 J/m^3

(c) -2.94×10^4 J/m^3 (d) none of these

63. Two identical cylindrical vessels with their bases at the same level each contains a liquid of density d. The height of the liquid in one vessel is h_1 and that in the other vessel is h_2. The area of either base is A. The work done by gravity in equalizing the levels, when the two vessels are connected is :

(a) $(h_1 - h_2)gd$ (b) $(h_1 - h_2)gAd$

(c) $\frac{1}{2}(h_1 - h_2)gAd$ (d) $\frac{1}{4}(h_1 - h_2)gAd$

64. Water flows along a horizontal pipe whose cross-section is not constant. The pressure is 1 cm of Hg where the velocity is 35 cm/s. At a point where the velocity is 65 cm/s, the pressure will be :

(a) 0.89 cm of Hg (b) 8.9 cm of Hg

(c) 0.5 cm of Hg (d) 1 cm of Hg

65. The difference of square of speeds of fluid particles at two ends of the conical section of a pipe, if the radii of its ends are 0.1 m and 0.04 m and the pressure drops across its length is 10 N/m^2, is : (The density of flowing fluid through the pipe is 1.25×10^3 kg/m^3)

(a) 16×10^{-3} m/s (b) 10^{-3} m/s

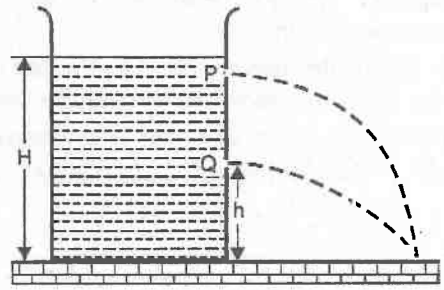
(c) 4×10^{-3} m/s (d) none of these

66. A pilot tube was inserted in a pipe to measure the velocity of water in it. If the water rises in the tube is 200 mm, the velocity of water is :

(a) 9.8 m/s (b) 1.98 m/s

(c) 19.6 m/s (d) 196 m/s

67. A cylindrical vessel is filled with water to a height H. A vessel has two small holes in the side, from which water is rushing out horizontally and the two streams strike the ground at the same point. If the lower hole Q is h height above the ground, then the height of hole P above the ground will be :



(a) $2h$ (b) H/h

(c) $H - h$ (d) $H/2$

68. A water tank standing on the floor has two small holes vertically one above the other punched on one side. The holes are h_1 cm and h_2 cm above the floor. How high does water stand in the tank when the jets from the holes hit the floor at the same point ?

(a) $(h_2 - h_1)$ (b) $(h_2 + h_1)$

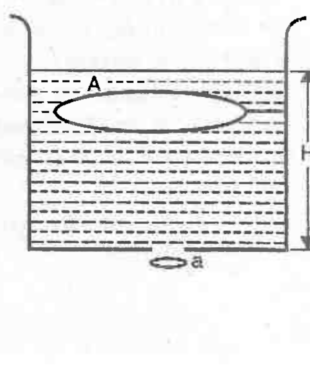
(c) $(h_2^2 - h_1^2)$ (d) $\dfrac{h_2}{h_2 - h_1}$

69. A liquid having area of free surface 'A' has an orifice at a depth 'h' with an area 'a', below the liquid surface, then the velocity v of flow through the orifice is :

(a) $v = \sqrt{2gh}$ (b) $v = \sqrt{2gh}\sqrt{\dfrac{A^2}{A^2 - a^2}}$

(c) $v = \sqrt{2gh}\sqrt{\dfrac{A}{A - a}}$ (d) $v = \sqrt{2gh}\sqrt{\dfrac{A^2 - a^2}{A^2}}$

70. There is a wide tank of cross-section area A contain a liquid to a height H has a small orifice at its base of area 'a' ($a << A$). The time during which liquid level falls to a height $h = \dfrac{H}{\eta}$:



(where $\eta > 1$)

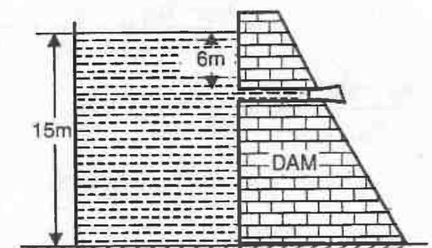
(a) $t = \left(\frac{A}{a}\right)\left[\sqrt{\frac{1}{g}}\left(\sqrt{H} - \sqrt{\frac{H}{\eta}}\right)\right]$

(b) $t = \left(\frac{a}{A}\right)\left[\sqrt{\frac{2}{g}}\left(\sqrt{H} - \sqrt{\frac{H}{\eta}}\right)\right]$

(c) $t = \left(\frac{a}{A}\right)\left[\sqrt{\frac{1}{g}}\left(\sqrt{H} - \sqrt{\frac{H}{\eta}}\right)\right]$

(d) $t = \left(\frac{A}{a}\right)\left[\frac{1}{\sqrt{2g}}\left(\sqrt{H} - \sqrt{\frac{H}{\eta}}\right)\right]$

71. Water stands at a depth of 15 m behind a reservoir dam. A horizontal pipe 4 cm in diameter passes through the dam 6 m below the surface of water as shown. There is plug which secures the pipe opening. Then the friction between the plug and pipe wall is :

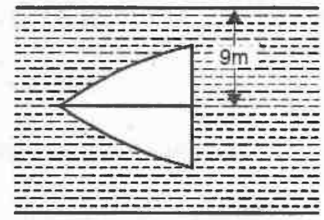


(a) 70 N (b) 79 N
(c) 74 N (d) 65 N

72. A rectangular plate 2 m × 3 m is immersed in water in such a way that its greatest and least depth are 6 m and 4 m respectively from the water surface. The total thrust on the plate is :

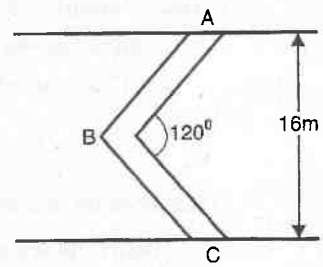
(a) 294×10^3 N (b) 294 N
(c) 100×10^3 N (d) 400×10^3 N

73. An isosceles triangle of base 3 m and altitude 6 m, is immersed vertically in water having its axis of symmetry horizontal as shown in the figure. If height of water on its axis is 9 m, the total thrust on the plate is :



(a) 793.8×10^3 N (b) 700×10^3 N
(c) 500×10^3 N (d) 300×10^3 N

* 74. Two lock gates of 7.5 m height are provided in a canal of 16 m width meeting at an angle of 120°. The force acting on each gate, when the depth of water in upstream side is 5 m, is :



(a) 1000 kN
(b) 1133 kN
(c) 500 kN
(d) 400 kN

* 75. A cylindrical buoy of 3 m diameter and 4 m long is weighing 150 kN when immersed in water. Then :
(a) it may float vertically in water
(b) it cannot float vertically in water
(c) it must float vertically in water
(d) (a) and (c) are correct

Answers

Level-1

1. (b)	2. (a)	3. (b)	4. (b)	5. (c)	6. (a)	7. (b)	8. (a)	9. (d)	10. (c)
11. (a)	12. (a)	13. (c)	14. (b)	15. (a)	16. (b)	17. (b)	18. (a)	19. (c)	20. (a)

Level-2

1. (d)	2. (b)	3. (b)	4. (c)	5. (a)	6. (c)	7. (b)	8. (a)	9. (b)	10. (b)
11. (b)	12. (c)	13. (d)	14. (b)	15. (c)	16. (a)	17. (b)	18. (c)	19. (b)	20. (c)
21. (d)	22. (a)	23. (a)	24. (a)	25. (b)	26. (b)	27. (b)	28. (c)	29. (b)	30. (b)
31. (c)	32. (d)	33. (b)	34. (c)	35. (b)	36. (b)	37. (d)	38. (c)	39. (a)	40. (a)
41. (c)	42. (a)	43. (c)	44. (b)	45. (b)	46. (d)	47. (a)	48. (c)	49. (b)	50. (c)
51. (a)	52. (a)	53. (c)	54. (a)	55. (d)	56. (c)	57. (a)	58. (a)	59. (c)	60. (b)
61. (c)	62. (b)	63. (d)	64. (a)	65. (a)	66. (b)	67. (c)	68. (b)	69. (b)	70. (d)
71. (c)	72. (a)	73. (a)	74. (b)	75. (b)					

12

Some Mechanical Properties of Matter

Syllabus: Interatomic and intermolecular forces, states of matter, elastic properties, Hooke's law, Young's modulus of elasticity, Bulk modulus of rigidity, Forces of cohesion and adhesion, surface energy and surface tension, viscosity. Stoke's law, terminal velocity.

Review of Concepts

1. Definition of elasticity : The property of a material by virtue of which it resists strain when deforming forces are applied on it and recovers from strain, when deforming forces are removed, is called elasticity of that material :

(a) If the body regains its original shape and size completely after the removal of deforming forces then the body is said to be perfectly elastic.

(b) If the body does not recover its original shape and size, the body is said to be perfectly plastic.

2. Stress: The restoring force setup inside the body per unit area is known as stress.

Restoring force : If the magnitude of applied deforming force at equilibrium $= F$

then, $\text{Stress} = \frac{F}{A}$

In SI system, unit of stress is N/m^2.

(a) When the stress is applied normal to a surface, then it is known as **normal stress.**

(b) When the stress is applied tangentially to a surface, then it is called **tangential** or **shearing stress.**

Both stress and pressure are defined as force even then they differ from each other due to following reasons :

(i) Pressure is scalar but stress is tensor quantity.

(ii) Pressure always acts normal to the surface, but stress may be normal or tangential.

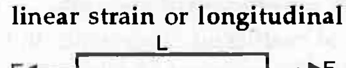
(iii) Pressure is compressive in nature but stress may be compressive or tensile.

3. Strain : When the size or shape of a body is changed under an external force, the body is said to be strained. The change occurred in the unit size of the body is called strain.

$$\text{Strain} = \frac{\text{Change in dimension}}{\text{Original dimension}}$$

(a) It has no dimension as it is a pure number.

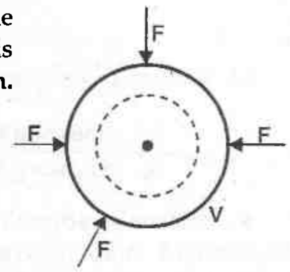
(b) (i) If the change in length is occurred, the strain is called **linear strain or longitudinal strain.**



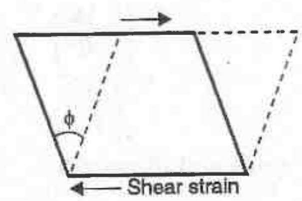
$$\text{Logitudinal strain} = \frac{\Delta L}{L}$$

(ii) If the change in volume is occurred, the strain is called **volumetric strain.**

$$\text{Volumetric strain} = \frac{\Delta V}{V}$$

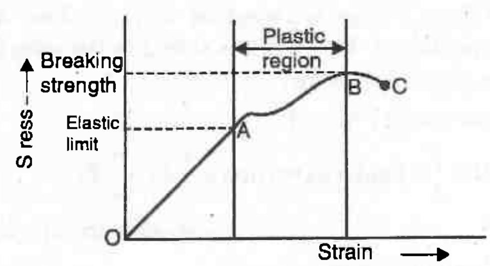


(iii) Generally, if the change in shape is occurred, the strain is called **shearing strain or shear.**



Shearing strain $= \phi$

4. Stress-strain graph : From graph, it is obvious that in elastic limit, stress is proportional to strain. This is known as Hooke's law.



$\therefore$ Stress $\propto$ Strain

$\therefore$ Stress $= E \times$ strain

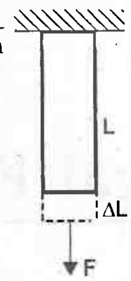
$\therefore$ $E = \frac{\text{Stress}}{\text{Strain}}$

where E is proportionality dimensional constant known as coefficient of elasticity.

5. Types of coefficient of elasticity :

(a) Young's modulus $= Y = \dfrac{\text{Logitudinal stress}}{\text{Longitudinal strain}}$

$$\therefore \qquad Y = \frac{F}{A\dfrac{\Delta L}{L}} = \frac{FL}{A\Delta L}$$

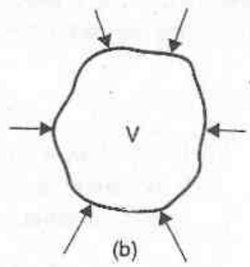


(a)

(b) Bulk modulus $= B$

$$= \frac{\text{Volumetric stress}}{\text{Volumetric strain}}$$

Compressibility $= \dfrac{1}{B}$



(b)

(c) Modulus of rigidity

$$= \eta = \frac{F}{A\phi} = \frac{\text{Shearing stress}}{\text{Shearing strain}}$$

6. Poisson's ratio : The ratio of the lateral strain to the longitudinal strain is constant for a given material. This constant is called as Poisson's ratio which is denoted by σ.

$$\text{Poisson's ratio} = \sigma = \frac{\text{Lateral strain}}{\text{Longitudinal strain}} = \frac{\left(-\dfrac{\Delta R}{R}\right)}{\left(\dfrac{\Delta L}{L}\right)}$$

(a) σ has no units and dimensions.

(b) Theoretically, $\quad -1 < \sigma < \dfrac{1}{2}$

(c) Practically $\quad 0 < \sigma < \dfrac{1}{2}$

7. Work done or Potential energy stored in a stretched wire : When a wire is stretched work is done against the interatomic forces. This work is stored in the wire in the form of elastic potential energy.

Elastic energy stored,

$$U = \frac{1}{2} \times \text{load} \times \text{extension} = \frac{1}{2} Fx = \frac{1}{2} kx^2 \qquad (\because F = kx)$$

$$= \text{stress} \times \text{strain} \times \text{volume}$$

For twisting motion,

$$U = \frac{1}{2} \times \text{torque} \times \text{angular twist} = \frac{1}{2} \tau \times \theta = \frac{1}{2} C\theta^2$$

Elastic energy density,

$$U = \frac{1}{2} \times \text{stress} \times \text{strain J/m}^3 = \frac{1}{2} Y \times \text{strain}^2 \text{ J/m}^3$$

Some important points regarding elasticity :

(a) Greater is the modulus of elasticity, the material is more elastic.

(b) $E_{solid} > E_{liquid} > E_{gas}$

(c) Relation among some elastic constants *viz.*, Y, B, η and σ.

(i) $Y = 2\eta(1 + \sigma)$ (ii) $Y = 3B(1 - 2\sigma)$

(iii) $Y = \dfrac{9B\eta}{3B + \eta}$ (iv) $\sigma = \dfrac{3B - 2\eta}{6B + 2\eta}$

(d) When temperature increases, coefficients of elasticity (Y, B, η) decrease.

(e) Gases have two Bulk moduli,

(i) Isothermal elasticity $E_\theta = P$

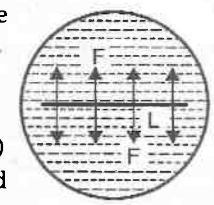
(ii) Adiabatic elasticity $E_\phi = \gamma P$

8. Surface tension: $T = \dfrac{F}{L}$

Here L = length of imaginary line drawn at the surface of liquid.

and

F = force acting on one side of line (shown in figure)



(a) Surface tension does not depend upon surface area.

(b) When temperature increases, surface tension decreases.

(c) At critical temperature surface tension is zero.

9. Rise or fall of a liquid in a capillary tube,

$$h = \frac{2T\cos\theta}{r\rho g}$$

Here : θ = angle of contact

r = radius of capillary tube

ρ = density of liquid

For a given liquid and solid at a given place, hr = constant.

10. Surface energy density is defined as work done against surface tension per unit area. It is numerically equal to surface tension.

$$W = \text{work} = \text{surface tension} \times \text{area}$$

(a) For a drop of radius R, $W = 4\pi R^2 T$

(b) For a soap bubble, $W = 8\pi R^2 T$

11. Excess pressure :

(a) For drop, $P = \dfrac{2T}{R}$

(b) For soap bubble, $P = \dfrac{4T}{R}$

12. Viscosity:

(a) Newton's law of viscous force :

$$F = -\eta A \frac{dv}{dy}$$

where $\dfrac{dv}{dy}$ = velocity gradient

A = area of liquid layer

η = coefficient of viscosity

The unit of coefficient of viscosity in CGS is poise.

(b) SI unit of coefficient of viscosity

= poiseuille = 10 poise.

(c) In the case of liquid, viscosity increases with density.

(d) In the case of gas, viscosity decreases with density.

(e) In the case of liquid, when temperature increases, viscosity decreases.

(f) In the case of gas, when temperature increases, viscosity increases.

13. Poiseuille's equation $V = \dfrac{P\pi r^4}{8\eta L}$

where V = the volume of liquid flowing per second through a capillary tube of length L and radius r

η = coefficient of viscosity

and P = pressure difference between ends of the tube

14. Stoke's law: The viscous force acting on a spherical body moving with constant velocity v in a viscous liquid is $F = 6\pi\eta r v$

where r = radius of spherical body

15. **Determination of η:** $\eta = \dfrac{2r^2(\rho - \sigma)g}{9v}$

where r = radius of spherical body moving with constant velocity v in a viscous liquid of coefficient of viscosity η and density ρ

and σ = density of spherical body

16. **Critical velocity (v_0):**

$$v_0 = \frac{k\eta}{\rho r}$$

where k = Reynold's number, for narrow tube, $k \sim 1000$.

(a) For stream line motion, flow of velocity $v < v_0$.

(b) For turbulant motion, flow of velocity $v > v_0$.

Objective Questions

Level-1

1. A one metre long steel wire of cross-sectional area 1 mm^2 is extended by 1 mm. If $Y = 2 \times 10^{11}$ Nm^{-2}, then the work done is :

(a) 0.1 J (b) 0.2 J
(c) 0.3 J (d) 0.4 J

2. A long rod of radius 1 cm and length 2 m which is fixed at one end is given a twist of 0.8 radian. The shear strain developed will be :

(a) 0.002 (b) 0.004
(c) 0.008 (d) 0.016

3. Two wires of the same material and length are stretched by the same force. Their masses are in the ratio 3 : 2, their elongations are in the ratio :

(a) 3 : 2 (b) 9 : 4
(c) 2 : 3 (d) 4 : 9

4. A long wire hangs vertically with its upper end clamped. A torque of 8 Nm applied to the free end twisted it through 45°, the potential energy of the twisted wire is :

(a) π joule (b) $\frac{\pi}{2}$ joule
(c) $\frac{\pi}{4}$ joule (d) $\frac{\pi}{8}$ joule

5. Theoretically the value of Poisson's ratio σ lies between :

(a) $0 < \sigma < 1$ (b) $-1 < \sigma < 0.5$
(c) $0.2 < \sigma < 0.4$ (d) $-1 < \sigma < 1$

6. When a rubber cord is stretched, the change in volume with respect to change in its linear dimension is negligible, the Poisson's ratio for rubber is :

(a) 1 (b) 0.25
(c) 0.5 (d) 0.75

7. A uniform rod suffers a longitudinal strain of 2×10^{-3}. The Poisson's ratio of the material of the rod is 0.50. The percentage change in volume is :

(a) zero (b) 0.1
(c) 0.2 (d) 0.6

8. A cable that can support a load of 800 N is cut into two equal parts. The maximum load that can be supported by either part is :

(a) 100 N (b) 400 N
(c) 800 N (d) 1600 N

9. The breaking stress of wire of length l and radius r is 5 kg wt m^{-2}. The length and radius of wire are doubled, the breaking stress in kg wt m^{-2} is :

(a) 5 (b) 10
(c) 20 (d) 80

10. The Young's modulus and Bulk modulus of elastic material is 7×10^{10} Nm^{-2} and 11×10^{10} Nm^{-2} respectively then the Poisson's ratio of the material is :

(a) 0.12 (b) 0.24
(c) 0.31 (d) 0.39

11. When a weight of 5 kg is suspended from a copper wire of length 30 m and radius 0.5 mm, the length of the wire increases by 2.4 cm. If the radius is doubled, the extension produced is :

(a) 1.2 cm (b) 0.6 cm
(c) 0.3 cm (d) 0.15 cm

12. A cylindrical rod has breaking stress of 10^6 Nm^{-2}. The maximum possible height of the rod is 5 m. The density of material of the rod is : (taken $g = 10$ m/s^2)

(a) 10^3 kg m^{-3} (b) 10^4 kg m^{-3}
(c) 2×10^4 kg m^{-3} (d) 1 kg m^{-3}

13. The pressure applied from all directions on a cube is P. How much its temperature should be raised to maintain the original volume ? The volume elasticity of the cube is B and the coefficient of volume expansion is γ:

(a) $\frac{P}{\gamma B}$ (b) $\frac{P\gamma}{B}$
(c) $\frac{PB}{\gamma}$ (d) $\frac{\gamma B}{P}$

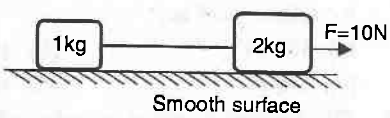
Level-2

1. The dimensions of Poisson's ratio is :
(a) $[M^0L^0T^0]$ (b) $[ML^{-1}T^{-2}]$
(c) $[ML^2T^{-4}]$ (d) $[ML^2T^{-3}]$

2. One end of a wire 2 m long and diameter 2 mm, is fixed in a ceiling. A naughty boy of mass 10 kg jumps to catch the free end and stays there. The change in length of wire is : (Take $g = 10\ m/s^2$, $Y = 2 \times 10^{11}\ N/m^2$)
(a) 31.84×10^{-5} m (b) 2 mm
(c) 3 mm (d) 4 m

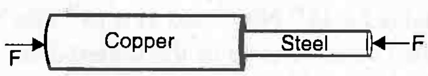
3. In above problem, if Poisson's ratio is $\sigma = 0.1$, the change in diameter is :
(a) 3.184×10^{-5} m (b) 31.84×10^{-5} m
(c) 3.184×10^{-8} m (d) 31.84×10^{-8} m

4. Two bodies of masses 1 kg and 2 kg are connected by a metal wire shown in figure. A force of 10 N is applied on the body of mass 2 kg. The breaking stress of metal wire is $2 \times 10^9\ N/m^2$. What should be minimum radius of the wire used, if it is not to break ?



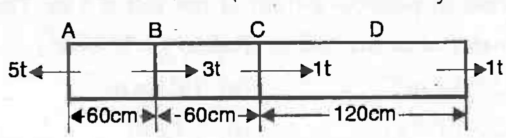
(a) 0.23×10^{-4} m (b) 4×10^{-4} m
(c) 5×10^{-4} m (d) 5.2×10^{-4} m

5. Two wires, one made of copper and other of steel are joined end to end. (as shown in figure). The area of cross-section of copper wire is twice that of steel wire.



They are placed under compressive force of magnitudes F. The ratio of their lengths such that change in lengths of both wires are same is: ($Y_S = 2 \times 10^{11}\ N/m^2$ and $Y_C = 1.1 \times 10^{11}\ N/m^2$)
(a) 2.1 (b) 1.1
(c) 1.2 (d) 2

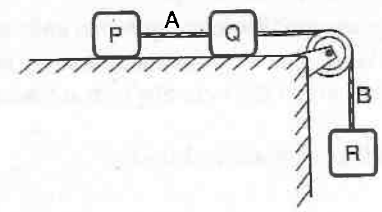
6. The total elongation of the bar, if the bar is subjected to axial forces as shown in figure and the cross-sectional area of bar is 10 cm^2, is : (Take $E = 8 \times 10^2\ dyne/cm^2$)



(a) 0.01 cm (b) 0.5 cm
(c) 0.0675 cm (d) 0.775 cm

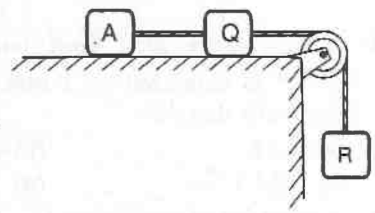
7. When tension in a metal wire is T_1, its length was l_1 and when tension is T_2, the length is l_2. Its unstretched length is :
(a) $\sqrt{l_1 l_2}$ (b) $\dfrac{l_1 + l_2}{2}$
(c) $\dfrac{(l_1T_2 - l_2T_1)}{T_2 - T_1}$ (d) $\dfrac{l_1T_2 + T_1l_2}{T_1 + T_2}$

8. Three blocks system is shown in the figure. Each has mass 3 kg. String connected to P and Q are of equal cross-section and Young's modulus of 0.005 cm^2 and $2 \times 10^{11}\ N/m^2$ respectively, neglect friction. The longitudinal strain in A and B are :



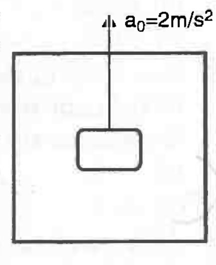
(a) $2.5 \times 10^{-4}, 1 \times 10^{-4}$ (b) $1 \times 10^{-4}, 2 \times 10^{-4}$
(c) $0.2 \times 10^{-4}, 2 \times 10^{-4}$ (d) none of these

9. In the previous problem, the elastic potential energy stored per unit volume in wire connecting blocks P in steady state is : (Take $g = 10\ m/s^2$)



(a) 500 J/m^3 (b) 1000 J/m^3
(c) 2000 J/m^3 (d) 3000 J/m^3

10. One end of a steel wire is fixed to ceiling of an elevator moving up with an acceleration 2 m/s^2 and a load of 10 kg hangs from other end. Area of cross-section of the wire is 2 cm^2. The longitudinal strain in the wire is: (Take $g = 10\ m/s^2$ and $Y = 2 \times 10^{11}\ N/m^2$)

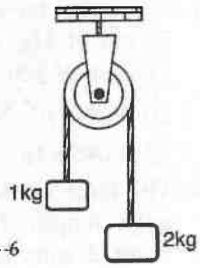


(a) 4×10^{11} (b) 3×10^{-6}
(c) 8×10^{-6} (d) 2×10^{-6}

11. Equal weights are suspended from two wires of the same metal one of these wire is of length 2 m and diameter 1 mm, while the other is of length 1 m and diameter 0.5 mm. Then :
(a) first wire has greater extension
(b) second wire has greater extension
(c) both wire have the same extension
(d) extension in both wires are zero

12. Two wires one of copper and other of steel having same cross-sectional area and lengths 1.0 m and 0.5 m respectively, are fastened end to end and stretched by a load M. If copper wire is stretched by 1 mm, the total extension of the combined wire is :
(Given: Young's modulii are $Y_{copper} = 1 \times 10^{11}\ N/m^2$, and $Y_{steel} = 2 \times 10^{11}\ N/m^2$)
(a) 0.125 cm (b) 0.2 cm
(c) 0.120 cm (d) 0.25 cm

13. Two bodies of masses 1 kg and 2 kg are connected by a steel wire of cross-section 2 cm^2 going over a smooth pulley (as shown in figure). The longitudinal strain in the wire is: (Take $g = 10\ m/s^2$, $Y = 2 \times 10^{11}\ N/m^2$)



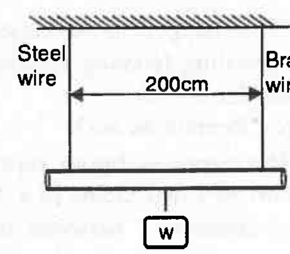
(a) 3.3×10^{-7} (b) 3.3×10^{-6}
(c) 2×10^{-6} (d) 4×10^{-6}

14. A body of mass 1 kg is fastened to one end of a steel wire of cross-sectional area $3 \times 10^{-6}\ m^2$ and is rotated in horizontal circle of radius 20 cm with a constant speed 2 m/s. The elongation of the wire is: ($Y = 2 \times 10^{11}\ N/m^2$)
(a) 0.33×10^{-5} m (b) 0.67×10^{-5} m
(c) 2×10^{-5} m (d) 4×10^{-5} m

15. A body of mass $m = 10$ kg is attached to a wire of length 0.3 m. The maximum angular velocity with which it can be rotated in a horizontal circle is: (Breaking stress of wire $= 4.8 \times 10^7\ N/m^2$ and area of cross-section of a wire $= 10^{-6}\ m^2$)
(a) 4 rad/s (b) 8 rad/s
(c) 1 rad/s (d) 2 rad/s

16. Two equal parts of a cable are joined together. The maximum load that can be supported by either part is w. Then the maximum load that can be supported by the cable after joining is:
(a) $w/2$ (b) $w/3$
(c) $w/4$ (d) w

17. From the ceiling, a light rod of length 200 cm is suspended horizontally with the help of two vertical wires of equal length as shown in figure. If one wire is made of brass and have cross-sectional area 0.2 cm^2 and other of steel of 0.1 cm^2 of cross-sectional area, then at what distance along rod a weight may be hung to produce equal stress in both the wires?



(a) $\frac{4}{3}$ m from steel wire (b) $\frac{4}{3}$ m from brass wire
(c) 1 m from steel wire (d) $\frac{1}{4}$ m from brass wire

18. If a conical wire is stretched by two forces F applied parallel to its length and in opposite direction, normal to end faces. The length of wire is L and its end radius are r_1 and r_2. Find out the extension produced: (Given: Y = Young's modulus of wire)
(a) $\frac{FL}{\pi r_1^2 Y}$ (b) $\frac{FL}{\pi r_1 Y}$
(c) $\frac{FL}{\pi r_1 r_2 Y}$ (d) $\frac{FLY}{\pi r_1 r_2}$

19. The velocity of projection of a missile of mass 5 g, when a rubber cord is stretched to 12 cm and then released to project the missile, is: (Given: Area of cross-section of cord $= 1\ mm^2$, total unstretched length = 10 cm, Young's modulus of rubber $= 5 \times 10^8\ N/m^2$)
(a) 20 m/s (b) 25 m/s
(c) 22 m/s (d) 18 m/s

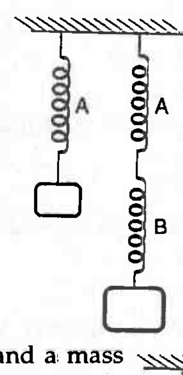
20. When does an elastic metal rod change its length?
(a) If it fall vertically under its weight
(b) If it is pulled along its length by a force acting at one end
(c) If it is rotated about an axis at one end
(d) If it slides on a smooth surface

21. On what factor should the coefficient of restitution depend when two bodies having masses m and M ($m < M$) collide with each other?
(a) Coefficient of restitution depends upon Young's modulus of elasticity of heavier body only
(b) Coefficient of restitution depends upon Young's modulus of elasticity of lighter body only
(c) Coefficient of restitution depends upon Young's modulus of elasticity of both the bodies
(d) Coefficient of restitution depends upon Nature of collision (wheather it is head on or oblique)

22. If a metal wire of length L, having area of cross-section A and Young's modulus Y, behaves as a spring of spring constant k. The value of k is:
(a) $\frac{YA}{L}$ (b) $\frac{YA}{2L}$
(c) $\frac{2YA}{L}$ (d) $\frac{YL}{A}$

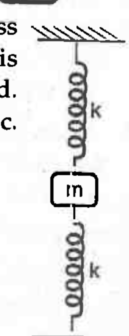
23. Two identical springs of steel and copper are equally stretched. W_A and W_B represent works for steel and copper. Then:
(a) $W_A > W_B$ (b) $W_A < W_B$
(c) $W_A = W_B$ (d) $W_A > W_B$

24. In the figure three identical springs are shown. From spring A, a mass of 4 kg is hung and spring shows elongation of 1 cm. But when a weight of 6 kg is hung on B, the Hook's descends:



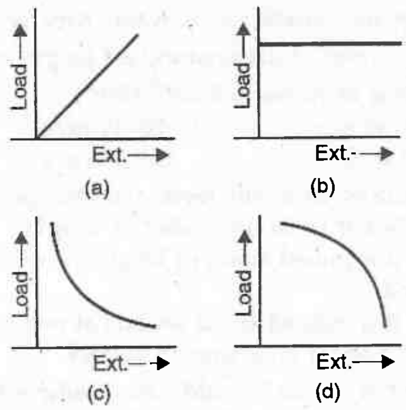
(a) 1 cm
(b) 2 cm
(c) 3 cm
(d) 4 cm

25. A system consists of two springs and a mass $m = 1$ kg as shown in figure. If mass m is displaced slightly along vertical and released. The system oscillates with a period of 2 sec. Then the spring constant k is:

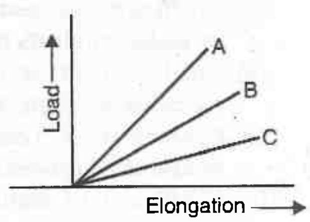


(a) $\frac{\pi^2}{4}$ (b) $\frac{\pi^2}{6}$
(c) $\frac{\pi^2}{8}$ (d) $\frac{\pi^2}{2}$

26. Which of following graphs satisfies the Hooke's law under elastic limit ?



27. Elongation-load graph within elastic limit is shown in figure of three wires A, B and C made of same material and of same length. The thickest wire is :



(a) A
(b) B
(c) C
(d) none of the above

28. What will happen if a metal wire is stretched a little beyond its elastic limit (or yield point) and released ?
(a) It loses its elastic property completely
(b) It does not contract
(c) It contracts, but its final length will be greater than its initial length
(d) It contracts only up to its length at the elastic limit

29. The linear strain in x, y and z-directions are e_x, e_y and e_z respectively. Then the volumetric strain is given by :
(a) $e_x e_y e_z$ (b) $e_x + e_y + e_z$
(c) $e_z = e_x e_y$ (d) $e_z = \frac{e_x + e_y}{2}$

30. Young's modulus is defined for :
(a) solid (b) liquid
(c) gas (d) all of these

31. The bulk modulus for an incompressible liquid is :
(a) ∞ (b) 0
(c) 1 (d) 2

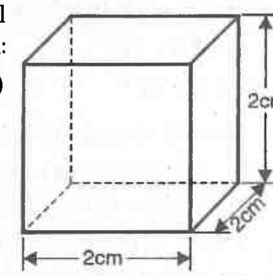
32. The value of modulus of rigidity for liquids is :
(a) ∞ (b) 0
(c) 1 (d) 2

33. If for a material, Y and B are Young's modulus and Bulk modulus then :
(a) $Y < 3B$ (b) $Y = 3B$
(c) $Y > 3B$ (d) $3Y = B$

34. When a sphere is taken to bottom of sea 1 km deep, it contracts by 0.01%. The bulk modulus of elasticity of the material of sphere is : (Given: Density of water $= 1\ g/cm^3$)
(a) $9.8 \times 10^{10}\ N/m^2$ (b) $10.2 \times 10^{10}\ N/m^2$
(c) $0.98 \times 10^{10}\ N/m^2$ (d) $8.4 \times 10^{10}\ N/m^2$

35. The stress for one litre of a perfect gas, at a pressure of 72 cm of Hg, when it is compressed isothermally to a volume of 900 cc, is :
(a) $9.88 \times 10^3\ N/m^2$ (b) $10.88 \times 10^3\ N/m^2$
(c) $1.088 \times 10^3\ N/m^2$ (d) $2 \times 10^3\ N/m^2$

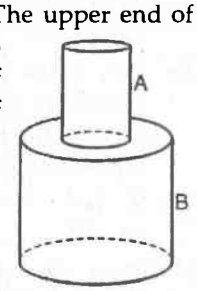
36. The force needed to punch a hole in shape of square of edge length 2 cm in a steel sheet 2 mm thick, is : (Given: Shearing stress $= 3.5 \times 10^8\ N/m^2$)



(a) 5.6×10^3 N
(b) 6.2×10^4 N
(c) 5.6×10^4 N
(d) 7.6×10^4 N

37. If the shear modulus of a wire material is $5.9 \times 10^{11}\ dyne/cm^2$ then the potential energy of a wire of 4×10^{-3} cm in diameter and 5 cm long twisted through an angle of 10′, is :
(a) 1.253×10^{-12} J (b) 2×10^{-12} J
(c) 1.00×10^{-12} J (d) 0.8×10^{-12} J

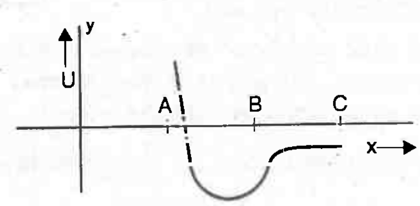
38. Two cylinders of same material and of same length are joined end to end as shown in figure. The upper end of A is rigidly fixed. Their radii are in ratio of 1 : 2 respectively. If the lower end of B is twisted by an angle θ, the angle of twist of cylinder A is :



(a) $\frac{15}{16}\theta$ (b) $\frac{16}{15}\theta$
(c) $\frac{16}{17}\theta$ (d) $\frac{17}{16}\theta$

39. What happen to the elastic property of a substance after annealing (cooling slowly after heating) ?
(a) Increases (b) Decreases
(c) Remain as such (d) Becomes zero

40. The curve in figure represents potential energy (U) in between two atoms in a diatomic molecule as a function of distance 'x' between atoms. The atoms are :



(a) attracted when x lies between 'A' and 'B' and repelled when x lies between B and C
(b) attracted when x lies between B and C and repelled when x lies between A and B
(c) attracted when they reach B
(d) repelled when they reach B

41. Surface tension of liquid :
(a) rises with rise in temperature
(b) fall with rise in temperature
(c) is independent of temperature
(d) none of the above

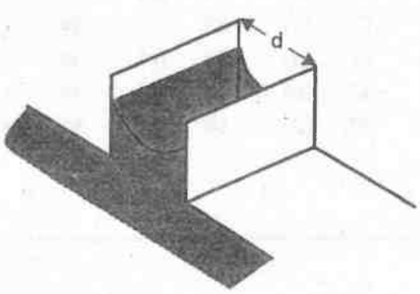
42. A capillary tube of area of cross-section A is dipped in water vertically. The amount of heat evolved as the water rises in the capillary tube up to height h is : (The density of water is ρ)
(a) $\frac{A\rho g h^2}{2}$ (b) $Agh^2\rho$
(c) $2Agh^2\rho$ (d) none of these

43. In an experiment a capillary tube is kept vertical, then water rises up in the tube up to 3 mm height. When the tube is tilted at an angle of 60° with vertical, what should be the height of water rise ?
(a) 6 mm (b) 4 mm
(c) 3 mm (d) None of these

44. The rise of water in a capillary tube when kept vertical in water whose radii is 1/4th of that capillary tube which when kept, vertical water rise in it upto a height of 3 mm, is :
(a) 12 mm (b) 10 mm
(c) 4 mm (d) 3 mm

45. The heat evolved for the rise of water when one end of the capillary tube of radius r is immersed vertically into water, is : (Assume surface tension $= T$ and density of water to be ρ)
(a) $\frac{2\pi T}{\rho g}$ (b) $\frac{\pi T^2}{\rho g}$
(c) $\frac{2\pi T^2}{\rho g}$ (d) none of these

46. Two parallel glass plates having separation 'd' are dipped in water. Some water rise up in the gap between the plates. The surface tension of water is S, atmospheric pressure $= P_0$, pressure of water just below the water surface in the region between the plates is P, find the relation between them :



(a) $P = P_0 - \frac{2S}{d}$ (b) $P = P_0 + \frac{2S}{d}$
(c) $P = P_0 - \frac{4S}{d}$ (d) $P = P_0 + \frac{4S}{d}$

47. In a liquid there is air bubble of radius 1 mm at a depth 10 cm below the free space. The surface tension of liquid is 0.075 N/m and density is 1000 kg/m^3. By what amount is the pressure inside the bubble greater than the atmospheric pressure ?
(a) 1130 pascal (b) 1200 pascal
(c) 1100 pascal (d) 1000 pascal

48. The work done by a boy in making a soap bubble of diameter 1.4 cm by blowing, if the surface tension of soap solution is 0.03 N/m, is :
(a) 3×10^{-5} J (b) 3.696×10^{-5} J
(c) 2×10^{-5} J (d) 4.2×10^{-5} J

49. A drop of radius r is broken into n equal drops. The work done if surface tension of water is T, is :
(a) $4r\pi R^2 nT$ (b) $4\pi R^2 T(n^{2/3} - 1)$
(c) $4\pi R^2 T(n^{1/3} - 1)$ (d) none of these

50. What will happen if n drops of a liquid each has surface energy E, combine to form a single drop ?
(a) No energy will be released in the process
(b) Some energy will be absorbed in the process
(c) Energy released or absorbed will be $E(n - n^{2/3})$
(d) Energy released or absorbed will be $nE(2^{2/3} - 1)$

51. If a bigger drop of liquid at temperature t, breaks up into number of small droplets, then what is temperature of the droplets ? (Assume bigger drop is isolated from its surroundings)
(a) Equal to t
(b) Greater than t
(c) Less than t
(d) Either (a), (b), (c) depending on surface tension of liquid

52. The excess pressure inside a soap bubble of radius 4 cm is 30 dyne/cm^2. The surface tension is :
(a) 30 dyne/cm (b) 20 dyne/cm
(c) 40 dyne/cm (d) 80 dyne/cm

53. The work done against surface tension in formation of a drop of mercury of radius 4 cm is :
(surface tension for mercury = 465 dyne/cm)
(a) 9.34×10^{-3} J (b) 10×10^{-2} J
(c) 4×10^{-3} J (d) 466 J

54. The energy required to increase the radius of a soap bubble from 1 cm to 2 cm is : (The surface tension is 30 dyne/cm)
(a) 240π erg (b) 720π erg
(c) 480π erg (d) none of these

55. A film of a liquid is held on a circular ring of radius r. If the surface tension of the liquid is T, the surface energy of liquid is :
(a) $\pi r^2 T$ (b) $2\pi r^2 T$
(c) $4\pi r^2 T$ (d) none of these

56. The common radius of curvature 'r', when two soap bubbles with radii r_1 and r_2 $(r_1 > r_2)$ come in contact, is :
(a) $r = \frac{r_1 + r_2}{2}$ (b) $r = \frac{r_1 r_2}{r_1 - r_2}$
(c) $r = \frac{r_1 r_2}{r_1 + r_2}$ (d) $r = \sqrt{r_1 r_2}$

57. Water is flowing in a river. If the velocity of a layer at a distance 10 cm from the bottom is 20 cm/s, the velocity of layer at a height of 40 cm from the bottom is :
(a) 10 m/s (b) 20 cm/s
(c) 30 cm/s (d) 80 cm/s

58. A horizontal plate (10 cm × 10 cm) moves on a layer of oil of thickness 4 mm with constant speed of 10 cm/s. The coefficient of viscosity of oil is 4 poise. The tangential force applied on the plate to maintain the constant speed of the plate is :
(a) 10^3 dyne (b) 10^4 dyne
(c) 10^5 dyne (d) none of these

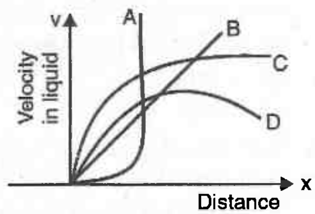
59. A liquid is flowing through a narrow tube. The coefficient of viscosity of liquid is 0.1308 poise. The length and inner radius of tube are 50 cm and 1 mm respectively. The rate of flow of liquid is 360 cm^3/min. The pressure difference between ends of tube is :
(a) 10^6 dyne/cm^2 (b) 10^4 dyne/cm^2
(c) 10 dyne/cm^2 (d) none of these

60. The terminal velocity of solid sphere of radius 0.1 m moving in air in vertically downward direction, is : ($\eta = 1.8 \times 10^{-5}$ Ns/m^2, density of sphere = 1000 kg/m^3 and $g = 10$ m/s^2)
(a) 2×10^5 m/s (b) 1.2×10^8 cm/s
(c) 4×10^2 cm/s (d) none of these

61. Eight equal drops of water each of radius $r = 2$ mm are falling through air with a terminal velocity of 16 cm/s. The eight drops combine to form a big drop. The terminal velocity of big drop is :
(a) 16 cm/s (b) 32 cm/s
(c) 64 cm/s (d) none of these

62. At 20°C, to attain the terminal velocity how fast will an aluminium sphere of radii 1 mm fall through water? [Assume flow to be laminar flow and specific gravity (Al) = 2.7, $\eta_{water} = 8 \times 10^{-4}$ Pa]
(a) 5 m/s (b) 4.7 m/s
(c) 4 m/s (d) 2 m/s

63. The journey of a small spherical solid ball dropped in a viscous liquid is best described by :



(a) curve *A*
(b) curve *B*
(c) curve *C*
(d) curve *D*

64. The speed of flow of water through a long cylindrical pipe of diameter 2 cm so that flow become turbulent, is : (Assume at temperature of 20°C, viscosity $\eta = 1 \times 10^{-3}$ Pa. second, Reynold number = 3000)
(a) 1.5 m/s (b) 0.15 m/s
(c) 2 m/s (d) 1 m/s

Answers

Level-1

1. (a)	2. (b)	3. (c)	4. (a)	5. (b)	6. (c)	7. (a)	8. (b)	9. (a)	10. (d)
11. (b)	12. (c)	13. (a)							

Level-2

1. (a)	2. (a)	3. (c)	4. (a)	5. (b)	6. (c)	7. (c)	8. (b)	9. (b)	10. (b)
11. (b)	12. (a)	13. (a)	14. (b)	15. (a)	16. (d)	17. (a)	18. (c)	19. (a)	20. (b)
21. (c)	22. (a)	23. (a)	24. (c)	25. (d)	26. (a)	27. (a)	28. (c)	29. (b)	30. (a)
31. (a)	32. (b)	33. (a)	34. (a)	35. (b)	36. (c)	37. (a)	38. (c)	39. (b)	40. (b)
41. (b)	42. (a)	43. (a)	44. (a)	45. (c)	46. (a)	47. (a)	48. (b)	49. (c)	50. (c)
51. (b)	52. (a)	53. (a)	54. (b)	55. (b)	56. (b)	57. (d)	58. (b)	59. (a)	60. (b)
61. (c)	62. (b)	63. (c)	64. (b)						

Solutions

Level-1

1. $$F = \frac{YA\,\Delta L}{L}$$

Work done $= \frac{1}{2} F\,\Delta L = \frac{1}{2}\frac{YA\,\Delta L^2}{L}$

$$= \frac{2 \times 10^{11} \times 10^{-6} \times 10^{-6}}{2 \times 1}$$

$= 0.1$ J

3. $$Y = \frac{FL}{A\,\Delta L}$$

or $\Delta L \propto \frac{1}{A}$

Again $m - Al\rho$ or $m \propto A$

$\therefore$ $\Delta l \propto \frac{1}{m}$

$\therefore$ $\frac{\Delta l_1}{\Delta l_2} = \frac{m_2}{m_1} = \frac{2}{3}$

13

Wave Motion and Waves on String

Syllabus: *Wave motion, speed of a wave, transverse wave, superposition of waves, progressive and standing waves, vibration of string.*

Review of Concepts

1. Wave : It is a process by which transfer of energy and momentum take place from one portion of medium to another portion of medium.

(a) If a wave reaches at a point, then the particle of that point starts to oscillate. The presence of a wave at a point is caused by disturbance at that point. The disturbance consists of momentum and energy.

(b) **Wave function :** Any function of space and time which obeys $\frac{\partial^2 y}{\partial x^2} = \frac{1}{c^2}\frac{\partial^2 y}{\partial t^2}$ represents a wave.

Mathematically, $y = f(x, t)$

Remember that wave function should be continuous, single valued, harmonic and finite.

2. Travelling or progressive wave : Any wave equation which is in the form of $y = f(\omega t \pm kx)$ represents a progressive wave.

(a) If the sign of t and x are opposite, wave is propagating along positive x-axis.

(b) If the sign of t and x are same, then wave is propagating in negative x-direction.

(c) Wave speed, $c = \frac{\omega}{k}$.

(d) If $\omega t - kx$ = phase = constant, then the shape of wave remains constant.

(e) Particle velocity, $v_{\text{particle}} = \frac{\partial y}{\partial t}$.

(f) Slope $= \frac{\partial y}{\partial x}$.

(g) For a wave, $v_{\text{particle}} = -$ C (Slope).

(h) For a given t, y-x graph gives the shape of pulse or string.

3. Plane harmonic progressive or travelling wave : For progressive wave, $y = f(\omega t \pm kx)$. If the function 'f' is sine or cosine function, then the wave is harmonic progressive wave.

(a) The equation of plane harmonic progressive wave moving along positive x-axis is

$$y = A \sin(\omega t - kx)$$

$$y = A \sin(\omega t - kx + \phi) \quad \text{(In general)}$$

(b) The equation of plane harmonic progressive wave moving along negative axis is

$$y = A \sin(\omega t + kx)$$

In general, $\quad y = A \sin(\omega t + kx + \phi)$

(c) **Different form of plane harmonic progressive wave :**

$$y = A \sin \omega\left(t - \frac{x}{c}\right) \qquad y = A \cos \omega\left(t - \frac{x}{c}\right)$$

$$y = A \sin(\omega t - kx), \qquad y = A \cos(\omega t - kx)$$

$$y = A \sin(\omega t + kx), \qquad y = A \cos(\omega t + kx)$$

$$y = A \sin 2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right) \qquad y = A \cos 2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right)$$

$$y = A \sin k(ct - x), \qquad y = A \cos k(ct - x)$$

$$y = A \sin k(ct + x), \qquad y = A \cos k(ct + x)$$

4. Speed of transverse wave :

$$c = \sqrt{\left(\frac{T}{\mu}\right)} = \sqrt{\left(\frac{T}{\rho A}\right)}$$

where, T = force of tension

μ = linear density = mass per unit length

ρ = volume density

5. Stationary or standing wave : The superposition of two identical waves travelling in opposite direction along the same line is known as stationary wave. If two waves

$$y_1 = a \sin(\omega t - kx) \quad \text{and} \quad y_2 = a \sin(\omega t + kx)$$

These two waves form stationary wave. Then

$$y = y_1 + y_2 = 2a \cos kx \sin \omega t$$

Some important points regarding standing or stationary waves :

(a) Every particle of the medium vibrates in SHM manner but amplitude depends on position, *i.e.*, $A = 2A \cos kx$.

(b) The point of medium with zero amplitude is a point of node and the point of medium with maximum amplitude (*i.e.*, $A_{\max} = 2a$) is a point of antinode.

(c) The particle of medium at node remains permanently at rest. Also nodes divide the medium into loops. All particles of a medium lying in a loop (node to node) vibrate in same phase having different amplitude.

(d) Total energy of a loop remains constant.

(e) At node displacement is zero but pressure is maximum.

(f) At antinode, displacement is maximum but pressure is minimum.

(g) The equation of stationary wave for a string fixed at one end is

$$y = 2a \sin kx \cos \omega t$$

(i) For a given time t, the y-x graph gives the shape of string.

(ii) The distance between two successive nodes or the distance between two successive antinodes is $\lambda/2$.

(iii) The distance between nearest node and antinode is $\lambda/4$.

(h) The equation of stationary wave on a string fixed at one end is

$$y = 2a \sin kx \cos \omega t$$

6. Mode of vibration of string fixed at both ends:

(a) The frequency of vibration is

$$f_n = \frac{n}{2l}\sqrt{\left(\frac{T}{\mu}\right)}$$

Ratio of harmonics produced $= 1 : 2 : 3$

where, l = length of string

T = tension in string

μ = linear mass density.

(b) If the strings vibrates in p loops, pth harmonic is produced then frequency of pth harmonic is $f_p = \frac{p}{2l}\sqrt{\left(\frac{T}{m}\right)}$

(c) **Characteristics of different harmonics and overtones:**

S. No.	Harmonic	Mode	Number of loops	Number of nodes	Number of antinodes	Frequency	Wavelength
1.	Ist	Fundamental	1	2	1	$n_1 = n$	$\frac{2l}{1}$
2.	IInd	Ist overtone	2	3	2	$n_2 = 2n$	$\frac{2l}{2}$
3.	IIIrd	IInd overtone	3	4	3	$n_3 = 3n$	$\frac{2l}{3}$
	⋮	⋮	⋮	⋮	⋮	⋮	⋮
4.	pth	$(p-1)$th overtone	p	$(p+1)$	p	$n_p = pn$	$\frac{2l}{p}$

Some important points about vibration of string:

(i) If string is in resonance with a source, then any one of its natural frequencies coincides with that of the source.

(ii) If a string is vibrating in nth mode of vibration, then

(a) number of harmonics $= n$.

(b) $f_n = nf$, where f is frequency of first or fundamental mode of vibration.

(c) the number of loops $= n$.

(d) the number of antinodes $= n$.

(e) the number of nodes $= n + 1$.

(f) the number of overtones $= n - 1$.

But at $n = 1$, overtones is fundamental.

(iii) If the vibration takes place in a composite string formed by joining two strings of different lengths, cross-section and densities but having same tension throughout the string, then the common frequency of vibration is

$$f_0 = n_1 f_1 = n_2 f_2$$

Here, f_1 = fundamental frequency for first string

f_2 = fundamental frequency for second string

(iv) The meaning of interval is the ratio of two frequencies.

(v) The meaning of octave is 2, *e.g.*, if f_2 is nth octave higher than f_1, then

$$f_2 = 2^n f_1$$

7. The average power transmitted by wave is $\overline{P} = \frac{1}{2}\mu A^2 \omega^2 c$.

8. The intensity of wave is

$$I = \frac{1}{2}\rho\omega^2 A^2 c$$

9. The amplitude of reflected wave is $\left(\frac{c_2 - c_1}{c_1 + c_2}\right) A_i$ and the amplitude of transmitted wave is

$$A_t = A_i\left(\frac{2c_2}{c_1 + c_2}\right)$$

Here, A_i = amplitude of incident wave in first medium

c_1 = speed of wave in first medium

c_2 = speed of wave in second medium

10. Melde's law : $p\sqrt{T}$ = constant

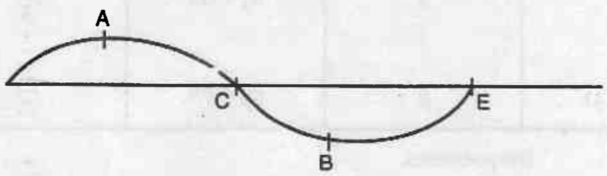
Objective Questions

Level-1

1. A transverse wave consists of :
   (a) only crest
   (b) only trough
   (c) both crest and trough
   (d) rarefactions and compressions

2. The speed of wave of time period T and propagation constant k is :
   (a) $\frac{2\pi}{Tk}$
   (b) $\frac{Tk}{2\pi}$
   (c) $\frac{1}{Tk}$
   (d) $\frac{T}{k}$

3. The equation of a travelling wave is $y = 60 \cos(1800t - 6x)$ where y is in microns, t in seconds and x in metres. The ratio of maximum particle velocity to velocity of wave propagation is :
(a) 3.6×10^{-11} (b) 3.6×10^{-6}
(c) 3.6×10^{-4} (d) 3.6
4. The phase difference between the prongs of a tuning fork is :
(a) π (b) 3π
(c) 2π (d) none of these
5. If $x_1 = a \sin\left(\omega t + \frac{\pi}{6}\right)$ and $x_2 = a \cos \omega t$, the phase difference between waves is :
(a) $\frac{\pi}{3}$ (b) $\frac{\pi}{6}$
(c) $\frac{\pi}{2}$ (d) π
6. Figure shows the shape of string, which pairs of points are in opposite phase ?



(a) A and B (b) B and C
(c) C and E (d) none of these
7. The phase change between incident and reflected sound wave from a fixed wall is :
(a) 0 (b) π
(c) 3π (d) $\frac{\pi}{2}$
8. Which of following represents the equation of standing wave ?
(a) $a \cos \omega t \sin kx$ (b) $a \cos kx \cos \omega t$
(c) $a \sin kx \sin \omega t$ (d) all of these
9. For the standing wave $y = 2 \sin \frac{\pi x}{15} \cos 96 \pi t$, where x and y are in cm and t is in second, the amplitude at node is :
(a) zero (b) 2 cm
(c) 4 cm (d) none of these
10. In previous problem, the minimum distance between node and antinode is :
(a) 15 cm (b) 30 cm
(c) 7.5 cm (d) none of these
11. In the case of standing wave, constructive interference is formed at :
(a) node
(b) antinode
(c) either node or antinode
(d) none of the above
12. A string of length 2 m fixed between two supports vibrates in two loops. The distance between node and antinode is :
(a) 50 cm (b) 10 cm
(c) 100 cm (d) 200 cm
13. Standing waves are produced in a 10 m long stretched string. If the string vibrates in 5 segments and the wave velocity is 20 ms^{-1} then the frequency is :
(a) 2 Hz (b) 4 Hz
(c) 5 Hz (d) 10 Hz
14. A note has a frequency 200 Hz. The frequency of a note 3 octaves higher than it is :
(a) 200 Hz (b) 600 Hz
(c) 1600 Hz (d) 1200 Hz
15. A pulse or a wave train trands along a stretched string and reaches the fixed end of the string. It will be reflected back with :
(a) the same phase as the incident pulse but with velocity reversed
(b) a phase change of 180° with no reversal of velocity
(c) the same phase as the incident pulse with no reversal of velocity
(d) a phase change of 180° with velocity reversed.
16. The number of waves each of wavelength 10 cm produced in string of 100 cm length, is :
(a) 1 (b) 10
(c) 20 (d) 30
17. The example of forced vibration is :
(a) resonance (b) beats
(c) interference (d) diffraction
18. Coherent sources are characterized by the same :
(a) phase and phase velocity
(b) wavelength, amplitude and phase velocity
(c) wavelength, amplitude and frequency
(d) wavelength and phase

Level-2

1. Which of the following cannot represent a travelling wave ?
(a) $y = a \cos(\omega t + kx)$ (b) $y = a \cos(ax + bt)$
(c) $y = A \sin(x - vt)$ (d) $y = f(x^2 - vt^2)$
2. A wave pulse in the shape of $y = f(x)$ at $t = 0$ is moving along positive x-axis with a constant speed c. The equation of wave is :
(a) $y = f(x + ct)$ (b) $y = f(x - ct)$
(c) $y = f(cx + t)$ (d) none of these
3. A wave pulse is propagating with speed c towards positive x-axis. The shape of pulse at $t = 0$, is $y = ae^{-x/b}$ where a and b are constant. The equation of wave is :

(a) $ae^{-\left(\frac{x-ct}{b}\right)}$ (b) $ae^{\frac{ct+x}{b}}$

(c) ae^{x-ct} (d) none of these

4. A wave propagates on a string in positive x-direction with a speed of 40 cm/s. The shape of string at $t = 2$ s is $y = 10\cos\frac{x}{5}$, where x and y are in centimetre. The wave equation is :

(a) $y = 10\cos\left(\frac{x}{5} - 8t\right)$ (b) $y = 10\sin\left(\frac{x}{5} - 8t\right)$

(c) $y = 10\cos\left(\frac{x}{5} - 8t + 16\right)$ (d) $y = 10\sin\left(\frac{x}{5} - 8t + 16\right)$

5. A travelling wave is propagating along negative x-axis through a stretched string. The displacement of a particle of the string at $x = 0$ is $y = a\cos\omega t$. The speed of wave is c. The wave equation is :

(a) $y = a\cos\omega t$ (b) $y = 2a\cos\omega t$

(c) $y = a\cos\omega\left(t - \frac{x}{c}\right)$ (d) $y = a\cos\left(\omega t + \frac{\omega x}{c}\right)$

6. The equation of a wave travelling on a stretched string along the x-axis is $y = ae^{-(bx+ct)}$. The direction of propagation of wave is :

(a) along negative y-axis (b) along positive y-axis

(c) along negative x-axis (d) along positive x-axis

7. In above problem, the maximum displacement of particle of string is :

(a) a (b) b

(c) c (d) c/b

8. In previous problem, the speed of wave is :

(a) c/b (b) b/c

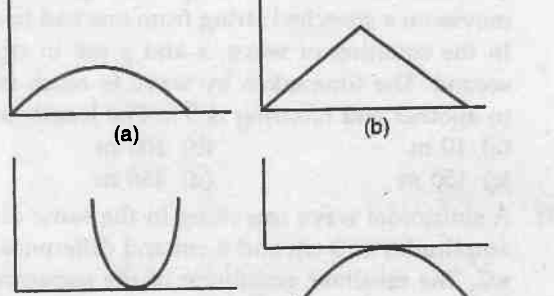
(c) a (d) c

9. The wave travels along a string whose equation is $y = \frac{p^3}{p^2 + (px - qt)^2}$, where $p = 2$ unit and $q = 0.5$ unit. The direction of propagation of wave is :

(a) along $+y$-axis (b) along $-x$-axis

(c) along $+x$-axis (d) none of these

10. If a travelling wave $y = a\sin(kx - \omega t)$ is moving along x-axis, which of the following represents the shape of pulse ?

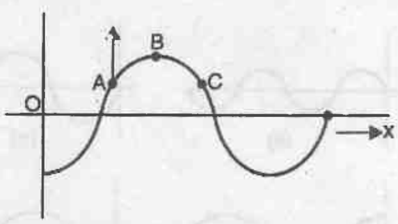


11. If wave $y = A\cos(\omega t + kx)$ is moving along x-axis, the shape of pulse at $t = 0$ and $t = 2$ s :

(a) are different (b) are same

(c) may not be same (d) none of these

12. At any instant a wave travelling along the string is shown in fig. Here, point 'A' is moving upward. Which of the following statements is true ?



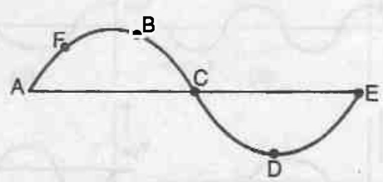
(a) The wave is travelling to the right

(b) The displacement amplitude of wave is equal to displacement of B at this instant

(c) At this instant 'C' also directed upward.

(d) None of these

13. In the given figure :



(a) the speeds of particles B and C are same

(b) the speeds of particles A, C and E are maximum

(c) the particle F moves upward

(d) all particles have same speed

14. If a wave propagates through a medium, then the velocity of particle of medium is given by :

(a) wave velocity $\times$ strain

(b) $\frac{\text{wave velocity}}{\text{strain}}$

(c) wave velocity

(d) $\frac{\text{angular frequency}}{\text{propagation constant}}$

15. In a wave motion $y = a\sin(kx - \omega t)$, y can represent :

(a) electric field

(b) magnetic field

(c) displacement, pressure

(d) all of the above

16. The equation of a wave travelling on a stretched string is :

$$y = 4\sin 2\pi\left(\frac{t}{0.02} - \frac{x}{100}\right)$$

Here x and y are in cm and t is in second. The speed of wave is :

(a) 50 m/s (b) 40 m/s

(c) 50 cm/s (d) 40 cm/s

17. In previous problem, the ratio of maximum particle velocity and wavelength is :

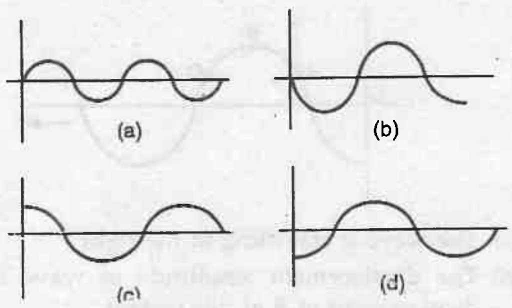
(a) π (b) 2π

(c) 3π (d) 4π

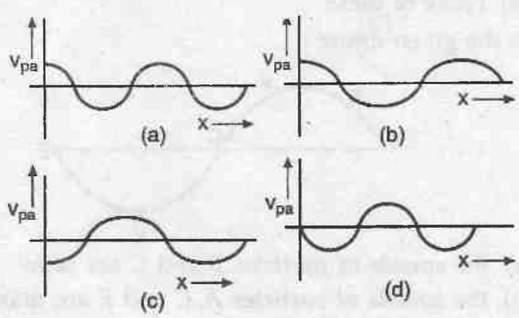
18. In previous problem, the relative deformation amplitude of medium is :

(a) 0.02π (b) 0.08π
(c) 0.06π (d) none of these

19. A plane wave $y = a \sin(\omega t - kx)$ propagates through a stretched string. The particle velocity versus x graph at $t = 0$ is :



20. In above problem relative deformation versus x graph is :



21. Along a stretched string equation of transverse wave is

$$y = 3 \sin\left[2\pi\left(\frac{x}{20} - \frac{t}{0.01}\right)\right]$$

where, x, y are in cm and t is in sec. The wave velocity is :

(a) 20 m/s (b) 30 m/s
(c) 15 m/s (d) 25 m/s

22. A transverse wave along a string is given by

$$y = 2 \sin\left(2\pi(3t - x) + \frac{\pi}{4}\right)$$

where, x and y are in cm and t in second. The acceleration of a particle located at $x = 4$ cm at $t = 1$ s is :

(a) $36\sqrt{2}\pi^2$ cm/s^2 (b) $36\pi^2$ cm/s^2
(c) $-36\sqrt{2}\pi^2$ cm/s^2 (d) $-36\pi^2$ cm/s^2

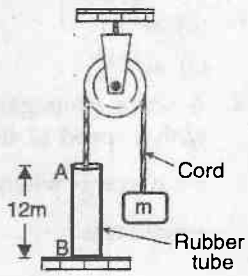
23. If $y = y_0 \sin 2\pi\left(ft - \frac{x}{\lambda}\right)$ is the equation of transverse wave, then for what value of 'λ' the maximum particle velocity is equal to four times the wave velocity ?

(a) $y_0\pi$ (b) $\frac{y_0\pi}{2}$
(c) $2y_0\pi$ (d) $1.5y_0\pi$

24. Along a stretched wire a transverse wave passes with speed 3000 m/s. If the tension in the wire increased four times, then the velocity of the wave is

(a) 1500 m/s (b) 3000 m/s
(c) 6000 m/s (d) 9000 m/s

25. A long rubber tube having mass 0.9 kg is fastened to a fixed support and the free end of the tube is attached to a cord which passes over a pulley and supports an object, with a mass of 5 kg as shown in fig. If the tube is struck by a transverse blow at one end, the time required for the pulse to reach the other end is :



(a) 5 s (b) 0.47 s
(c) 4.7 s (d) 3.2 s

26. For a wave

$$y = 0.0002 \sin\left[2\pi\left(110t - \frac{x}{3}\right) + \frac{\pi}{3}\right]$$

is travelling in a medium. The energy per unit volume being transfered by wave if density of medium is 1.5 kg/m^3, is :

(a) 14×10^{-4} J/m^3 (b) 143.2×10^{-4} J/m^3
(c) 14.3×10^{-4} J/m^3 (d) 1.43×10^{-4} J/m^3

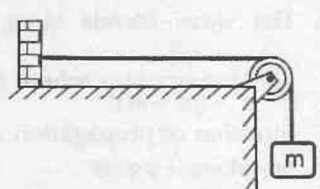
27. The time taken by a transverse wave to travel the full length of a uniform rope of mass 0.1 kg and length 2.45 m hanging from the ceiling, is :

(a) 1 s (b) 0.5 s
(c) 2 s (d) 1.5 s

28. The speed of the wave travelling on the uniform circular hoop of string, rotating clockwise in absence of gravity with tangential speed v_0, is :

(a) $v = v_0$ (b) $v = 2v_0$
(c) $v = \frac{v_0}{\sqrt{3}}$ (d) $v = \frac{v_0}{2}$

29. A transverse wave is passing through a light string shown in the figure. The equation of wave is $y = A \sin(\omega t - kx)$. The area of cross-section of string is A and density is ρ. The hanging mass is :



(a) $A\omega$ (b) $\frac{\omega}{kg}$
(c) $\frac{\rho A \omega^2}{k^2 g}$ (d) none of these

30. A transverse wave of equation $y = 2 \sin(0.01x + 30t)$ moves on a stretched string from one end to another end. In the equation of wave, x and y are in cm and t is in second. The time taken by wave to reach from one end to another end of string is 5 s. The length of string is :

(a) 10 m (b) 100 m
(c) 150 m (d) 160 m

31. A sinusoidal wave travelling in the same direction have amplitudes of 3 cm and 4 cm and difference in phase by $\pi/2$. The resultant amplitude of the superimposed wave is :

(a) 7 cm (b) 5 cm
(c) 2 cm (d) 0.5 cm

32. Two simple harmonic motions are represented by the equations

$$y_1 = 10 \sin\left(3\pi t + \frac{\pi}{4}\right)$$

and $y_2 = 5\,(3 \sin 3\pi t + \sqrt{3} \cos 3\pi t)$

Their amplitudes are in the ratio of :

(a) $\sqrt{3}$ (b) $1/\sqrt{3}$

(c) 2 (d) 1/6

33. Predict for the wave $y = A \cos \frac{2\pi x}{\lambda} \sin\left(\frac{2\pi v t}{\lambda}\right)$:

(a) It is a porgressive wave

(b) It is a transverse progressive wave

(c) It is a longitudinal progressive wave

(d) It is a stationary wave

34. A string of length l is fixed at both ends and is vibrating in second harmonic. The amplitude at antinode is 2 mm. The amplitude of a particle at distance $l/8$ from the fixed end is :

(a) $5\sqrt{2}$ mm (b) $\frac{5}{\sqrt{2}}$ mm

(c) 5 mm (d) $\frac{10}{\sqrt{2}}$ mm

35. In above problem, the tension in string is T and the linear mass density of string is μ. The ratio of magnitude of maximum velocity of particle and the magnitude of maximum acceleration is :

(a) $\frac{1}{2\pi}\sqrt{\left(\frac{\mu l^2}{T}\right)}$ (b) $2\pi\sqrt{\left(\frac{\mu l^2}{T}\right)}$

(c) $\frac{1}{2\pi}\sqrt{\left(\frac{T}{\mu l^2}\right)}$ (d) $\frac{1}{4\pi}\sqrt{\left(\frac{\mu l^2}{T}\right)}$

36. In above problem, if at $t = 0$, $y = 2.5$ mm, the equation of standing wave is :

(a) $(2.5 \text{ mm}) \sin \frac{2\pi}{l} x \cos\left(2\pi\sqrt{\left(\frac{T}{\mu l^2}\right)}\right)$

(b) $(5 \text{ mm}) \sin \frac{\pi}{l} x \cos 2\pi t$

(c) $(5 \text{ mm}) \sin \frac{2\pi}{l} x \cos\left(2\pi\sqrt{\left(\frac{T}{\mu l^2}\right)}\right)t$

(d) $(5 \text{ mm}) \cos \frac{2\pi}{l} x \cos\left(2\pi\sqrt{\left(\frac{T}{\mu l^2}\right)}\right)t$

37. What is the resultant wave obtained for $\phi = \frac{\pi}{2}$ rad when two harmonic waves are

$$y_1(x, t) = 0.2 \sin (x - 3t)$$
$$y_2(x, t) = 0.2 \sin (x - 3t + \phi)\ ?$$

(a) $y = 0.28 \sin\left(x - 3t + \frac{\pi}{4}\right)$ (b) $y = 3 \sin (x - 3t)$

(c) $y = 0.28 \sin\left(x - 3t - \frac{\pi}{4}\right)$ (d) $y = 0.28 \sin\left(x + 3t - \frac{\pi}{4}\right)$

38. The equation of the standing wave in a string clamped at both ends, vibrating in its third harmonic is given by

$$y = 0.4 \sin (0.314x) \cos (600\pi t)$$

where x and y are in cm and t is in sec :

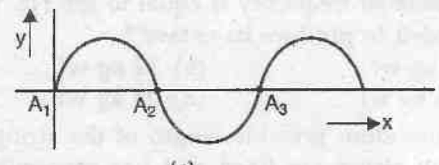
(a) The frequency of vibration is 300 Hz

(b) The length of the string is 30 cm

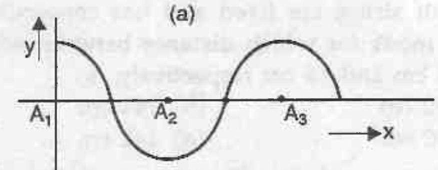
(c) The nodes are located at $x = 0$, 10 cm, 30 cm

(d) All of the above

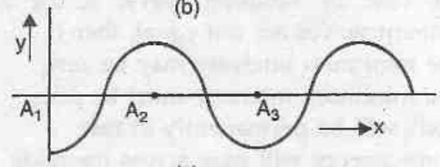
39. The equation of standing wave is $y = a \cos kx \sin \omega t$ which one of following graphs is for the wave at $t = \frac{T}{4}$?



(a)



(b)



(c)

(d) none of the above

40. If a string fixed at both ends vibrates in four loops, the wavelength is 10 cm. The length of string is :

(a) 5 cm (b) 15 cm

(c) 30 cm (d) none of these

41. In above problem, the distance of plucking point from the fixed end is :

(a) 5 cm (b) 10 cm

(c) 2.5 cm (d) 7.5 cm

42. A stretched wire carries a body of density $\sigma = 8000$ kg/m^3 at its end. The fundamental frequency of vibration of wire is 260 Hz. The body is dipped completely in a vessel of water. The new frequency of fundamental mode of vibrations is : (The density of water is $\rho = 1000$ kg/m^3)

(a) 262 Hz (b) 260 Hz

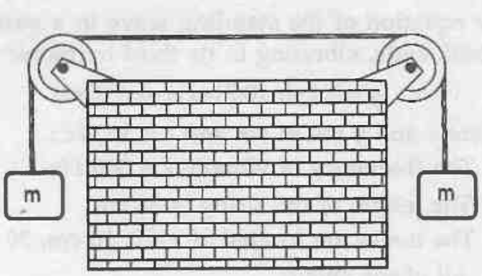
(c) 243.2 Hz (d) 255.5 Hz

43. An elastic string of length 2 m is fixed at its end. The string starts to vibrate in third overtone with a frequency 1200 Hz. The ratio of frequency of lower overtone and fundamental is :

(a) 1 (b) 2

(c) 3 (d) 4

44. In the given arrangement, if hanging mass will be changed by 4%, then percentage change in the wave speed in string will be :



(a) 2% (b) 8%
(c) 3% (d) 4%

45. If a string is stretched with a weight 4 kg then the fundamental frequency is equal to 256 Hz. What weight is needed to produce its octave?
(a) 4 kg wt (b) 12 kg wt
(c) 16 kg wt (d) 24 kg wt

46. The minimum possible length of the string when both ends of string are fixed and has consecutive standing wave mode for which distance between adjacent nodes are 18 cm and 16 cm respectively, is:
(a) 150 cm (b) 144 cm
(c) 140 cm (d) 142 cm

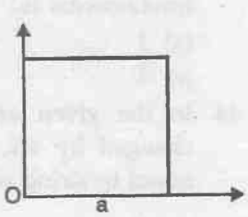
47. In the case of standing wave, if the amplitude of component waves are not equal, then:
(a) the minimum intensity may be zero
(b) the minimum intensity must be zero
(c) node will be permanently at rest
(d) some energy will pass across the node

48. The relation between frequency 'n' of the string, if $n_1, n_2, n_3, \ldots$ are the frequencies of segments of the stretched string, is:
(a) $n = n_1 + n_2 + n_3 + \ldots$ (b) $n = \sqrt{n_1 \times n_2 \times n_3 \times \ldots}$
(c) $\frac{1}{n} = \frac{1}{n_1} + \frac{1}{n_2} + \frac{1}{n_3} + \ldots$ (d) none of these

49. In a sonometer experiment the bridges are separated by a fixed distance. If 'T' is tension in slightly elastic wire, which emits a tone of frequency 'n', then frequency of the tone emitted by the wire when tension is increased to 4%, is:
(a) n
(b) $2n$
(c) slightly greater than n
(d) slightly less than $2n$

50. A sonometer wire 65 cm long, is in resonance with a tuning fork of frequency f. If the length of the sonometer wire is increased by 1 cm and it is vibrated with the same tuning fork, 8 beats are heard per second. The value of f is:
(a) 256 Hz (b) 512 Hz
(c) 260 Hz (d) 520 Hz

51. A rectangular membrance of length a and breadth b is fixed at $x = 0$ and $x = a$. If the surface of membrance is disturbed, the distance between two successive nodal lines in the condition of m mode of vibration, is:



(a) $\frac{a}{m}$ (b) $\frac{2a}{m}$
(c) $\frac{a}{2m}$ (d) $\frac{a}{3m}$

52. Find the radius vector defining the position of a point source of spherical waves if the source is situated on the straight line between the points with radius vectors $\vec{r}_1$ and $\vec{r}_2$ at which the intensities of waves are equal to a_1 and a_2. The medium is homogeneous and the damping of wave is negligible:
(a) $\frac{\vec{r}_1 + \vec{r}_2}{2}$ (b) $\frac{\vec{r}_2 - \vec{r}_1}{2}$
(c) $\frac{a_1\vec{r}_1 + a_2\vec{r}_2}{a_1 + a_2}$ (d) none of these

53. A wave of angular frequency ω propagates so that a certain phase of oscillation moves along x-axis, y-axis and z-axis with speeds c_1, c_2 and c_3 respectively. The propagation constant k is:
(a) $\frac{\omega}{\sqrt{c_1^2 + c_2^2 + c_3^2}}(\hat{i} + \hat{j} + \hat{k})$
(b) $\frac{\omega}{c_1}\hat{i} + \frac{\omega}{c_2}\hat{j} + \frac{\omega}{c_3}\hat{k}$
(c) $(\omega\hat{i} + \omega\hat{j} + \omega\hat{k})\frac{1}{c}$
(d) none of the above

54. Mark correct option/s:
(a) The phase of transmitted wave always remains unchanged
(b) The amplitude of transmitted wave does not depend upon the velocity of wave in media
(c) The amplitude of reflected wave and transmitted wave are same to each other for a given incident wave
(d) The amplitude of reflected wave is equal to the amplitude of incident wave

55. Wave of frequency 500 Hz has a phase velocity 360 m/s. The phase difference between two displacement at a certain point at time 10^{-3} s apart will be:
(a) π radian (b) $\frac{\pi}{2}$ radian
(c) $\frac{\pi}{4}$ radian (d) 2π radian

56. Equation of a plane wave is given by $4\sin\frac{\pi}{4}\left[2t + \frac{x}{8}\right]$. The phase difference at any given instant of two particles 16 cm apart is:
(a) 60° (b) 90°
(c) 30° (d) 120°

57. Two points lie on a ray are emerging from a source of simple harmonic wave having period 0.045. The wave speed is 300 m/s and points are at 10 m and 16 m from the source. They differ in phase by:
(a) π (b) $\pi/2$
(c) 0 or 2π (d) none of these

Answers

Level-1

1. (c)	2. (a)	3. (c)	4. (c)	5. (a)	6. (c)	7. (a)	8. (d)	9. (a)	10. (c)
11. (a)	12. (a)	13. (c)	14. (c)	15. (b)	16. (b)	17. (a)	18. (b)		

Level-2

1. (d)	2. (b)	3. (a)	4. (c)	5. (d)	6. (c)	7. (a)	8. (a)	9. (c)	10. (a)
11. (b)	12. (b)	13. (b)	14. (a)	15. (d)	16. (a)	17. (d)	18. (b)	19. (a)	20. (d)
21. (a)	22. (c)	23. (b)	24. (c)	25. (b)	26. (b)	27. (a)	28. (a)	29. (c)	30. (c)
31. (b)	32. (b)	33. (d)	34. (b)	35. (a)	36. (c)	37. (a)	38. (d)	39. (b)	40. (b)
41. (c)	42. (c)	43. (b)	44. (a)	45. (c)	46. (b)	47. (d)	48. (c)	49. (c)	50. (b)
51. (a)	52. (c)	53. (b)	54. (a)	55. (a)	56. (b)	57. (a)			

Solutions

Level-1

2. $$\omega = \frac{2\pi}{T}$$

and $$c = \frac{\omega}{k} = \frac{2\pi}{Tk}$$

3. $$\frac{(v_p)_{\max}}{c} = \frac{a\omega}{c} = ak \qquad \left(\because c = \frac{\omega}{k}\right)$$

$$= 60 \times 10^{-6} \times 6$$

$$= 3.6 \times 10^{-4}$$

5. $$x_1 = a \sin\left(\omega t + \frac{\pi}{6}\right)$$

and $$x_2 = a \sin\left(\omega t + \frac{\pi}{2}\right)$$

$$\therefore \quad \Delta\phi = \omega t + \frac{\pi}{2} - \left(\omega t + \frac{\pi}{6}\right)$$

$$= \frac{\pi}{2} - \frac{\pi}{6} = \frac{3\pi - \pi}{6}$$

$$= \frac{2\pi}{6} = \frac{\pi}{3}$$

10. The standard equation is $y = 2a \sin kx \cos \omega t$

$$\therefore \quad k = \frac{\pi}{15}$$

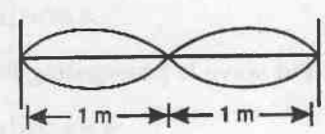
$$\therefore \quad \frac{2\pi}{\lambda} = \frac{\pi}{15}$$

$$\therefore \quad \lambda = 30 \text{ cm}$$

The distance between node and antinode is

$$\frac{\lambda}{4} = \frac{30}{4} = 7.5 \text{ cm}$$

12. $$\because \quad \frac{\lambda}{2} = 1$$



$$\therefore \quad \lambda = 2 \text{ metre}$$

$\therefore$ Distance between nearest node and antinode is

$$\frac{\lambda}{4} = \frac{2}{4} = \frac{1}{2} \text{ m} = 50 \text{ cm}$$

13. $$f = \frac{pc}{2l}$$

$$= 5 \times \frac{20}{2 \times 10}$$

$$= \frac{100}{20} = 5 \text{ Hz}$$

14. $$\frac{f_2}{f_1} = 2^n$$

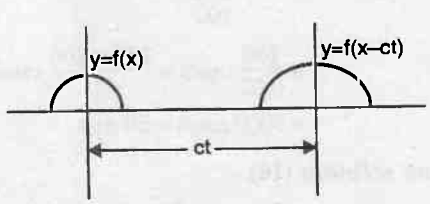
$$\therefore \quad f_2 = 2^3 f_1 = 8 \times 200$$

$$= 1600 \text{ Hz}$$

16. $$n = \frac{l}{\lambda} = \frac{100}{10} = 10$$

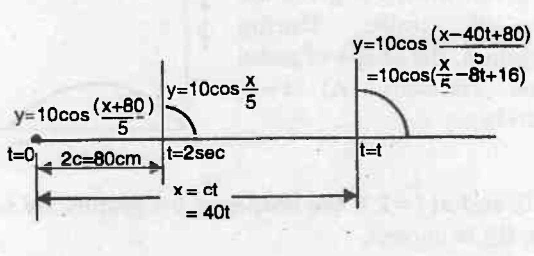
Level-2

2.



$$y = f(x - ct)$$

4.



14 Sound Wave

Syllabus: Longitudinal wave, vibration of air column, beats, resonance, Doppler's effect in sound.

Review of Concepts

1. Longitudinal wave : If a longitudinal wave is passing through a medium, the particles of medium oscillate about their mean position along the direction of propagation of wave. The propagation of transverse wave takes place in the form of crest and trough. But the propagation of longitudinal wave takes place in the form of rarefaction and compression.

Some important points regarding longitudinal wave :

(i) Mechanical transverse wave is not possible in gaseous and liquid medium. But longitudinal wave is possible in solid, liquid and gas.

(ii) In liquid and gas, sound is longitudinal wave. But in solid, sound wave may be transverse, may be longitudinal.

(iii) The velocity of longitudinal wave (sound) is $v = \sqrt{\left(\frac{E}{\rho}\right)}$.

Here, E = coefficient of elasticity

ρ = density of medium

2. Velocity of sound :

(a) Velocity of sound in a medium is given by $v = \sqrt{\left(\frac{E}{\rho}\right)}$, where E is the modulus of elasticity and ρ is the density of the medium.

(b) Velocity of sound is maximum in solids and minimum in gases since, solids are more elastic.

(c) In a solid, elasticity E is replaced by Young's modulus Y so that $v = \sqrt{\left(\frac{Y}{\rho}\right)}$

(d) In a fluid (liquid or gas) E is replaced by Bulk's modulus B so that $v = \sqrt{\left(\frac{B}{\rho}\right)}$.

(e) In a gas,

$$v = \sqrt{\left(\frac{\gamma RT}{M}\right)}$$

$$= \sqrt{\left(\frac{\gamma P}{\rho}\right)}$$

Here, $\gamma = \frac{C_p}{C_v}$ = adiabatic constant

P = normal pressure

ρ = density of gas

(f) **Newton's formula :** According to Newton, when sound propagates through air, temperature remains constant, *i.e.*, the process is isothermal. So,

$$B = E_\theta = P$$

$$\therefore \quad v_{air} = \sqrt{\left(\frac{P}{\rho}\right)}$$

At NTP for air,

$$P = 1.01 \times 10^5 \text{ N/m}^2 \text{ and } \rho = 1.3 \text{ kg/m}^3$$

So, $v_{air} = \sqrt{\left(\frac{1.01 \times 10^5}{1.3}\right)} = 279$ m/s

This value is very much less than the value obtained experimentally (= 332 m/s).

(g) **Laplace's correction :** The formula given by Newton is modified by Laplace assuming that propagation of sound in air is an adiabatic process, *i.e.*, $B = E_\phi = \gamma P$

So that $v = \sqrt{\left(\frac{\gamma P}{\rho}\right)}$

$$= \sqrt{1.41} \times 279 = 331.3 \text{ m/s}$$

Some important points regarding velocity of sound in air or gaseous medium:

(i) The speed of sound does not change due to variation of pressure.

(ii) $\frac{v_2}{v_1} = \sqrt{\left(\frac{T_2}{T_1}\right)}$

(iii) Due to change of temperature by 1°C, the speed of sound is changed by 0.01 m/s.

(iv) For small variation of temperature,

$$c_t = (c_0 + 0.61t) \text{ m/s}$$

where, c_0 = speed of sound at 0°C

c_t = speed of sound at t°C

(v) The speed of sound increases due to increase of humidity.

(vi) The velocity of sound in air is measured by resonance tube.

(vii) The velocity of sound in gases is measured by Quinke's tube.

(viii) Kundt's tube is useful to measure the speed of sound in solid and gases.

3. Displacement wave and pressure wave: If displacement wave equation is $y = A\sin(\omega t - kx)$, then the pressure wave is

$$P = P_0 \cos(\omega t - kx)$$

(a) Pressure amplitude is $P_0 = BAk$.

where, B = Bulk modulus of elasticity.

A = displacement amplitude

k = propagation constant or angular wave number

(b) The phase difference between pressure wave and displacement wave is $\pi/2$.

(c) Longitudinal wave may be considered either as displacement wave or pressure wave.

4. Energy of sound: The kinetic energy per unit volume of medium

$$= \frac{1}{2}\rho a^2\omega^2 \cos^2(\omega t - kx)$$

Here, ρ = density of medium

a = displacement amplitude

$\therefore$ Energy density = $(KE)_{max} = \frac{1}{2}\rho a^2\omega^2$

5. Power: It is defined as rate of transmission of energy.

$$\because \quad \bar{P} = \frac{1}{2}\rho c\,\omega^2 a^2 A$$

6. Intensity: $I = \frac{1}{2}\rho\omega^2 a^2 c = \frac{\bar{P}}{A} = \frac{P_0^2}{2\rho c}$

Here, P_0 = pressure amplitude.

(a) $I \propto a^2$

(b) $I \propto P_0^2$

(c) The intensity due to point source of power P is $I = \frac{P}{4\pi r^2}$

$$\therefore \quad I \propto \frac{1}{r^2}, \text{ for point source}$$

(d) The intensity due to straight line source is $I \propto \frac{1}{r}$.

(e) The intensity due to a source situated at infinity is constant at every point.

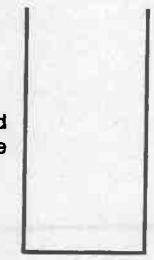
(f) Loudness = intensity level = $L = 10\log_{10}\left(\frac{I}{I_0}\right)$ decibel (dB).

Here, $I_0 = 10^{-12}\ \text{W/m}^2$

For zero level sound, $I = I_0$.

7. Organ pipe: It is a cylindrical tube of uniform cross-section.

(a) Closed end organ pipe: Its one of end is closed.



Closed end organ pipe

$$f = (2m-1)\frac{\lambda}{4} = (2m-1)\frac{v}{4l}$$

where, v = speed of wave

l = length of tube

$m = 1, 2, 3, \ldots$

= number of modes of vibration

$2m - 1$ = number of harmonics

Some important points regarding closed end organ pipe:

(i) The closed end is always a point of displacement node and pressure antinode.

(ii) Open end of the closed end organ pipe is always a point of displacement antinode and pressure node.

(iii) If end correction is taken into account, then the effected length of tube is

$$l = L + e$$

where, L = actual length of tube

$e = 0.3\,D$

(iv) The maximum possible wavelength is $4l$.

(v) The fundamental frequency is $f_1 = \frac{v}{4l}$.

(vi) Present harmonics: first, third, fifth and so on

Present overtones: fundamental, first, second and so on

(vii) The modes of vibration of closed end organ pipe are similar to the modes of vibration of rod fixed or clamped at one end.

(b) Open end organ pipe: Its both ends are open. The frequency of vibration is

$$f = \frac{mv}{2l}$$

where, $m = 1, 2, 3, \ldots$

v = speed of wave

l = length of tube

Open end organ pipe.

Some important points regarding open end organ pipe:

(i) All harmonics are present.

(ii) Open ends are points of displacement antinode and pressure node.

(iii) Possible harmonics: 1, 2, 3, 4, 5

Possible overtones: fundamental, 1, 2, 3, 4

(iv) The number of overtones is $n = m - 1$.

(v) The number of harmonics = m.

(vi) The maximum possible wavelength is $2l$.

(vii) Fundamental frequency $f_1 = \frac{v}{2l}$.

(viii) The modes of vibration of open end organ pipe are similar with the modes of vibration of rod clamped at the middle.

(ix) When a closed end organ pipe is converted into open end organ pipe, frequency becomes twice.

(x) When an open end organ pipe is submerged in water upto half of its length. It behaves as a closed end organ pipe. But frequency remains unchanged.

(xi) If end correction is taken into account, the effected length of the open end organ pipe is

$$l = L + 2e$$

where, $e = 0.3$ D (D is diameter of the pipe)

(xii) If the diameter of organ pipe decreases, frequency increases.

(xiii) The frequency of open end organ pipe does not change if the ratio of speed of sound in it to its length remains constant.

8. Resonating air column experiment :

(a) At first resonance,

$$L_1 + e = \frac{\lambda}{4}$$

At second resonance,

$$L_2 + e = \frac{3\lambda}{4}$$

So, $$L_2 - L_1 = \frac{3\lambda}{4} - \frac{\lambda}{4} = \frac{\lambda}{2}$$

or $$\lambda = 2\,(L_2 - L_1)$$

(b) End correction,

$$e = \frac{(L_2 - 3L_1)}{2}$$

9. Beats: The superposition of two waves of small difference in frequency in same direction is known as beats.

If $y_1 = a \sin \omega_1 t$ and $y_2 = a \sin \omega_2 t$

then $$y = 2a \cos \omega t \sin \omega_{av}\, t$$

Here, $$\omega = \frac{\omega_1 - \omega_2}{2} = 2\pi \frac{(f_1 - f_2)}{2}$$

and $$\omega_{av} = \frac{\omega_1 + \omega_2}{2} = 2\pi \left(\frac{f_1 + f_2}{2}\right)$$

Some important points regarding beats:

(i) The beats frequency = number of beats per second $= |f_1 - f_2|$.

(ii) In the case of beats, the intensity at a point varies periodically.

(iii) If beats frequency is fraction then round off is not allowed, *e.g.*, if beats frequency is 5.2 Hz, then in five second 26 beats (not 25) are heard.

(iv) Due to waxing or wanning to a tuning fork, frequency decreases.

(v) Due to filing a tuning fork, frequency increases.

10. Musical sound: A musical sound consists of a quick succession of regular and periodic rarefactions and compressions without any sudden change in its amplitude.

(a) A note is a musical sound consisting of two or more tones.

(b) A tone is a musical sound of a single frequency.

11. Doppler's effect of sound:

$$n' = \left(\frac{v - v_o}{v - v_s}\right) n$$

v = velocity of sound in medium.

v_o = velocity of observer in the medium

v_s = velocity of source in the medium

Here, n' = apparent frequency.

n = frequency of source

For solving the problem, source to observer direction is taken as positive.

(a) When source moves towards stationary observer

$$n' = \left(\frac{v}{v - v_s}\right) n$$

(b) When source moves away from observer

$$n' = \left(\frac{v}{v + v_s}\right) n$$

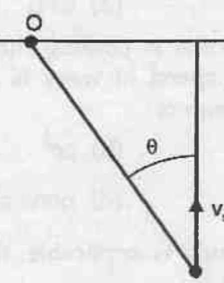
(c) When observer moves towards the stationary source

$$n' = \left(\frac{v + v_o}{v}\right) n$$

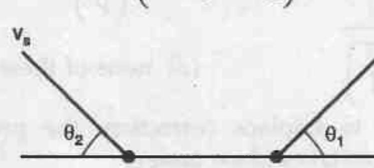
(d) When observer moves away from the stationary source

$$n' = \left(\frac{v - v_o}{v}\right) n$$

(e) Here, $$n' = \frac{v}{(v - v_s \cos \theta)}\, n$$

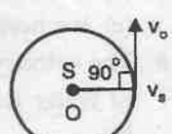


(f) Here, $$n' = \left(\frac{v - v_o \cos \theta_1}{v + v_s \cos \theta_2}\right) n$$

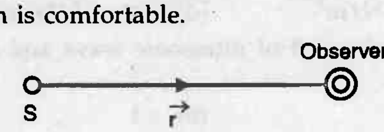


(g) When source is at centre and observer is moving on the circular path

$$n' = n$$



(h) For solving the problem, Doppler's effect in vector form is comfortable.



$$n' = \left(\frac{\vec{v} \cdot \hat{r} - \vec{v}_o \cdot \hat{r}}{\vec{v} \cdot \hat{r} - \vec{v}_s \cdot \hat{r}}\right)$$

$\vec{v}_o$ = velocity of observer

$\vec{v}_s$ = velocity of source

Here, $\hat{r}$ = unit vector along the line joining source and observer.

$\vec{v}$ = velocity of sound in the medium. Its direction is always taken from source to observer

n = actual frequency of source

n' = apparent frequency

Objective Questions

Level-1

1. Which of the following is the longitudinal wave ?
   (a) Sound waves (b) Waves on plucked string
   (c) Water waves (d) Light waves
2. Which of following can not travel through vacuum ?
   (a) Electromagnetic wave
   (b) Sound wave
   (c) Light wave
   (d) X-ray
3. A longitudinal wave consists of :
   (a) rarefactions and compressions
   (b) only compressions
   (c) only rarefactions
   (d) crest and trough
4. The velocity of sound is maximum in :
   (a) CO_2 (b) SO_2
   (c) NH_3 (d) CH_4
5. A longitudinal wave is passing through a medium of density ρ. If the speed of wave is c, bulk modulus of elasticity of medium is :
   (a) ρc (b) ρc^2
   (c) $\frac{1}{2}\rho c^2$ (d) none of these
6. If Newton's formula is applicable, then the formula for velocity of sound is :
   (a) $\sqrt{\left(\frac{P}{\rho}\right)}$ (b) $\sqrt{\left(\frac{\gamma P}{\rho}\right)}$
   (c) $\sqrt{\left(\frac{\gamma RT}{M}\right)}$ (d) none of these
7. According to Laplace correction, the propagation of sound in gas takes place under :
   (a) isothermal condition (b) isobaric condition
   (c) isochoric condition (d) adiabatic condition
8. The velocity of sound in water is 1400 m/s. The density of water is 1000 kg/m^3. The bulk modulus of elasticity is :
   (a) 5×10^{11} N/m^2 (b) 1.96×10^{9} N/m^2
   (c) 4×10^{9} N/m^2 (d) none of these
9. The ratio of speed of ultrasonic wave and sound wave is :
   (a) $= 1$ (b) > 1
   (c) < 1 (d) > 1
10. The sound of lightning flash is heard 3 second after the flash is seen. The distance of the lightning is 1020 metre. The speed of sound is :
    (a) 1400 m/s (b) 332 m/s
    (c) 340 m/s (d) none of these
11. The speed of sound in air is 340 m/s, while in water is 1445 m/s. If the wavelength of sound in water is 8.5 cm, the wavelength of sound in air is :
    (a) 2 cm (b) 4.5 cm (c) 5.5 cm (d) 8.5 cm
12. At which temperature, velocity of sound at 27°C doubles ?
    (a) 54°C (b) 327°C
    (c) 927°C (d) −123°C
13. Calculate the speed of sound in oxygen at 0°C and 1 atm. (Bulk modulus of elasticity of O_2 is 1.41×10^5 Pa and density is 1.43 kg/m^3) :
    (a) 300 m/s (b) 340 m/s
    (c) 314 m/s (d) none of these
14. Consider the following statements :
    Assertion (A) : Due to variation of pressure, speed of sound does not change.
    Reason (R) : The variation of pressure is proportional to variation of density.
    (a) Both A and R are correct and R is the correct explanation of A
    (b) R is the wrong explanation of A
    (c) Both A and R are wrong
    (d) A is wrong but R is correct
15. An astronaut can not hear his companion's sound at the surface of moon because :
    (a) produced frequencies are above the audio frequency
    (b) sound wave does not propagate through vacuum
    (c) temperature is too low during night and high during day
    (d) none of the above
16. The speed of sound in air is 333 m/s. The fundamental frequency of the open pipe is 333 Hz. The second overtone of the open organ pipe can be produced with a pipe of length :
    (a) 0.5 m (b) 1 m (c) 1.5 m (d) 2 m
17. Velocity of sound waves in air is 330 m/s. For a particular sound in air, a path difference of 40 cm is equivalent to a phase difference of 1.6 π. The frequency of this wave is :
    (a) 165 Hz (b) 150 Hz
    (c) 660 Hz (d) 330 Hz

18. Which one is not produced by sound waves in air ?
(a) Polarisation (b) Diffraction
(c) Refraction (d) Reflection

19. If $y_1 = a \sin \omega t$ and $y_2 = a \cos \omega t$
the resultant amplitude due to superposition of both equations is :
(a) $\sqrt{2}\, a$ (b) a
(c) $2a$ (d) none of these

20. The ratio of amplitudes at distances r and $3r$ from a point source is :
(a) 3 : 1 (b) 3 : 2
(c) 1 : 3 (d) 2 : 3

21. The intensity for loudness 20 dB is :
(a) 10 watt/m^2 (b) 10^{-10} watt/m^2
(c) 10^{10} watt/m^2 (d) none of these

22. If two sources of loudness 20 dB is combined, the resultant loudness is :
(a) 23 dB (b) 30 dB
(c) 40 dB (d) 10 dB

23. If intensity of sound wave is increased nine times, then by what factor the pressure amplitude of the wave is increased ?
(a) 3 (b) 6
(c) 9 (d) $\sqrt{3}$

24. If the temperature increases, then what happens to the frequency of the sound produced by the organ pipe ?
(a) Increases (b) Decreases
(c) Remains unchanged (d) None of these

25. An open organ pipe has fundamental frequency of 300 Hz. The length of pipe is :
(speed of sound = 330 m/s)
(a) 10 cm (b) 20 cm
(c) 55 cm (d) none of these

26. In the open organ pipe, the fundamental frequency is 30 Hz. If the organ pipe is closed, then the fundamental frequency will be :
(a) 10 Hz (b) 20 Hz
(c) 30 Hz (d) 15 Hz

27. Two open organ pipes of length 50 cm and 50.5 cm produce 0.3 beats/sec then the velocity of sound is :
(a) 300 m/s (b) 30 m/s
(c) 303 m/s (d) none of these

28. The air column in a pipe which is closed at one end will be in resonance with a vibrating tuning fork at a frequency 260 Hz, if the length of the air column is :
(a) 31.73 cm (b) 62.5 cm
(c) 35.75 cm (d) 12.5 cm

29. In closed end organ pipe, the frequency of first harmonic is 300 Hz. The frequency of third overtone is :
(a) 900 Hz (b) 2100 Hz
(c) 1500 Hz (d) none of these

30. The air column in a closed end organ pipe is vibrating in second overtone. The frequency of vibration is 440 Hz. The speed of sound in air is 330 m/s. The length of air column is :
(a) $\frac{15}{16}$ m (b) $\frac{16}{15}$ m
(c) $\frac{3}{4}$ m (d) none of these

31. The musical interval between two tones of frequency 400 Hz and 200 Hz is :
(a) 2 (b) 200
(c) 1 (d) none of these

32. A cylindrical resonance tube, open at both ends, has a fundamental frequency, F in air. If half of the length is dipped vertically in water, the fundamental frequency of the air column will be :
(a) $\frac{F}{2}$ (b) F
(c) $\frac{3F}{2}$ (d) $2F$

33. The walls of the hall built for music concerts should :
(a) amplify sound (b) transit sound
(c) reflect sound (d) absorb sound

34. When a tuning fork vibrates, the waves produced in the stem are :
(a) longitudinal (b) transverse
(c) both (a) and (b) (d) none of these

35. Tuning forks A and B produce two beats in the time interval of 0.4 second. The beats frequency is :
(a) 5 Hz (b) 8 Hz
(c) 10 Hz (d) 6 Hz

36. A tuning fork of frequency 100 Hz when sounded together with another tuning fork of unknown frequency produces 2 beats per second. On loading the tuning fork whose frequency is not known and sounded together with a tuning fork of frequency 100 Hz produces one beat, then the frequency of the other tuning fork is :
(a) 102 (b) 98
(c) 99 (d) 101

37. A tuning fork and sonometer wire were sounded together and produce 4 beats per second. When the length of sonometer wire is 95 cm or 100 cm, the frequency of the tuning fork is :
(a) 156 Hz (b) 152 Hz
(c) 148 Hz (d) 160 Hz

38. Two tuning forks A and B vibrating simultaneously produce 5 beats. Frequency of B is 512. It is seen that if one arm of A is filed, then the number of beats increases. Frequency of A will be :
(a) 502 (b) 507 (c) 517 (d) 522

39. A tuning fork of frequency 480 Hz, produces 10 beats per second when sounded with a vibrating sonometer string. What must have been the frequency of the string if a slight increase in tension produces fewer beats per second than before ?
(a) 460 Hz (b) 470 Hz
(c) 480 Hz (d) 490 Hz

40. An unknown frequency x produces 8 beats per second with a frequency of 250 Hz and 12 beats with 270 Hz source then x is :
(a) 258 Hz (b) 242 Hz
(c) 262 Hz (d) 282 Hz

41. Two tuning forks have frequencies 450 Hz and 454 Hz respectively. On sounding these forks together, the time interval between successive maximum intensities will be :
(a) $\frac{1}{4}$ sec (b) $\frac{1}{2}$ sec
(c) 1 sec (d) 2 sec

42. A source of sound is travelling with a velocity 40 km/hour towards stationary observer and emits sound of frequency 2000 Hz. If velocity of sound is 1220 km/hour, then what is the apparent frequency heard by the observer ?
(a) 2210 Hz (b) 1920 Hz
(c) 2068 Hz (d) 2086 Hz

43. A source of sound is travelling towards a stationary observer. The frequency of sound is n_0. The frequency heard by observer is $\frac{5n_0}{4}$. The ratio of speed of sound and the speed of source is :
(a) 1 : 5 (b) 1 : 4
(c) 1 : 3 (d) 1 : 2

44. A source of frequency 150 Hz is moving in the direction of a person with a velocity of 110 m/s. The frequency heard by the person will be (speed of sound in medium = 330 m/s)
(a) 225 Hz (b) 200 Hz
(c) 15 Hz (d) 100 Hz

45. A whistle sends out 256 waves in a second. If the whistle approaches the observer with velocity $\frac{1}{3}$ of the velocity of sound in air, the number of waves per second will be received by the observer, is :
(a) 384 (b) 192
(c) 300 (d) 200

46. A source of sound of frequency 450 cycles/s is moving towards a stationary observer with speed 34 m/s. If the speed of sound is 340 m/s, then the apparent frequency will be :
(a) 410 cycle/s (b) 500 cycle/s
(c) 550 cycle/s (d) 450 cycle/s

47. An observer is watching two vehicles moving with same velocity 4 m/s. The former is approaching towards the observer while the later receding. If the frequency of the siren of the vehicle is 240 Hz and velocity of sound in air is 320 m/s, then the beats produced is :
(a) 6 (b) 3
(c) zero (d) 12

48. An object producing a pitch of 1200 Hz is moving with a velocity of 40 m/s towards a stationary person. The velocity of sound is 350 m/s. The frequency of sound heard by stationary person is :
(a) 700 Hz (b) 1400 Hz
(c) 1050 Hz (d) 1250 Hz

49. Two passenger trains moving with a speed of 108 km/hour cross each other. One of them blows a whistle whose frequency is 750 Hz. If speed of sound is 300 m/s, then passengers sitting in the other train, after trains cross each other, will hear sound whose frequency will be :
(a) 900 Hz (b) 625 Hz
(c) 750 Hz (d) 800 Hz

50. A source of sound emitting a note of frequency 200 Hz moves towards an observer with a velocity v equal to the velocity of sound. If the observer also moves away from the source with the same velocity v, the apparent frequency heard by the observer is :
(a) 50 Hz (b) 100 Hz
(c) 150 Hz (d) 200 Hz

51. A source of sound is travelling towards a stationary observer. The frequency of sound heard by the observer is of the three times of the original frequency. The velocity of sound is v m/s. The speed of source will be :
(a) $\frac{2}{3}v$ (b) v
(c) $\frac{3}{2}v$ (d) $3v$

52. Suppose that the speed of sound in air at a given temperature is 400 m/s. An engine blows a whistle at 1200 Hz frequency. It is approaching an observer at the speed of 100 m/s. The apparent frequency as heard by the observer will be :
(a) 600 Hz (b) 1200 Hz
(c) 1500 Hz (d) 1600 Hz

53. A star radiates radiation of wavelength λ and it is receding from the earth with a speed v_0. The speed of light is c_0. The shift in spectral line is :
(a) $-\lambda\frac{v_0}{c_0}$ (b) $-\lambda\frac{v_0^2}{c_0^2}$
(c) $\frac{v_0^2}{c}\lambda$ (d) none of these

54. The frequency of a radar is 780 MHz. The frequency of the reflected wave from aeroplane is increased by 2.6 kHz. The velocity of the aeroplane is :
(a) 2 km/s
(b) 1 km/s
(c) 0.5 km/s
(d) 0.25 m/s

Level-2

1. Mark correct option(s):
(a) In gas sound wave is always longitudinal wave
(b) In liquid, sound wave is always transverse wave
(c) In solid, sound waves may be transverse wave motion
(d) In solid, sound waves may be longitudinal wave motion

2. A Physicist points out that glass is rarer than water:
(a) This statement is correct in the case of sound
(b) This statement is always wrong
(c) This statement is correct in the case of light
(d) This statement is always correct

3. When height increases, velocity of sound decreases:
(a) this is due to decrease of pressure
(b) this is due to decrease in temperature
(c) this is due to both decrease in temperature and pressure
(d) statement is wrong

4. The velocity of sound is not affected by change in:
(a) temperature (b) medium
(c) pressure (d) wavelength

5. A 40 cm long brass rod is dropped, one end first on to a hard floor but it is caught before it topples over. With an oscilloscope it is determined that the impact produces a 3 kHz tone. What is the speed of sound in brass?
(a) 1200 m/s (b) 2400 m/s
(c) 3600 m/s (d) 3000 m/s

6. If copper has modulus of rigidity 4×10^{10} N/m^2 and Bulk modulus 1.2×10^{11} N/m^2 and density 9 g/cm^3, then the velocity of longitudinal wave, when set-up in solid copper, is:
(a) 4389 m/s (b) 5000 m/s
(c) 4000 m/s (d) 4300 m/s

7. A piezo electric quartz plate of Young's modulus of elasticity 8×10^{10} N/m^2 and density 2.65×10^3 kg/m^3 is vibrating in resonant condition. The fundamental frequency of vibrating is 550 kHz. What is thickness of the plate?
(a) 0.05 cm (b) 0.5 cm
(c) 1.25 cm (d) 0.55 cm

8. The value of adiabatic constant γ for oxygen and nitrogen is same. The speed of sound in oxygen is 470 m/s at STP. The speed of sound in nitrogen at STP is:
(a) 340 m/s (b) 580 m/s
(c) 502 m/s (d) none of these

9. The speed of sound in air at 27°C is 340 m/s in rainy season, it is found that sound travels 660 m in two second in a given season.
Assume that no variation takes place in density of air due to variation of season. The season on the basis of temperature is:
(a) winter
(b) summer
(c) may be summer or winter
(d) all of the above

10. At STP, the speed of sound in hydrogen is 1324 m/s then the speed of sound in air is:
(a) 331 m/s (b) 220 m/s
(c) 340 m/s (d) 230 m/s

11. If the speed of sound is changed by 1 per cent, how much must the temperature of air near 0°C be changed?
(a) 5°C (b) 6°C
(c) 5.5°C (d) 6.5°C

12. If the speed of sound wave in a stretched string is v and Hooke's law is obeyed, then the extenion in string is x. The extension in the string if the speed of sound wave will become $1.22v$, is:
(a) $1.5x$ (b) $1x$
(c) $0.5x$ (d) $2x$

13. A boy watches a jet plane flying from north to south. When the jet is just seen above his head, the sound of jet appears to reach him making some angle with horizontal from north. If the velocity of sound is v, and velocity of jet is $v/2$, then the angle is:
(a) 60° (b) 30°
(c) 45° (d) 15°

14. If a stone is dropped into a lake from a tower, the sound of splash is heard by a man after 11.5 s, then what is the height of tower?
(a) 1000 m (b) 100 m
(c) 500 m (d) 150 m

15. A light pointer fixed to one prong of a tuning fork touches a vertical plate. The fork is set vibrating at a frequency of 56 Hz and allowed to free fall. How many complete oscillations are counted when plate falls at 10 cm?
(a) 10 (b) 9
(c) 8 (d) 7

16. The equation of a sound wave in air is
$$P = 0.01 \cos (1000t - 3x)$$
where P, x and t are in SI. The bulk modulus of elasticity is 1.4×10^5 N/m^2. The displacement amplitude is:
(a) 0.24 m (b) 0.24×10^{-7} m
(c) 8×10^{-7} m (d) 10 m

17. A sound wave of pressure amplitude 14 pascal propagates through the air medium. The normal pressure of air is 1.0×10^5 N/m^2. The difference between maximum and minimum pressure in the medium is:
(a) 5×10^5 N/m^2 (b) 10×10^5 N/m^2
(c) 10 N/m^2 (d) none of these

18. Choose the correct statement with respect to the plane harmonic sound wave:
(a) The excess pressure (P) is ahead of displacement in phase by $\frac{\pi}{2}$

(b) The excess pressure (P) is lagging behind displacement in phase by $\pi/2$
(c) The excess pressure and displacement are in the phase
(d) The excess pressure and displacement are out of the phase

19. A sound wave has a frequency of 100 Hz and pressure amplitude of 10 Pa, then the displacement amplitude is : (Given speed of sound in air = 340 m/s and density of air = 1.29 kg/m^3)
(a) 3.63×10^{-5} m (b) 3×10^{-5} m
(c) 4.2×10^{-5} m (d) 6.4×10^{-5} m

20. The equation of a transverse wave is
$$z = a \sin\left\{\omega t - \frac{k}{2}(x+y)\right\}$$
The equation of wavefront is :
(a) x = constant (b) y = constant
(c) $x + y$ = constant (d) $y - x$ = constant

21. In above problem, the direction of propagation of wave with the x-axis is :
(a) 135° (b) 45°
(c) 90° (d) none of these

22. The displacement wave is given by $y = A\sin(\omega t - kx)$. The wave is reflected by rigid surface situated at $x = 0$. The intensity of reflected wave is 0.16 times that of the incident wave. The corresponding equation of reflected wave is :
(a) $y = -0.4A\cos(\omega x - kx)$
(b) $y = -0.4A\sin(\omega t + kx)$
(c) $y = 0.4A\sin(\omega t + kx)$
(d) none of the above

23. When a wave is propagated from rarer medium to denser medium, which of the following will remain unchanged ?
(a) Wave speed (b) Propagation constant
(c) Frequency (d) None of the above

24. In passing through a boundary, refraction will not take place, if
(a) the index of refraction of the two media are same
(b) the boundary is not visible
(c) angle of incidence is lesser than angle of refraction but greater than $\sin^{-1}\dfrac{\mu_R}{\mu_D}$
(d) all the above

25. Lissajous figure obtained by combining
$$x = a\sin\omega t$$
and $$y = a\sin\left(\omega t + \frac{\pi}{4}\right),$$ will be :
(a) an ellipse (b) a straight line
(c) a circle (d) a parabola

26. According to classical electromagnetic theory, an accelerated electron radiates energy at the rate $\dfrac{ke^2a^2}{c^3}$.

where $k = 6 \times 10^9$ Nm^2/C^2, a = instantaneous acceleration, c = speed of light
If an electron is oscillating along a straight line with frequency f_0 and amplitude A, how much energy would it radiate away during one cycle ? Assume that the motion is described adequately by $x = A\sin 2\pi f_0 t$ during any one cycle :
(a) $\dfrac{A^2ke^2}{c^3}$ (b) $8\pi^4 f_0^{\,3}\dfrac{A^2ke^2}{c^3}$
(c) $\dfrac{f_0^{\,2}A^2ke^2}{c^3}$ (d) $\dfrac{A^2e^2}{c^3}$

27. A small speaker has a capacity of power 3 watt. A microphone is placed at distance 2 m from the speaker. The displacement amplitude of particles of air near the microphone if the frequency of sound emitted by speaker is 1.0 kHz, is : (Density of air = 1.2 kg/m^3 and speed of sound in air = 330 m/s)
(a) 2.76×10^{-4} cm (b) 4×10^{-4} cm
(c) 10×10^{-4} cm (d) 3.8×10^{-3} cm

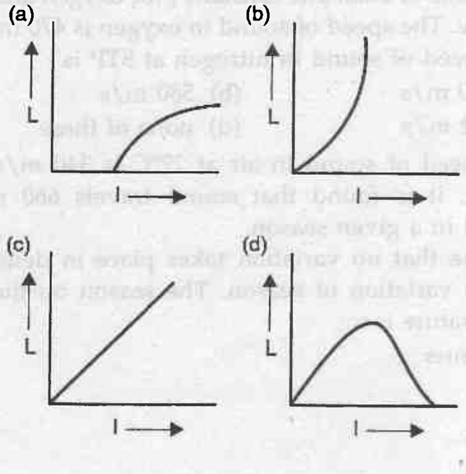
28. From a height of 2 m, a drop of water of radius 2×10^{-3} m fall and produces a sound. The sound produced can be heard upto a distance of 20 metre. If the gravitational energy is converted into sound energy in 0.5 s, then the intensity at a distance of 20 m is :
(a) 2×10^{-7} W/m^2 (b) 2.6×10^{-6} W/m^2
(c) 2.6×10^{-7} W/m^2 (d) 3×10^{-7} W/m^2

29. The difference of sound level between two points is 30 decibel. The ratio of pressure amplitude between points is :
(a) 10 (b) 20
(c) 30 (d) 32

30. If the sound emitted by a point source reaches a particular position with an intensity I, then the change in intensity level at that position if N such sources are placed together, is :
(a) $\log N$ (b) $2\log N$
(c) $10\log N$ (d) $12\log N$

31. For audible sound, the time interval between two words should be :
(a) 0.1 s (b) 0.2 s
(c) 0.4 s (d) none of these

32. Which of the following represents loudness versus intensity of sound graph ?



33. Beats are the result of :
(a) diffraction
(b) destructive interference
(c) constructive and destructive interference
(d) superposition of two waves of nearly equal frequencies

34. Mark correct option or options :
(a) Any function $y(x,t) = f(\omega t + kx)$ represents a progressive wave
(b) The stationary wave on a string under tension fixed at end does not have well defined nodes
(c) The phenomenon of beats is not observed in the case of visible light waves
(d) All of the above

35. Beat phenomenon is physically meaningful only, if :
(a) $|\omega_1 - \omega_2| >> |\omega_1 + \omega_2|$
(b) $|\omega_1 - \omega_2| << |\omega_1 + \omega_2|$
(c) $\frac{\omega_1}{\omega_2} < 17$
(d) $|\omega_1 + \omega_2| >> \frac{\omega_1}{\omega_2}$

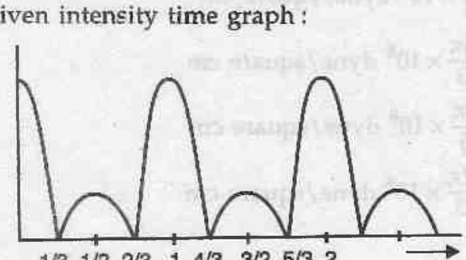
36. A tuning fork A of frequency 512 Hz produces 4 beats per second when sounded with a tuning fork B. Due to filing of the prongs of the tuning fork B, the number of the beats per second becomes 6. The actual frequency of B is :
(a) 516 Hz (b) 508 Hz
(c) 512 Hz (d) none of these

37. A tuning fork A of frequency 260 c/s produces 4 beats per second with tuning fork B. When the tuning fork A is loaded with wax, then the number of beats produced per second becomes 3. Then what is the frequency of tuning fork B?
(a) 264 (b) 263
(c) 256 (d) 260

38. If beat frequency is 3.2 Hz, then :
(a) in 5[th] second, only four beats will be heard
(b) in 3[rd] second, only three beats will be heard
(c) in first second only three beats will be heard
(d) all the above

39. When temperature of air is 20°C, a tuning fork sounded over the open end of an air column produces 4 beats per second, the tuning fork given a lower note. If the frequency of tuning fork is 34 Hz, then how many beats will be produced by the tuning fork if temperature falls to 5°C ?
(a) 2 beat/sec (b) 4 beat/sec
(c) 1 beat/sec (d) 3 beat/sec

40. In the given intensity time graph :



(a) the beat frequency is 2
(b) the beat frequency is not determined by this graph
(c) the beat frequency may be 2
(d) sources of wave must be same

41. Two wires A and B of same length, radius and same material are in unison. If tension in A is increased by 4%, 4 beats are heard, then the frequency of the note produced when they were in unison, will be :
(a) 50 Hz (b) 100 Hz
(c) 150 Hz (d) 200 Hz

42. If two tuning forks side by side are vibrating at 225 and 257 Hz, then their combined effect would be :
(a) that of middle octave
(b) that of one of tuning fork
(c) that of middle C
(d) 256 vibration per second

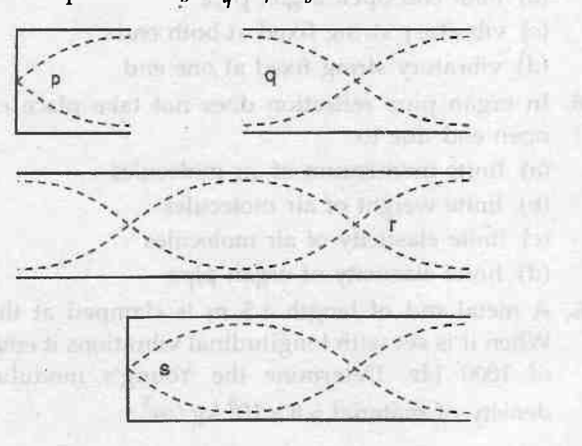
43. Two sound waves of length 1 m and 1.01 m in a gas produce 10 beats in 3 s. The velocity of sound in gas is :
(a) 360 m/s (b) 300 m/s
(c) 337 m/s (d) 330 m/s

44. The fundamental frequency of a closed organ pipe is equal to second overtone of an open organ pipe. If the length of closed organ pipe is 15 cm, the length of open organ pipe is :
(a) 90 cm (b) 30 cm
(c) 15 cm (d) 20 cm

45. In the case of closed end organ pipe :
(a) the maximum possible wavelength is same as that of open end organ pipe
(b) the maximum possible wavelength is less than that of open end organ pipe
(c) the maximum possible wavelength may be less than that of open end organ pipe
(d) the maximum possible wavelength is greater than that of open end organ pipe

46. An organ pipe closed at one end resonates with a tuning fork of frequencies 180 Hz and 300 Hz. It will also resonate with tuning fork of frequencies :
(a) 360 Hz (b) 420 Hz
(c) 480 Hz (d) 540 Hz

47. Figures shows the vibrations of four air columns. The ratio of frequencies $n_p : n_q : n_r : n_s$ is :



(a) 12 : 6 : 3 : 4 (b) 1 : 2 : 4 : 3
(c) 4 : 2 : 3 : 1 (d) 4 : 3 : 2 : 1

48. In the case of standing waves in organ pipe, the value of $\frac{\partial y}{\partial x}$ at the open end is :
(a) >0 (b) <0
(c) $=0$ (d) none of these

49. Two organ pipes are emitting their fundamental notes. When each closed at end, give 5 beats per sec. If their fundamental frequencies are 250 Hz and 255 Hz, then the ratio of their lengths is :
(a) $\frac{49}{50}$ (b) $\frac{49}{51}$
(c) $\frac{50}{51}$ (d) $\frac{51}{50}$

50. In the case of vibration of closed end organ pipe in fundamental mode of vibration, the pressure is maximum at :
(a) open end (b) closed end
(c) at middle (d) none of these

51. An air column in a pipe which is closed at one end will be in resonance with a vibrating tuning fork of frequency 264 Hz if the length of the air column in cm is : (Speed of sound in air = 340 m/s)
(a) 32.19 cm (b) 64.39 cm
(c) 100 cm (d) 140 cm

52. At the temperature of 27°C, the length of the organ pipe is 30 cm. What should be the change in the length required, if the temperature falls to 7°C but frequency remains unchanged ?
(a) Decreased by 1 cm (b) Increased by 1 cm
(c) Decreased by 2 cm (d) Iecreased by 2 cm

53. A closed organ pipe and an open pipe of the same length produce 4 beats when they are set into vibrations simultaneously. If the length of each of them were twice their initial lengths, the number of beats produced will be :
(a) 2 (b) 4
(c) 1 (d) 8

54. A tube with both ends closed has same set of natural frequency as :
(a) one end closed organ pipe
(b) both end open organ pipe
(c) vibratory string fixed at both ends
(d) vibratory string fixed at one end

55. In organ pipe reflection does not take place exactly at open end due to :
(a) finite momentum of air molecules
(b) finite weight of air molecules
(c) finite elasticity of air molecules
(d) finite elasticity of organ pipe

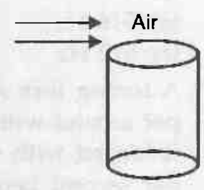
56. A metal rod of length 1.5 m is clamped at the centre. When it is set with longitudinal vibrations it emits a note of 1000 Hz. Determine the Young's modulus if the density of material $= 8\times10^3$ kg/m^2 :
(a) 7×10^{10} N/m^2 (b) 7.2×10^{10} N/m^2
(c) 0.7×10^{10} N/m^2 (d) 6.8×10^{10} N/m^2

57. The frequency of a note next higher to fundamental as given by a rod of an alloy 1 meter long and clamped at its mid point is 1000. If the density of rod is 7500 kg/m^3, its Young's modulus is :
(a) $\frac{1}{3}\times10^{10}$ N/m^2 (b) $\frac{1}{6}\times10^{10}$ N/m^2
(c) $\frac{2}{3}\times10^{10}$ N/m^2 (d) $\frac{1}{2}\times10^{10}$ N/m^2

58. A metallic rod of length one metre is rigidly clamped at its mid-point. Longitudinal stationary waves are set-up in the rod in such a way that there are two nodes on either side of the mid-point, then :
(a) wavelength of wave is 0.4 m
(b) the standard form of the equation of stationary wave is $y = A\cos kx \sin\omega t$
(c) the standard form of the equation of stationary wave is $y = A\sin kx\cos\omega t$
(d) both (a) and (b) are correct

59. A whistle gives a note when sounded at temperature 18°C. What must be the temperature, so that it gives a note of 9/8 of first frequency ?
(a) 25°C (b) 50°C
(c) 60°C (d) 95.3°C

60. A long tube of length $l = 25$ cm and diameter equal to 2 cm is taken and at its mouth air is blown as shown in figure. The sound emitted by tube will have all the frequencies of the group : (velocity of sound = 330 m/s)



(a) 660, 1320, 1980 Hz (b) 660, 1000, 3300 Hz
(c) 302, 684, 1320 Hz (d) 330, 990, 1690 Hz

61. λ_1, λ_2 and λ_3 are the wavelength of the waves giving resonance in the fundamental, first and second overtones respectively. Within a pipe closed at one end, the ratio of the wavelengths is :
(a) 1 : 2 : 3 (b) 5 : 3 : 1
(c) $1 : \frac{1}{2} : \frac{1}{3}$ (d) $1 : \frac{1}{3} : \frac{1}{5}$

62. The equation of a stationary wave in a metal rod is given by $y = 0.002\sin\frac{\pi x}{3}\sin 1000t$ where x is in cm and t is in second. The maximum tensile stress at a point $x = 2$ cm : (Young's modulus Y of material of rod $= 8\times10^{11}$ dyne/square cm) will be
(a) $\frac{\pi}{3}\times10^8$ dyne/square cm
(b) $\frac{4\pi}{3}\times10^8$ dyne/square cm
(c) $\frac{8\pi}{3}\times10^8$ dyne/square cm
(d) $\frac{2\pi}{3}\times10^8$ dyne/square cm

63. Two boats are floating on a pond in the same direction with the same speed v. Each boat sends a signal to the other through water. The frequencies f_0 of the generated signals are the same. Then : (Speeds of boats are lesser than speed of sound)
(a) the time of journey of both signals are same
(b) the wavelengths are same
(c) the frequencies received by the boats are same
(d) none of the above

64. A source of sound whose frequency is n_0, is moving with a speed v ($v < c$). The waves travel to a fixed obstacle and reflected by the obstacle and are registered by a receiver that moves together with the source. What frequency is registered by the receiver if the speed of sound in the medium is c?
(a) $\left(\frac{1+\frac{v}{c}}{1-\frac{v}{c}}\right) n_0$ (b) $\left(\frac{1-\frac{v}{c}}{1+\frac{v}{c}}\right) n_0$
(c) $\left(\frac{c-v}{c}\right) n_0$ (d) None of these

65. Two sources A and B are sounding notes of frequency 680 Hz. A listener moves from A to B with a constant velocity u. If the speed of sound is 340 m/s, what must be the value of u, so that he hears 10 beats per second?
(a) 2 m/s (b) 2.5 m/s
(c) 3 m/s (d) 3.5 m/s

66. The apparent frequency is f_1 when a source of sound approches a stationary observer with a speed u and f_2 when the observer approches the stationary source with same speed. If v is the velocity of sound, then :
(a) $f_1 = f_2$
(b) $f_1 > f_2$ if $u < v$
(c) relation between f_1 and f_2 cannot be predicted
(d) $f_2 > f_1$ if $u < v$

67. A source at rest sends waves of constant wavelength. A wall moves towards the source with a velocity 33 m/s. The velocity of sound in the medium is 330 m/s. What is the percentage change in wavelength of sound after reflection from the wall?
(a) 0.1% (b) 2%
(c) 9.1% (d) 1%

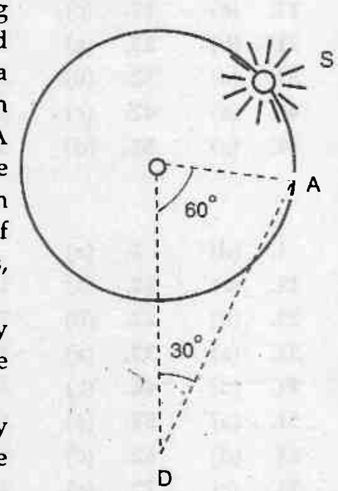
68. A locomotive engine approaches a railway station and whistles at a frequency of 400 Hz. A stationary observer on the platform observes a change of 40 Hz as the engine passes across him. If the velocity of sound is 330 m/s, the speed of the engine is
(a) 33 m/s (b) 18 m/s
(c) 16.5 m/s (d) 24 m/s

69. Two trains, one moving at a speed of 30 mile/hour and other at 60 mile/hour, approaching each other. When a faster train blows a whistle, the apparent frequency of the note heard by an observer at rest behind the faster train is 1852 Hz. The frequency of note produced by faster train is : (Assume speed of sound to be 1100 ft/s)
(a) 2000 vib/s (b) 1500 vib/s
(c) 1000 vib/s (d) 2500 vib/s

70. A disc of radius R is rotating uniformly with angular frequency ω. A source of sound is fixed to the rim of the disc. The ratio of maximum and minimum frequencies heard by stationary observer, far away from the disc and in the plane of the disc is : (Given: v = speed of sound)
(a) $\left(\frac{v}{v-R\omega}\right)$ (b) $\left(\frac{v}{v+R\omega}\right)$
(c) $\left(\frac{v-R\omega}{v+R\omega}\right)$ (d) $\left(\frac{v+R\omega}{v-R\omega}\right)$

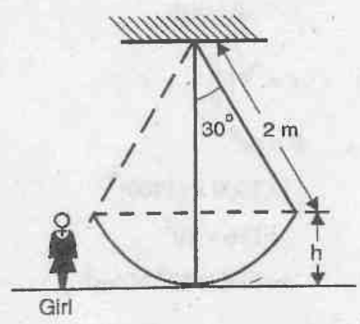
71. A boy with a radio, playing a music at a frequency 'f' is moving towards a wall with velocity v_b. A motorist is following the boy with a speed v_m. The expression for the beat frequency heard by the motorist., if the speed of sound is v, is :
(a) $\left(\frac{v+v_m}{v+v_b}\right) f$ (b) $\frac{v+v_n}{v-v_b} f$
(c) $\frac{2v_b(v+v_m)}{v^2-v_b^2} f$ (d) $\frac{2v_m(v+v_b)}{(v^2-v_m^2)} f$

* 72. A source of sound S having frequency of generated sound 300 Hz is moving in a circle of radius 2 m with angular speed $10/\pi$ rps. A detector D in the plane of the circle is at a distance of 30 m from the centre. The speed of sound in air is 300 m/s, then :



(a) the maximum frequency detected at D will be 340 Hz
(b) the minimum frequency detected at D will be 280 Hz
(c) the average frequency of listening the frequency 300 Hz is $\frac{20}{\pi}$ per second
(d) the source reaches A when maximum frequency is detected at D

* 73. A boy is sitting on a swing and blowing a whistle at a frequency of 1000 Hz. The swing is moving to an angle of 30° from vertical. The boy is at 2 m from the point of

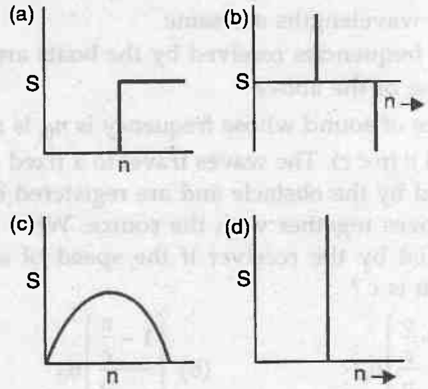


support of swing and a girl stands infront of swing. Then the maximum frequency she will hear, is :
(Given: velocity of sound = 330 m/s)
(a) 1000 Hz (b) 1001 Hz
(c) 1007 Hz (d) 1011 Hz

74. There is a road between two parallel rows of buildings and distance between the rows of buildings is 106 m. The velocity of car if a car blows a horn whose echo is heard by the driver after 1 s, is :
(Given: speed of sound = 340 m/s)
(a) 180 m/s (b) 165 m/s
(c) 323 m/s (d) 150 m/s

75. Bullets are fired at regular interval of 20 s from a car *A*, moving with 54 km/h towards a car, *B* which is approaching *A* with 30 km/h. If the speed of sound is 330 m/s and that of wind is 10 m/s along *BA*, then the firing interval observed by a person in the car *B* is :
(a) 21.64 s (b) 22.2 s
(c) 18.5 s (d) 18 s

76. The graph between distance between source and observer and apparent frequency in the case of Doppler's effect will be :



Answers

Level-1

1. (a)	2. (b)	3. (a)	4. (d)	5. (b)	6. (a)	7. (d)	8. (b)	9. (a)	10. (c)
11. (a)	12. (c)	13. (c)	14. (a)	15. (b)	16. (a)	17. (c)	18. (a)	19. (a)	20. (a)
21. (b)	22. (a)	23. (a)	24. (a)	25. (c)	26. (d)	27. (b)	28. (a)	29. (b)	30. (a)
31. (a)	32. (b)	33. (d)	34. (a)	35. (a)	36. (a)	37. (a)	38. (d)	39. (b)	40. (a)
41. (a)	42. (c)	43. (a)	44. (a)	45. (a)	46. (b)	47. (a)	48. (b)	49. (b)	50. (c)
51. (a)	52. (d)	53. (a)	54. (c)						

Level-2

1. (d)	2. (a)	3. (b)	4. (c)	5. (b)	6. (a)	7. (b)	8. (c)	9. (a)	10. (a)
11. (c)	12. (a)	13. (a)	14. (c)	15. (c)	16. (b)	17. (c)	18. (a)	19. (a)	20. (c)
21. (b)	22. (b)	23. (c)	24. (d)	25. (a)	26. (b)	27. (a)	28. (c)	29. (d)	30. (c)
31. (a)	32. (a)	33. (d)	34. (d)	35. (b)	36. (a)	37. (c)	38. (a)	39. (d)	40. (a)
41. (d)	42. (c)	43. (c)	44. (a)	45. (a)	46. (b)	47. (b)	48. (c)	49. (d)	50. (b)
51. (a)	52. (a)	53. (a)	54. (b)	55. (a)	56. (b)	57. (a)	58. (d)	59. (d)	60. (a)
61. (d)	62. (c)	63. (c)	64. (a)	65. (b)	66. (d)	67. (c)	68. (c)	69. (a)	70. (d)
71. (c)	72. (c)	73. (c)	74. (c)	75. (c)	76. (d)				

Solutions

Level-1

4. CH_4 is the lightest.

5.
$$c = \sqrt{\left(\frac{B}{\rho}\right)}$$
$$\therefore \quad B = \rho c^2$$

8.
$$c = \sqrt{\left(\frac{B}{\rho}\right)}$$
$$\therefore \quad B = \rho c^2$$
$$= 1000 \times (1400)^2$$
$$= 196 \times 10^7$$
$$= 1.96 \times 10^9 \text{ N/m}^2$$

10.
$$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$$
$$= \frac{1020}{3} = 340 \text{ m/s}$$

11. Frequency does not change due to change of medium.
$$\therefore \quad c_1 = f\lambda_1$$
$$\text{and} \quad c_2 = f\lambda_2$$
$$\therefore \quad \frac{\lambda_2}{\lambda_1} = \frac{c_2}{c_1}$$
$$\therefore \quad \lambda_1 = \left(\frac{340}{1445}\right) \times 8.5 = 2 \text{ cm}$$

15

Heat, Temperature and Calorimetry

Syllabus: Thermal expansion of solids and liquids and their specific heats.

Review of Concepts

1. Conversion of temperature reading from one scale to another.

$$\frac{C}{5}=\frac{F-32}{9}=\frac{K-273}{5}=\frac{R}{4}=\frac{R_n-492}{9}$$

Here, C = reading in centigrade,
F = reading in Fahrenheit,
R = reading in Reaumur,
K = reading in Kelvin,
R_n = reading in Rankin

2. Linear expansion:

(a) $l_2 = l_1[1+\alpha(t_2-t_1)]$

(b) The value of 'α' does not depends upon initial and the final length of the solid.

(c) The value of 'α' slightly depends upon initial and final temperature of the solid.

(d) The value of 'α' may be negative .

(e) The value of 'α' depends upon the unit chosen.
In the given formula :
l_1 = length at t_1°C , l_2 = length at t_2°C
The given formula is applicable only for the small range of temperature.
For the large range of temperature.

$$l_t = l_0(1+at+bt^2+\ldots)$$

(f) Percentage change in length, $\% \, \Delta l = 100\,\alpha\,\Delta t$

(g) If a scale gives correct reading l_1 at t_1°C, when temperature changes to t_2°C, such that $t_2 > t_1$, the length of scale increases.
Hence, it gives reading lesser than true value.
True value = scale reading $[(1+\alpha(t_2-t_1)]$

(h) In the case of pendulum, due to variation of temperature, the length of pendulum changes, hence, time period changes.

$$\therefore \quad T = 2\pi\sqrt{\left(\frac{l}{g}\right)}$$

$$\therefore \quad \frac{T_1}{T_2}=\sqrt{\left(\frac{l_1 g_2}{l_2 g_1}\right)}$$

(i) If time period is correct.
Then $\quad T_1 = T_2$

$$\therefore \quad l_2 g_1 = l_1 g_2 \qquad \ldots(i)$$

But $\quad l_2 = l_1[(1+\alpha(t_2-t_1)]$

Hence, $\quad l_1 = [1+\alpha(t_2-t_1)]g_1 = l_1 g_2$ [From (i)]

$$\therefore \quad g_2 = g_1[1+\alpha(t_2-t_1)]$$

When 'g' remains constant, then

$$\frac{T_2}{T_1}=\sqrt{\left(\frac{l_2}{l_1}\right)}=\sqrt{\left\{\frac{l_1[(1+\alpha(t_2-t_1)]}{l_1}\right\}}$$

or $\quad \frac{T_2}{T_1}=[1+\alpha(t_2-t_1)]^{1/2}$

$$\therefore \quad \frac{T_2}{T_1}=1+\frac{1}{2}\alpha\,\Delta t$$

where $\quad \Delta t = t_2 - t_1$ = change in temperature.

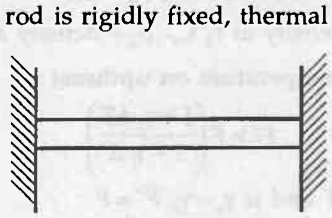
If $\Delta\tau$ is change in time and τ is the total time

$$\therefore \quad \Delta\tau = \tau\left[\frac{T_2}{T_1}-1\right]=\tau\left(1+\frac{1}{2}\alpha\,\Delta t-1\right)$$

$$\therefore \quad \Delta\tau = \frac{1}{2}\alpha\,\Delta t.\tau$$

If $\Delta\tau$ is positive, the watch becomes slow.
If $\Delta\tau$ is negative, the watch becomes fast.

(j) When rod is rigidly fixed, thermal strain



$$= \frac{\Delta l}{l} = \frac{l\,\alpha\,\Delta t}{l}$$

$$= \alpha\,\Delta t$$

$\therefore$ Thermal stress $= Y\alpha\,\Delta t$

Thermal force = stress × area $= YA\alpha\,\Delta t$

(k) When rod is not fixed; thermal strain is zero.

(l) If there is a hole A in a plate C, the area of the hole increases due to heating. The expansion in solid is independent of the presence of hole.

(m) If the difference of lengths of two rods of different materials are same at all temperatures then

$$\frac{l_1}{l_2}=\frac{\alpha_2}{\alpha_1}$$

(n) The range of temperature, $t \pm \Delta t$

$$l = \text{length at } t°\text{C}$$

$$\Delta l = l\,\alpha\,\Delta t$$

$$\therefore \quad \Delta t = \frac{\Delta l}{l\,\alpha}$$

(o) Variation of moment of inertia with temperature :

$$\because \quad l = l_0\,(1 + \alpha t)$$

or $\quad l^2 = l_0^2\,(1+\alpha t)^2 \quad$ or $\quad ml^2 = ml_0^2\,(1 + \alpha^2 t^2 + 2\alpha t)$

$\alpha^2 t^2$ are very small, so, it can be neglected

$\therefore \quad ml^2 = ml_0^2\,(1 + 2\alpha t) \quad$ or $\quad kml^2 = kml_0^2\,(1 + 2\alpha t)$

where k is a numerical constant

but $\quad kml^2 = \text{M.I. at } t°\text{C} = I$

and $\quad kml_0^2 = \text{M.I. at } 0°\text{C} = I_0$

$$\therefore \quad I = I_0\,(1 + 2\alpha t)$$

3. Superficial expansion :

$$A_2 = A_1\,[1 + \beta\,(t_2 - t_1)]$$

where A_1 = surface area at t_1°C,

A_2 = surface area at t_2°C

β = coefficient of superficial expansion

- For isotropic material, $\beta = 2\alpha$
- S.I. unit of β is per kelvin.

4. Cubical expansion :

$$V_2 = V_1\,[1 + \gamma\,(t_2 - t_1)]$$

where, V_2 = volume at t_2°C, V_1 = volume at t_1°C,

γ = temperature coefficient of cubical expansion

- SI unit of γ is per kelvin.
- For isotropic medium $\gamma = 3\alpha$.

5. Variation of density with temperature :

$$\rho_1 = \rho_2\,[1 + \gamma\,(t_2 - t_1)]$$

where, ρ_1 = density at t_1°C, ρ_2 = density at t_2°C

6. Effect of temperature on upthrust :

$$F' = F\left(\frac{1 + \gamma_s\,\Delta T}{1 + \gamma_l\,\Delta}\right)$$

If $\gamma_s > \gamma_l$, $F' > F$ and if $\gamma_s = \gamma_l$, $F' = F$

where γ_s = ratio of specific heats of solid

γ_l = ratio of specific heats of liquid

7. Expansion in liquid: **Liquids have no definite shape. So, only volume expansion is found in the case of liquid.**

(a) **Apparent expansion:** The observed expansion is the combined effect of expansion in container and the expansion in liquid.
i.e., real expansion in liquid = apparent expansion in liquid + expansion of container

or $\quad \Delta V_r = \Delta V_a + \Delta V_b$

(b) $\quad \gamma_r = \gamma_a + \gamma_b$

Here γ_r = coefficient of real expansion of liquid,

γ_a = coefficient of apparent expansion of liquid,

γ_b = coefficient of expansion of container.

(c) If $\gamma_r > \gamma_b$, the level of liquid in container will rise due to rise of temperature.

(d) If $\gamma_r = \gamma_b$, the level of liquid in container remains steady due to rise of temperature.

(e) If $\gamma_r < \gamma_b$, the level of liquid in container will fall due to rise of temperature.

(f) The expression for thrust on a body of volume V dipped in a liquid of density ρ,

$$F_t = F_0\,[1 + (\gamma_s - \gamma_l)\,t]$$

Here F_t = thrust on the body at t°C,

F_0 = thrust on the body at 0°C,

γ_s = coefficient of volume expansion of solid,

γ_l – coefficient of volume expansion of liquid.

(g) Since, $\gamma_s < \gamma_l$, so, due to rise of temperature, thrust on the body decreases.

(h) The coefficient of expansion of water at 4°C is zero.

8. Anomalous expansion of water :

(a) Some substances contract when heated over a certain temperature range. The most common example is water. The volume of water decreases as the temperature is raised from 0°C to 4°C, at which point, the volume is a minimum and the density is a maximum (1000 kg/m^3).

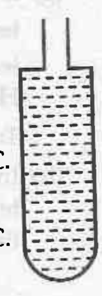
(b) Above 4°C, water expands with increasing temperature like most substances.

(c) The anomalous behaviour of water arises due to the fact that water has three types of molecules, *viz.*, H_2O, $(H_2O)_2$ and $(H_2O)_3$ having different volumes per unit mass and at different temperatures their properties in water are different.

9. Methods of measuring coefficient of expansion of liquid:

(a) Weight thermometer or specific gravity bottle.

$$\gamma = \frac{m_1 - m_2}{m_2\,(t_2 - t_1)} + \frac{m_1 \gamma_b}{m_2}$$



Here γ = coefficient of real expansion of liquid

m_1 = mass of experimental liquid in the bottle at t_1°C.

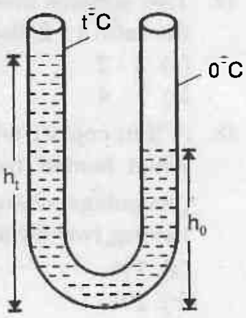
m_2 = mass of experimental liquid in the bottle at t_2°C.

γ_b = coefficient of expansion of the bottle.

(b) **Dulong and Petit's method:** In this method, a column of experimental liquid at t°C is balanced against other column of the experimental liquid at 0°C by taking them in U-tube.

Here $\quad \gamma = \dfrac{h_t - h_0}{h_0 t}$

(c) **Sinker's method:** A body of mass m_0 in air is dipped into liquid at two different temperatures.



Here $\gamma = \frac{(m_0 - m_1) - (m_0 - m_2)}{(m_0 - m_2)(t_2 - t_1)} + \left(\frac{m_0 - m_1}{m_0 - m_2}\right)\gamma_s$

Here m_1 = apparent weight of body in the liquid at t_1°C.

m_2 = apparent weight of liquid at t_2°C.

γ_s = coefficient of volume expansion of the body.

10. Calorimetry:

(a) It is based upon conservation principle of energy.

heat lost = heat gained

(b) $\Delta H = ms\Delta\theta$

(c) If n bodies of masses $m_1, m_2, m_3, \ldots, m_n$ at temperatures $\theta_1, \theta_2, \theta_3, \ldots, \theta_n$ are mixed together provided states of bodies do not change during mixing then

$$\theta = \frac{m_1 s_1 \theta_1 + m_2 s_2 \theta_2 + \ldots + m_n s_n \theta_n}{m_1 + m_2 + \ldots + m_n}$$

where θ = equilibrium temperature of the mixture.

(d) The S.I. unit of heat energy is joule.

10. Debyer T^3 law: Specific heat of a solid varies with temperature. It is $3R$ at higher temperature and near absolule zero $C_v \propto T^3$.

11. Clausius clapeyron's equation (or Latent heat equation) representing change of M.P. or B.P. with pressure is

$$\frac{dP}{dt} = \frac{Jl}{T(V_2 - V_1)}$$

Relation among different units :

(i) 1 pound calorie = 453.6 calorie

(ii) 1 British thermal unit = 252 calorie

(iii) 1 calorie = 4.2 joule..

(iv) 1 Therm = 10^5 British thermal unit

(v) The relation between specific heat (s) and heat capacity (C) :

$$C = ms$$

(vi) Water equivalent (W) :

$$W = \frac{ms}{4200} \quad \text{(In SI)}$$

where W = water equivalent in kg.

(vii) Water equivalent in gram and heat capacity in calorie per centigrade are numerically equal.

(viii) Latent heat = mL

(ix) During phase change, specific heat is infinity.

Objective Questions

Level-1

1. When a metal rod is heated it expands because :
   (a) the size of its atoms increases
   (b) the distance among its atoms increases
   (c) atmospheric air rushes into it
   (d) the actual cause is still unknown

2. When rod is heated but prevented from expanding, the stress is independent of :
   (a) material of the rod (b) rise in temperature
   (c) length of rod (d) none of these

3. Significant motion for the molecules of a monoatomic gas corresponds to :
   (a) translatory (b) vibratory
   (c) rotatory (d) none of these

4. A sphere, a cube and disc all of the same material quantity and volume are heated to 600°C and left in air. Which of these will have the lowest rate of cooling ?
   (a) Sphere (b) Cube
   (c) Disc (d) All will have same rate

5. Coefficient of cubical expansion of water is zero at :
   (a) 0°C (b) 4°C
   (c) 15.5°C (d) 100°C

6. A bar of iron is 10 cm at 20°C, at 19°C it will be (α of iron = 11×10^{-6}/°C) :
   (a) 11×10^{-6} cm longer
   (b) 11×10^{-6} cm shorter
   (c) 11×10^{-5} cm shorter
   (d) 11×10^{-5} cm longer

7. Amount of heat required to raise the temperature of a body through 1 K is called its :
   (a) water equivalent (b) thermal capacity
   (c) entropy (d) specific heat

8. A pendulum clock keeps correct time at 20°C, the correction to be made during summer per day where the average temperature is 40°C ($\alpha = 10^{-5}$/°C) will be :
   (a) 5.64 s (b) 6.64 s
   (c) 7.64 s (d) 8.64 s

9. The coefficient of real expansion of mercury is 0.38×10^{-3}/°C. If the density of Hg at 0°C is 13.6×10^{-3}/°C, its density at 200°C will be :
   (a) 13.3 g/cc (b) 13.2 g/cc
   (c) 13.1 g/cc (d) 13.6 g/cc

10. Two metal strips that constitute a thermostate must necessarily differ in their :
    (a) masses
    (b) lengths
    (c) resistivities
    (d) coefficients of linear expansion

11. The standard fixed point for temperature measurement is used these days is :
(a) melting point of ice at S.T.P.
(b) that temperature at which ice, water and water vapour coexist
(c) that temperature at which pure ice and pure water coexist
(d) none of the above

12. Water does not freeze at the bottom of the lakes in winter because :
(a) ice is a good conductor of heat
(b) ice reflects heat and light
(c) of anomalous expansion of water between 4°C to 0°C
(d) nothing can be said

13. When the pressure on water is increased, the boiling temperature of water as compared to 100°C will be :
(a) lower (b) the same
(c) higher (d) on the critical temperature

14. The density of substance at 100°C is 7.25 g/cc and at 0°C is 7.5 g/cc, coefficient of linear expansion is :
(a) $111 \times 10^{-6}/°C$ (b) $111 \times 10^{-5}/°C$
(c) $111 \times 10^{-4}/°C$ (d) $111 \times 10^{-3}/°C$

15. On heating a liquid of coefficient of cubical expansion α in a container having a coefficient of linear expansion $\alpha/3$, the level of the liquid in the container will :
(a) rise
(b) fall
(c) remain almost stationary
(d) it is difficult to say

16. The specific heat of gas in an isothermal process is :
(a) zero (b) infinite
(c) negative (d) remains constant

17. Two spheres made of same substance have diameters in the ratio 1 : 2, their thermal capacities are in the ratio of :
(a) 1 : 2 (b) 1 : 8
(c) 1 : 4 (d) 2 : 1

18. A thin copper wire of length l increases in length by 1% when heated from temperature T_1 to T_2. What is the percentage change in area, when a thin copper plate having two dimensions is heated from T_1 to T_2 ?
(a) 1% (b) 3%
(c) 2% (d) 4%

19. The volume coefficient expansion of a metal whose linear coefficient is $15 \times 10^{-6}/°C$, will be :
(a) $45 \times 10^{-6}/°C$ (b) $25 \times 10^{-6}/°C$
(c) $35 \times 10^{-6}/°C$ (d) $5 \times 10^{-6}/°C$

20. The coefficient of linear expansion of crystal in one direction is α_1 and that in every direction perpendicular to it is α_2. The coefficient of cubical expansion is :
(a) $\alpha_1 + \alpha_2$ (b) $2\alpha_1 + \alpha_2$
(c) $\alpha_1 + 2\alpha_2$ (d) none of these

21. As the pressure on the gas is increased from 1 to 2 atmosphere, its heat capacity :
(a) decreases linearly
(b) increases linearly
(c) increases logarithmically
(d) is practically constant

22. Heat conducted through a rod of radius 1 cm and length 22 cm in five minutes, if the coefficient of conduction is 0.1 CGS unit when the ends are at 30°C and 100°C, is :
(a) 300 cal (b) 100 cal
(c) 150 cal (d) 400 cal

Level-2

1. The temperature at which Centigrade thermometer and Kelvin thermometer gives the same reading, is :
(a) 4° (b) 273°
(c) not possible (d) 0°

2. What is the change in the temperature on Fahrenheit scale and on Kelvin scale, if a iron piece is heated from 30° to 90°C ?
(a) 108°F, 60K (b) 100°F, 55K
(c) 100°F, 65K (d) 60°F, 108K

3. What is the resistance of the wire at 30°C, if at 5°C, the resistance of same wire is 200 Ω and at 10°C, the resistance is 200.2 Ω ?
(a) 200 Ω (b) 201 Ω
(c) 204 Ω (d) 195 Ω

4. Which of the following carries anomalous expansion ?
(a) Mercury (b) Water
(c) Copper (d) Sodium

5. Two thermometers are constructed in such a way that one has a spherical bulb and the other has elongated cylindrical bulb. The bulbs are made of same material and thickness. Then :
(a) spherical bulb will respond more quickly to temperature changes
(b) cylindrical bulb will respond more quickly to temperature changes.
(c) both bulbs will respond same to temperature changes
(d) none of both bulbs respond to temperature changes

6. Mark correct option or options :
(a) Sun temperature is measured by radiation pyrometer
(b) Insect temperature is measured by thermocouple thermometer
(c) Moon's temperature is measured by berthometer
(d) All of the above

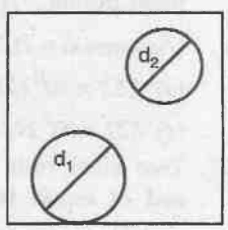
7. The temperature of a point in space is given by $T = (x^2 + y^2 - z^2)$. A mosquito located at (1, 1, 2) desires to fly in such a direction that it will get heat as soon as possible. Then unit vector is :
(a) $\frac{2}{3}\hat{i} + \frac{2}{3}\hat{j} - \frac{1}{3}\hat{k}$ (b) $-\frac{2}{3}\hat{i} - \frac{2}{3}\hat{j} + \frac{1}{3}\hat{k}$
(c) $\frac{2}{3}\hat{i} - \frac{2}{3}\hat{j} - \frac{1}{3}\hat{k}$ (d) none of these

8. A bird is flying at a speed of 5 m/s in the direction of the vector $4\hat{i} + 4\hat{j} - 2\hat{k}$. The temperature of the region is given by $T = x^2 + y^2 - z^2$.
The rate of increase of temperature per unit time, at the instant it passes through the point (1, 1, 2) is :
(a) $\frac{60}{3}$ °C/s (b) 3°C/s
(c) 18°C/s (d) 4°C/s

9. At 30°C, the hole in a steel plate has diameter of 0.99970 cm. A cylinder of diameter exactly 1 cm at 30°C is to be slide into the hole. To what temperature the plate must be heated ? (Given : $\alpha_{steel} = 1.1 \times 10^{-5}$ °C^{-1})
(a) 58°C (b) 55°C
(c) 57.3°C (d) 60°C

10. If same amount of heat is supplied to two identical spheres (one is hollow and other is solid), then :
(a) the expansion in hollow is greater than the solid
(b) the expansion in hollow is same as that in solid
(c) the expansion in hollow is lesser than the solid
(d) the temperature of both must be same to each other.

11. The metal sheet shown in figure, with two holes cut of unequal diameters d_1 and d_2 $(d_1 > d_2)$. If the sheet is heated :



(a) both d_1 and d_2 will decrease
(b) both d_1 and d_2 will increase
(c) d_1 will increase, d_2 will decrease
(d) d_1 will decrease, d_2 will increase

12. A steel scale gives correct reading at t_1°C. When temperature changes to t_2°C, then :
(a) if $t_2 > t_1$, reading is greater than true value
(b) if $t_2 > t_1$, reading is lesser than true value
(c) the reading is always equal to true value
(d) the reading is always less than true value

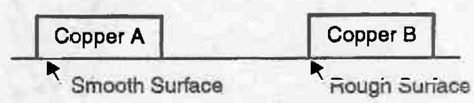
13. At 20°C, a steel ruler of 20 cm long is graduated to give correct reading, but when it is used at a temperature of 40°C, what will be the actual length of the steel ruler ? [$\alpha_{steel} = 1.2 \times 10^{-5}$ (°C)$^{-1}$]
(a) 22.02 cm (b) 19.6 cm
(c) 20.0048 cm (d) 18.0002 cm

14. The temperature of a pendulum, the time period of which is t, is raised by ΔT. The change in its time period is :
(a) $\frac{1}{2}\alpha t\,\Delta T$ (b) $2\alpha t\,\Delta T$
(c) $\frac{1}{2}\alpha\Delta T$ (d) $2\alpha\Delta T$

15. A second's pendulum clock having steel wire is calibrated at 20°C. When temperature is increased to 30°C, then how much time does the clock lose or gain in one week ? [$\alpha_{steel} = 1.2 \times 10^{-5}$ (°C)$^{-1}$]
(a) 0.3628 s (b) 3.626 s
(c) 362.8 s (d) 36.28 s

16. A uniform brass disc of radius a and mass m is set into spinning with angular speed ω_0 about an axis passing through centre of disc and perpendicular to the plane of disc. If its temperature increases from θ_1°C to θ_2°C without disturbing the disc, what will be its new angular speed ?
(The coefficient of linear expansion of brass is α).
(a) $\omega_0\,[1 + 2\alpha(\theta_2 - \theta_1)]$ (b) $\omega_0\,[1 + \alpha(\theta_2 - \theta_1)]$
(c) $\frac{\omega_0}{[1 + 2\alpha(\theta_2 - \theta_1)]}$ (d) None of these

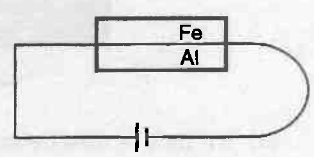
17. Two identical rods A and B are of equal lengths and at the same temperature. The rod A is placed at smooth surface but B is placed at rough surface. If the temperature of both are raised by the same amount, then :



(a) final length of A is greater than that of B
(b) final length of both are same
(c) final length of A is lesser than that of B
(d) none of the above

18. Calculate the compressional force required to prevent the metallic rod of length l cm and cross-sectional area A cm^2 when heated through t°C, from expanding along lengthwise. The Young's modulus of elasticity of the metal is E and mean coefficient of linear expansion is α per degree celsius :
(a) $EA\alpha t$ (b) $\frac{EA\alpha t}{(1 + \alpha t)}$
(c) $\frac{EA\alpha t}{(1 - \alpha t)}$ (d) $El\alpha t$

19. A plate composed of welded sheets of aluminium and iron is connected to an electrical circuit as shown in fig. What will happen if a fairly strong current be passed through the circuit ?



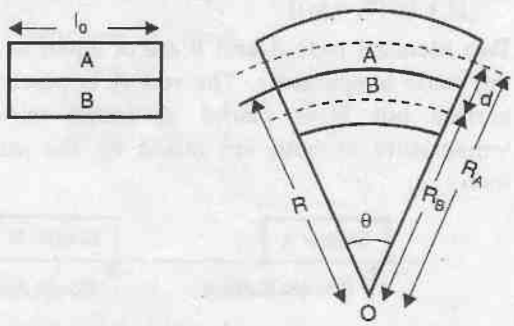
(a) Strip bends upward

(b) Strip bends downward
(c) Strip remains in its initial condition
(d) None of the above

20. A steel rod of 30 mm diameter and 0.3 m long is subjected to a tensile force W kilo newton acting axially. The temperature of the rod raised through 80°C and total extension measured as 0.35 mm. The value of W is: ($Y_s = 2 \times 10^5$ N/mm^2, $\alpha_s = 12 \times 10^{-6}$ /°C)

(a) 29.20 (b) 40
(c) 50 (d) 12

* **21.** At temperature T_0, two metal strips of length l_0 and thickness d, is bolted so that their ends coincide. The upper strip is made up of metal A and have coefficient of expansion α_A and lower strip is made up of metal B with coefficient of expansion α_B. ($\alpha_A > \alpha_B$). When temperature of their blastic strip is increased from T_0 to $(T_0 + \Delta T)$, one strip become longer than the other and blastic strip is bend in the form of a circle as shown in fig. Calculate the radius of curvature R of the strip:



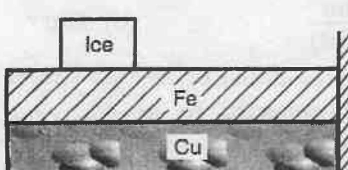
(a) $R = \dfrac{[2 + (\alpha_A + \alpha_B)\,\Delta T]\, d}{2\,(\alpha_A - \alpha_B)\,\Delta T}$

(b) $R = \dfrac{[2 - (\alpha_A + \alpha_B)\,\Delta T]\, d}{2\,(\alpha_A - \alpha_B)\,\Delta T}$

(c) $R = \dfrac{[2 + (\alpha_A - \alpha_B)\,\Delta T]\, d}{2\,(\alpha_A - \alpha_B)\,\Delta T}$

(d) $R = \dfrac{[2 - (\alpha_A - \alpha_B)\,\Delta T]\, d}{2\,(\alpha_A - \alpha_B)\,\Delta T}$

22. A cube of ice is placed on a bimetallic strip at room temperature as shown in the figure. What will happen if the upper strip is of iron and the lower strip is of copper?



(a) Ice moves downwards
(b) Ice moves upwards
(c) Ice remains in rest
(d) None of the above

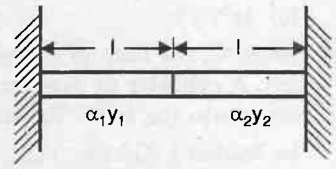
23. A copper rod of length l_0 at 0°C is placed on smooth surface. The rod is heated up to 100°C. The longitudinal strain developed is:
(α = coefficient of linear expansion)

(a) $\dfrac{100 l_0 \alpha}{l_0 + 100 l_0 \alpha}$ (b) $100\,\alpha$
(c) zero (d) none of these

24. A steel rod of diameter 1 cm is clamped firmly at each end when its temperature is 25°C so that it cannot contract on cooling. The tension in the rod at 0°C is:
($\alpha = 10^{-5}$/°C, $Y = 2 \times 10^{11}$ N/m^2)

(a) 4000 N (b) 7000 N
(c) 7400 N (d) 4700 N

* **25.** Two metal rods are fixed end to end between two rigid supports, as shown in figure. Each rod is of length 'l' and area of cross-section is A. When the system is heated up, determine the condition when the junction between rods does not shift?



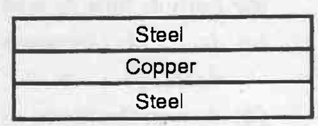
[Given: Y_1 and Y_2 are Young's modulus of materials of the rods, α_1 and α_2 are coefficients of linear expansion.]

(a) $\alpha_1 Y_2 = \alpha_2 Y_1$ (b) $\alpha_1 Y_1 = \alpha_2 Y_2$
(c) $\alpha_1 = \alpha_2$ (d) $Y_1 = Y_2$

26. What will be the stress at —20°C, if a steel rod with a cross-sectional area of 150 mm^2 is stretched between two fixed points? The tensile load at 20°C is 5000N:
(Assume $\alpha = 11.7 \times 10^{-6}$ /°C and $Y = 200 \times 10^{11}$ N/m^2)

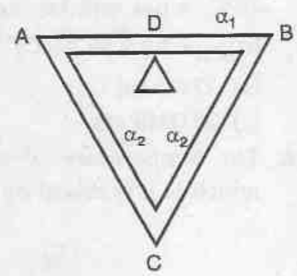
(a) 12.7×10^6 N/m^2 (b) 1.27×10^6 N/m^2
(c) 127×10^6 N/m^2 (d) 0.127×10^6 N/m^2

27. Two steel rods and copper rod of equal length l_0 and equal cross-sections are joined rigidly as shown. All the rods are in a state of zero tension at 0°C. The temperature of system increases upto 30°C, then:



(a) tensile force on either steel plate is half of copper plate
(b) the net expansion in copper plate is less than the thermal expansion of the copper plate
(c) the expansion in either steel plates is larger than thermal expansion in steel plates
(d) all of the above

* **28.** An equilateral triangle ABC is formed by joining three rods of equal length and D is the mid-point of AB. The coefficient of linear expansion for AB is α_1 and for AC and BC is α_2. Find the relation between α_1 and α_2, if



distance DC remains constant for small changes in temperature

(a) $\alpha_1 = \alpha_2$ (b) $\alpha_1 = 4\alpha_2$

(c) $\alpha_2 = 4\alpha_1$ (d) $\alpha_1 = \frac{1}{2}\alpha_2$

29. In an anisotropic medium, the coefficients of linear expansion of a solid are α_1, α_2 and α_3 in three mutually perpendicular directions. The coefficient of volume expansion for the solid is

(a) $\alpha_1 - \alpha_2 + \alpha_3$ (b) $\frac{\alpha_1 + \alpha_2 + \alpha_3}{3}$

(c) $\alpha_1 + \alpha_2 + \alpha_3$ (d) none of these

30. The density of a liquid at 0°C is ρ_0. The density of liquid at 0°C is : [volume expansion of liquid is γ.]

(a) $\frac{\rho_0}{[1 + \gamma(\theta_2 - \theta_1)]}$ (b) $\rho_0 [1 + \gamma(\theta_2 - \theta_1)]$

(c) $\rho_0 [1 + \gamma\theta_2]$ (d) none of these

31. The coefficient of linear expansion of glass is α_g per °C and the cubical expansion of mercury is γ_m per °C. The volume of the bulb of a mercury thermometer at 0°C is V_0 and cross-section of the capillary is A_0. What is the length of mercury column in capillary at T°C, if the mercury just fills the bulb at 0°C ?

(a) $\frac{V_0 T(\gamma_m + 3\alpha_g)}{A_0(1 + 2\alpha_g T)}$ (b) $\frac{V_0 T(\gamma_m - 3\alpha_g)}{A_0(1 + 2\alpha_g T)}$

(c) $\frac{V_0 T(\gamma_m + 2\alpha_g)}{A_0(1 + 3\alpha_g T)}$ (d) $\frac{V_0 T(\gamma_m - 2\alpha_g)}{A_0(1 + 3\alpha_g T)}$

32. The bulk modulus of water is 2.1×10^9 N/m^2. The pressure required to increase the density of water by 0.1% is :

(a) 2.1×10^3 N/m^2 (b) 2.1×10^6 N/m^2

(c) 2.1×10^5 N/m^2 (d) 2.1×10^2 N/m^2

33. At a temperature t°C, a liquid is completely filled in a spherical shell of copper. If ΔT increases temperature of the liquid and the shell, then the outward pressure dP on the shell resulted from increase in temperature is given by : (Given, K = Bulk modulus of the liquids, γ = coefficient of volume expansion, α = coefficient of linear expansion of the material of the shell)

(a) $\frac{K}{2}(\gamma - 3\alpha)\Delta T$ (b) $K(3\alpha - \gamma)\Delta T$

(c) $3\alpha(K - \gamma)\Delta T$ (d) $\gamma(3\alpha - K)\Delta T$

34. A liquid when heated in a copper vessel and when heated in a silver vessel, the apparent coefficient of expansion is 'C' and 'S', respectively. If coefficients of linear expansion of copper is 'A', then coefficient of linear expansion of silver is :

(a) $\frac{C + S - 3A}{3}$ (b) $\frac{C + 3A - S}{3}$

(c) $\frac{3A - S - C}{3}$ (d) $\frac{C + S + 3A}{3}$

35. Using the following, data, at what temperature will the wood just sink in benzene ?

Density of wood at 0°C = 8.8×10^2 kg/m^3

Density of benzene at 0°C = 9×10^2 kg/m^3

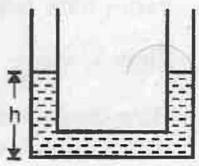
Cubical expansivity of wood = 1.5×10^{-4} K^{-1}

Cubical expansivity of benzene = 1.2×10^{-3} K^{-1}

(a) 27°C (b) 21.7°C

(c) 31°C (d) 31.7°C

36. In a U-tube, a liquid is poured to a height 'h' in each arm. When left and right arms of the tube is heated to temperature T_1 and T_2 respectively, the height in each arm changes to h_1 and h_2 respectively. What is the relation between coefficients of volume expansion of liquid and heights, h_1 and h_2 ?



(a) $\gamma = \frac{h_1 - h_2}{T_1 h_2 - T_2 h_1}$ (b) $\gamma = \frac{h_1 + h_2}{T_1 h_2 - T_2 h_1}$

(c) $\gamma = \frac{h_1 + h_2}{T_1 h_2 + T_2 h_1}$ (d) $\gamma = \frac{h_1 - h_2}{T_1 h_1 - T_2 h_2}$

37. A physicist says "a body contains 10 joule heat" but a physics learner says "this statement is correct only when the body is in liquid state". Mark correct option or options :

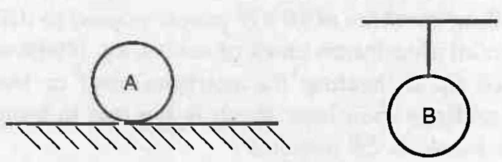
(a) physicist statement is correct

(b) physics learner's statement is correct

(c) both statements are correct

(d) both statements are wrong

38. A sphere A is placed at smooth table. An another sphere B is suspended as shown in figure. Both spheres are identical in all respects. Equal quantity of heat is supplied to both spheres. All kinds of heat loss are neglected. The final temperatures of A and B are T_A and T_B respectively, then :



(a) $T_A = T_B$ (b) $T_A > T_B$

(c) $T_A < T_B$ (d) none of these

39. The resulting temperature when 20 g of boiling water is poured into an ice-cold brass vessel of mass 100 g, is : (specific heat = 0.1 cal/g °C) :

(a) 66.66°C (b) 6.66°C

(c) 0.66°C (d) 50°C

40. The ratio of thermal capacities of two spheres A and B, if their diameters are in the ratio 1 : 2, densities in the ratio 2 : 1, and the specific heat in the ratio of 1 : 3, will be :

(a) 1 : 6 (b) 1 : 12

(c) 1 : 3 (d) 1 : 4

41. In similar calorimeters, equal volumes of water and alcohol, when poured, take 100 s. and 74 s respectively to cool from 50°C to 40°C. If the thermal capacity of each

calorimeter is numerically equal to volume of either liquid, then the specific heat capacity of alcohol is :
(Given: the relative density of alcohol as 0.8 and specific heat capacity of water as 1 cal/g/°C)
(a) 0.8 cal/g°C (b) 0.6 cal/g°C
(c) 0.9 cal/g°C (d) 1 cal/g°C

42. The molar heat capacity of rock salt at low temperatures varies with temperature according to Debye's T^3 law".
Thus, $C = k\dfrac{T^3}{\theta^3}$ where, $k = 1940\ \text{J mol}^{-1}\text{K}^{-1}$, $\theta = 281$ K.
How much heat is required to raise the temperature of 2 moles of rock salt from 10 K to 50 K?
(a) 800 J (b) 373 J
(c) 273 J (d) None of these

43. The specific heat of a substance at temperature t°C is $s = at^2 + bt + c$. The amount of heat required to raise the temperature of m g of the substance from 0°C to t_0°C, is :
(a) $\dfrac{mt_0^3 a}{3} + \dfrac{bt_0^2}{2} + ct_0$ (b) $\dfrac{mt_0^3 a}{3} + \dfrac{mbt_0^2}{2} + mct_0$
(c) $\dfrac{mt_0^3 a}{3} + \dfrac{mbt_0^2}{2}$ (d) none of these

44. In above problem, average value of specific heat is :
(a) $\dfrac{at_0^3}{3} + \dfrac{bt_0^2}{2} + ct_0$ (b) $\dfrac{at_0}{3} + \dfrac{bt_0^2}{2} + c$
(c) $at_0^2 + bt_0 + c$ (d) zero

45. If rotation of the earth stopped suddenly then the rise in temperature of the earth, assume total rotational energy is converted into thermal energy, is : (specific heat of earth = 0.15, radius of earth = 6400 km)
(a) 78.76°C (b) 6.876°C
(c) 68.76°C (d) 0.6876°C

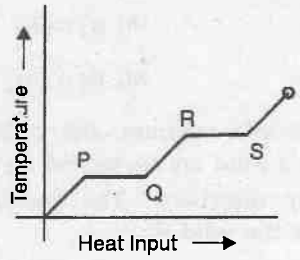
46. A drilling machine of 10 kW power is used to drill a bore in a small aluminium block of mass 8 kg. If 50% of power is used up in heating the machine itself or lost to the surroundings then how much is the rise in temperature of the block in 2.5 minutes?
(Given: specific heat of aluminium = 0.91 J/g°C)
(a) 103°C (b) 130°C
(c) 105°C (d) 30°C

47. A thermally insulated piece of metal is heated under atmosphere by an electric current so that it receives electric energy at a constant power P. This leads to an increase of the absolute temperature T of the metal with time t as follows

$$T = at^{1/4}$$

Then the heat capacity C_p is :
(a) $\dfrac{4PT^3}{a^4}$ (b) $\dfrac{4PT^2}{a^3}$
(c) $4PT^2$ (d) none of these

48. A source of heat supplies heat at a constant rate to a solid cube. The variation of the temperature of the cube with the heat supplied is shown in the fig. The slope of the part ST of the graph represents :



(a) the latent heat of the vapour
(b) the specific heat of the vapour
(c) the thermal capacity of the vapour
(d) the reciprocal of the thermal capacity

49. The temperature at which phase transition occurs, depends on :
(a) pressure (b) volume
(c) density (d) mass

50. Under some conditions, a material can be heated above or cooled below the normal phase change temperature without a phase change occurring. The resulting state :
(a) may be stable (b) may be unstable
(c) must be stable (d) must be unstable

51. Water at − 10°C is present in a thermally insulated container. The ratio of mass of ice formed and initial mass of water, if a small crystal of ice is thrown into it, will be :
(a) 1/15 (b) 1/17
(c) 2/15 (d) 1/8

52. It takes 20 minutes to melt 10 g of ice, when rays from the sun are focussed by a lens of diameter 5 cm on to a block of ice. The heat received from the sun on 1 cm^2 per minute is : (Given: $L = 80$ k cal/kg)
(a) $R = 2.04$ cal/cm^2-min (b) $R = 3.04$ cal/cm^2-min
(c) $R = 0.204$ cal/cm^2-min (d) $R = 204$ cal/cm^2-min

53. If in 1.1 kg of water which is contained in a calorimeter of water equivalent 0.02 kg at 15°C, steam at 100°C is passed, till the temperature of calorimeter and its contents rises to 80°C. The mass of steam condensed in kilogram is :
(a) 0.131 (b) 0.065
(c) 0.260 (d) 0.135

54. 5 g of water at 30°C and 5 g of ice at − 20°C are mixed together in a calorimeter. The water equivalent of calorimeter is negligible and specific heat and latent heat of ice are 0.5 cal/g°C and 80 cal/g respectively. The final temperature of the mixure is :
(a) 0°C (b) − 8°C
(c) − 4°C (d) 2°C

55. In an energy recycling process, X g of steam at 100°C becomes water at 100°C which converts Y g of ice at 0°C into water at 100°C. The ratio of X/Y will be :
(a) $\dfrac{1}{3}$ (b) $\dfrac{2}{3}$
(c) 3 (d) 2

56. At 30°C, a lead bullet of 50 g, is fired vertically upwards with a speed of 840 m/s. The specific heat of lead is 0.02 cal/g°C. On returning to the starting level, it strikes to a cake of ice at 0°C. The amount of ice melted is: (Assume all the energy is spent in melting only)
(a) 62.7 g (b) 55 g
(c) 52.875 kg (d) 52.875 g

Answers

Level-1

1. (b)	2. (c)	3. (a)	4. (a)	5. (b)	6. (c)	7. (b)	8. (d)	9. (c)	10. (d)
11. (b)	12. (c)	13. (c)	14. (a)	15. (a)	16. (b)	17. (b)	18. (c)	19. (a)	20. (c)
21. (d)	22. (a)								

Level-2

1. (c)	2. (a)	3. (b)	4. (b)	5. (b)	6. (d)	7. (a)	8. (a)	9. (c)	10. (a)
11. (b)	12. (b)	13. (c)	14. (a)	15. (d)	16. (c)	17. (a)	18. (b)	19. (a)	20. (a)
21. (a)	22. (a)	23. (c)	24. (a)	25. (b)	26. (c)	27. (d)	28. (b)	29. (c)	30. (a)
31. (b)	32. (b)	33. (a)	34. (b)	35. (b)	36. (a)	37. (d)	38. (c)	39. (a)	40. (b)
41. (b)	42. (c)	43. (b)	44. (a)	45. (c)	46. (a)	47. (a)	48. (d)	49. (a)	50. (d)
51. (d)	52. (a)	53. (a)	54. (a)	55. (a)	56. (d)				

Solutions

Level-1

6. $L = L_0(1 + \alpha\,\Delta\theta)$

$$10 = L_0(1 + 20\alpha)$$

and $L' = L_0(1 + 19\alpha)$

$$\frac{L'}{10} = \frac{1 + 19\alpha}{1 + 20\alpha} = \frac{1 + 19(11 \times 10^{-6})}{1 + 20(11 \times 10^{-6})}$$

Solving, we get $L' = 9.99989$ cm

L' is shorter by $(10 - 9.99989) = 0.00011$ cm

$$= 11 \times 10^{-5}\text{ cm}$$

8. Time difference per day

$$= \frac{1}{2}\alpha(\theta_2 - \theta_1) \times 86400\text{ sec}$$

$$= \frac{1}{2} \times 10^{-5}(40° - 20°) \times 86400$$

$$= 8.64\text{ sec}$$

14. $d_2 = d_1[1 - \gamma(t_2 - t_1)]$;

$$7.25 = 7.5(1 - \gamma \times 100)$$

$$\therefore \quad \gamma = \frac{7.5 - 7.25}{7.5 \times 100} = 333 \times 10^{-6}$$

$$\therefore \quad \alpha = \frac{\gamma}{3} = \frac{333 \times 10^{-6}}{3}$$

$$= 111 \times 10^{-6}/°\text{C}$$

20. $V = V_0(1 + \gamma\theta)$

$$L^3 = L_0(1 + \alpha_1\,\Delta\theta)\,L_0^2(1 + \alpha_2\,\Delta\theta)^2$$

$$1 + \gamma\,\Delta\theta = (1 + \alpha_1\,\Delta\theta)(1 + \alpha_2\,\Delta\theta)^2 \quad [\because L^3 = L_0^3(1 + \gamma\,\Delta\theta)]$$

$$\therefore \quad \gamma = \alpha_1 + 2\alpha_2$$

22. $Q = \dfrac{KA(\theta_2 - \theta_1)t}{d}$

$$= 0.1 \times \frac{22}{7} \times 1 \times \frac{70 \times 300}{22}$$

$$= 300\text{ cal}$$

Level-2

1. Since, $T = 273 + t$
where T = temperature in kelvin
and t = temperature in centrigrade
Hence, $T \neq t$
Hence, (c) is correct.

2. $\Delta T_C = 90° - 30°\text{C} = 60°\text{C}$

$$\Delta T_F = \frac{9}{5}\Delta T_C = \frac{9}{5}(60°) = 108°\text{F}$$

$$\Delta T = \Delta T_C$$

$$= 60\text{ K.}$$

16

Physics for Gaseous State

Syllabus: Thermal expansion in gases, ideal gas laws.

Review of Concepts

1. Ideal gas equation:

(a) $PV = nRT$

(b) $P = \frac{\rho RT}{M}$

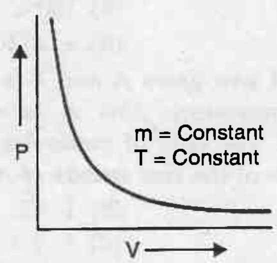
Here R = universal gas constant = 8.31 joule/mol-K

2. Gas laws :

(a) Boyle's law:

$$PV = \text{constant}$$

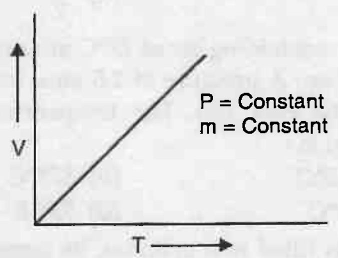
In general, $P_1V_1 = P_2V_2 = \ldots$



(b) Charle's law:

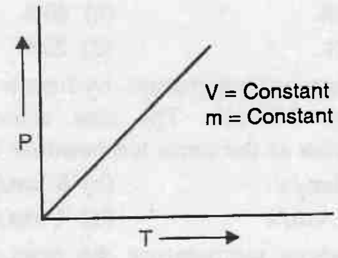
$$\frac{V}{T} = \text{constant}$$

In general, $\frac{V_1}{T_1} = \frac{V_2}{T_2} = \ldots$



(c) Gay Lussac's law:

$$\frac{P}{T} = \text{constant}$$



3. Different types of speeds of gas molecules :

(a) **RMS speed :**

$$v_{rms} = \sqrt{\left(\frac{v_1^2 + v_2^2 + \ldots + v_N^2}{N}\right)} = \sqrt{\bar{v}^2}$$

and according to kinetic theory of gases,

$$v_{rms} = \sqrt{\left(\frac{3PV}{M}\right)} = \sqrt{\left(\frac{3kT}{m}\right)}$$

(b) **Most probable speed :**

$$v_{mp} = \sqrt{\left(\frac{2RT}{M}\right)} = \sqrt{\left(\frac{2}{3}\right)} v_{rms}$$

(c) **Average speed :**

(i) $v_{av} = \frac{v_1 + v_2 + v_3 + \ldots + v_N}{N}$

(ii) $v_{av} = \sqrt{\left(\frac{8RT}{\pi M}\right)} = \sqrt{\left(\frac{8}{3\pi}\right)} v_{rms}$

(iii) $v_{mp} < v_{av} < v_{rms}$

Some important points concerning kinetic theory of gases :

(a) Pressure P exerted by an ideal gas is given by

$$P = \frac{1}{3}\frac{mN}{V}\bar{v}^2 = \frac{2}{3}\bar{E}$$

where $\bar{v}^2$ is the mean square velocity $\left(= \frac{v_1^2 + v_2^2 + \ldots}{N}\right)$

(b) Mean kinetic energy per gram mole of a gas is given by

$$E_{mole} = \frac{3}{2}kTN = \frac{3}{2}RT$$

(c) Average translational K.E. of gas molecules depends only on its temperature and is independent of its nature.

(d) (i) Mean free path is the average distance travelled by a gas molecule between two successive collisions and is given by

$$\lambda = \frac{1}{\sqrt{2}\,\pi d^2 n}$$

where d is the diameter of molecules and n is the number of molecules per unit volume.

(ii) The mean free path for air molecules at NTP is 0.01 μm.

(e) The internal energy of μ moles of a gas in which each molecule has f degrees of freedom, will be

$$U = \frac{1}{2}\mu f Rt$$

(i) For monoatomic gas, $f = 3$, so, $U = \frac{3}{2}\mu RT$

(ii) For diatomic gas, $f = 5$, so, $U = \frac{5}{2}\mu RT$

(iii) For polyatomic gas, $f = 6$, so, $U = \frac{6}{2}\mu RT$

Objective Questions

Level-1

1. Kinetic theory of gases provides a base for :
(a) Charles' law
(b) Boyle's law
(c) Charles' law and Boyle's law
(d) none of the above

2. The vapour of a substance behaves as a gas :
(a) below critical temperature
(b) above critical temperature
(c) at 100°C
(d) at 1000°C

3. Gas exerts pressure on the walls on the container because :
(a) gas has weight
(b) gas molecules have momentum
(c) gas molecules collide with each other
(d) gas molecules collide with the walls of the container

4. The temperature of an ideal gas is increased from 27°C to 927°C. The root mean square speed of its molecules becomes :
(a) twice (b) half
(c) four times (d) one-fourth

5. 4 moles of an ideal gas is at 0°C. At constant pressure it is heated to double its volume, then its final temperature will be :
(a) 0°C (b) 273°C
(c) 546°C (d) 136.5°C

6. In a gas of diatomic molecules, the ratio of the two specific heats of gas $\frac{C_P}{C_V}$ is :
(a) 1.66 (b) 1.40
(c) 1.33 (d) 1.00

7. Four molecules of a gas are having speeds 1, 4, 8 and 16 ms^{-1}. The root mean square velocity of the gas molecules is :
(a) 7.25 ms^{-1} (b) 52.56 ms^{-1}
(c) 84.25 ms^{-1} (d) 9.2 ms^{-1}

8. At 0°C the value of the density of fixed mass of an ideal gas divided by its pressure is x. At 100°C, this quotient is :
(a) $\frac{100}{273}x$ (b) $\frac{273}{100}x$
(c) $\frac{273}{373}x$ (d) $\frac{373}{273}x$

9. If $P = 10^6 KT$, then the number of molecules per unit volume of the gas is :
(a) 1 (b) 10^2
(c) 10^3 (d) 10^6

10. The mean kinetic energy per mole of an ideal gas at 0°C is approximately :
(a) 3.4 J (b) 3.4×10^2 J
(c) 3.4×10^3 J (d) 207 J

11. At what temperature the KE of gas molecule is half that of its value at 27°C ?
(a) 13.5°C (b) 150°C
(c) 150 K (d) −123 K

12. A mixture of two gases A and B is in a container at a constant temperature. Gas A is diatomic and B is monoatomic. The ratio of molecular masses of A and B is 4, the ratio of the rms speeds of A and B is :
(a) 1 : 1 (b) $1 : \sqrt{2}$
(c) $\sqrt{2} : 1$ (d) 1 : 2

13. A gas in a vessel is at the pressure P_0. If the masses of all the molecules be made half and their speed be made double, then the resultant pressure will be :
(a) $4P_0$ (b) $2P_0$
(c) P_0 (d) $\frac{P_0}{2}$

14. A flask containing air at 27°C at atmospheric pressure is corked up. A pressure of 2.5 atm. inside the flask would force the cork out. The temperature at which it will happen, is :
(a) 67.5°C (b) 577°C
(c) 670°C (d) 750 K

15. A gas is filled in a cylinder. Its temperature is increased by 20% on kelvin scale and volume is reduced by 10%. How much percentage of the gas has to leak for pressure to remain constant ?
(a) 30% (b) 40%
(c) 15% (d) 25%

16. At a certain temperature, hydrogen molecules have rms velocity 2 km/s. The rms velocity of the oxygen molecules at the same temperature is :
(a) 2 km/s (b) 8 km/s
(c) 0.5 km/s (d) 1 km/s

17. At a given temperature the ratio of rms velocities of hydrogen molecules and helium atoms will be :

(a) $\sqrt{2}:1$ (b) $1:\sqrt{2}$
(c) $1:2$ (d) $2:1$

18. The root mean square velocity of hydrogen molecule at 27°C is v_H and that of oxygen at 402°C is v_0 then :
(a) $v_0 > v_H$ (b) $4v_0 = 9v_H$
(c) $8v_0 = 3v_H$ (d) $9v_0 = 134v_H$

19. The rms speed of the molecules of a gas in a vessel is 400 m/s. If half of the gas leaks out at constant temperature, the rms speed of the remaining molecules will be :
(a) 800 m/s (b) $400\sqrt{2}$ m/s
(c) 400 m/s (d) 200 m/s

20. 22 g of CO_2 at 27°C is mixed with 16 g of O_2 at 37°C. The temperature of the mixture is :
(a) 32°C (b) 27°C
(c) 37°C (d) 30.5°C

21. Maximum density of H_2O is at the temperature :
(a) 32°F (b) 39.2°F
(c) 42°F (d) 4°F

22. The respective speeds of five molecules are 2, 1.5, 1.6, 1.6 and 1.2 km/s, the most probable speed in km/s will be :
(a) 2 (b) 1.58
(c) 1.6 (d) 1.31

23. The average translational kinetic energy of O_2 (molar mass 32) molecules at a particular temperature is 0.048 eV. The translational kinetic energy of N_2 (molar mass 28) molecules in eV at the same temperature is :
(a) 0.0015 (b) 0.003
(c) 0.048 (d) 0.768

24. The molecular weight of gas is 44. The volume occupied by 2.2 g of this gas at 0°C and 2 atm. pressure, will be :
(a) 0.56 litre (b) 1.2 litre
(c) 2.4 litre (d) 5.6 litre

25. The average kinetic energy of a gas molecule at 27°C is 6.21×10^{-21} J. Its average kinetic energy at 227°C will be :
(a) 52.2×10^{-21} J (b) 5.22×10^{-21} J
(c) 10.35×10^{-21} J (d) 11.35×10^{-21} J

26. At constant temperature on increasing the pressure of a gas by 5%, the gas will decrease in its volume by :
(a) 5% (b) 5.26%
(c) 4.26% (d) 4.76%

Level-2

1. A gas behaves more closely as an ideal gas at :
(a) low pressure and low temperature
(b) low pressure and high temperature
(c) high pressure and low temperature
(d) high pressure and high temperature

2. In troposphere, temperature varies linearly with elevation as $T = T_0 - ay$, where T_0 is the temperature at the earth's surface, then :
(a) the pressure does not change with elevation in troposphere
(b) the variation of pressure with elevation is linear
(c) the dimension of a is $[M^0L^{-1}\theta]$
(d) the pressure is independent of variation with temperature in the given situation

3. A vessel contains a mixture of nitrogen of mass 7 g and carbon dioxide of mass 11 g at temperature 290 K and pressure 1 atm. The density of the mixture is :
(a) 1.1 g/L (b) 1.2 g/L
(c) 1.515 g/L (d) 1.6 g/L

4. Two chambers, one containing 'm_1' g of a gas at 'P_1' pressure and other containing 'm_2' g of a gas at 'P_2' pressure, are put in communication with each other. If temperature remains constant, the common pressure reached will be :
(a) $\dfrac{P_1P_2(m_1+m_2)}{P_2m_1+P_1m_2}$ (b) $\dfrac{m_1m_2(P_1+P_2)}{(P_2m_1+P_1m_2)}$
(c) $\dfrac{P_1P_2m_1}{P_2m_1+P_1m_2}$ (d) $\dfrac{m_1m_2P_2}{(P_2m_1+m_2P_1)}$

5. 12 g of gas occupy a volume of 4×10^{-3} m^3 at a temperature of 7°C. After the gas is heated at constant pressure, its density becomes 6×10^{-4} g/cm^3. What is the temperature to which the gas was heated ?
(a) 1000 K (b) 1400 K
(c) 1200 K (d) 800 K

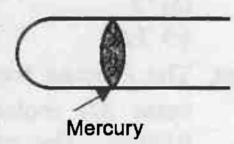
6. A closed vessel with a capacity of 1 m^3 contains 0.9 kg of water and 1.6 kg of O_2. The pressure in the vessel at a temperature of 500°C at which all the water will be converted into steam, is :
(a) 3.2×10^5 N/m^2 (b) 6.4×10^5 N/m^2
(c) 1.6×10^5 N/m^2 (d) 9.6×10^5 N/m^2

7. The pressure of a gas kept in an isothermal container is 200 kPa. If half the gas is removed from it, the pressure will be :
(a) 100 kPa (b) 200 kPa
(c) 400 kPa (d) 800 kPa

8. Let 'T_a' and 'T_b' be the final temperatures of the samples A and B respectively in the previous question, then
(a) $T_a < T_b$
(b) $T_a = T_b$
(c) $T_a > T_b$
(d) the relation between T_a and T_b cannot be deduced

9. The critical volume of a gas obeying van der Waal's equation is :
(a) $\dfrac{8a}{27R_b}$ (b) $\dfrac{a}{27b^2R}$
(c) $3b$ (d) $\dfrac{a}{27Rb}$

10. A uniform tube is shown in figure which is open at one end and closed at the other. To enclose a column of air inside the tube, a pellet of mercury is introduced. If the length of air column at 27°C is 18 cm, at what temperature its length will be 21.6 cm?



(a) 87°C (b) 91°C
(c) 85°C (d) 97°C

11. How many cylinders of hydrogen at atmospheric pressure are required to fill a balloon whose volume is 500 m^3, if hydrogen is stored in cylinders of volume 0.05 m^3 at an absolute pressure of 15×10^5 Pa?
(a) 700 (b) 675
(c) 605 (d) 710

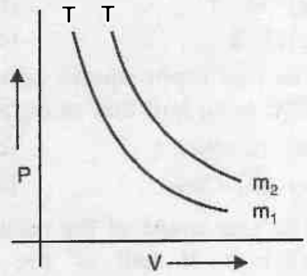
12. Two identical containers A and B have frictionless pistons. Both contain same volume of ideal gas at same temperature. The gas in each cylinder is allowed to expand isothermally to double the initial volume. The mass of the gas in A is m_A and the mass of the gas in B is m_B. The changes in the pressure in A and B are ΔP and $1.5\,\Delta P$ respectively, then:
(a) $4m_A = 9m_B$ (b) $2m_A = 3m_B$
(c) $3m_A = 2m_B$ (d) $9m_A = 4m_B$

13. Two gases A and B are contained in the same vessel which is at temperature T. The number of molecules of gas A is 'N' and mass of each is 'm'. The number of molecules of gas 'B' is $2N$, each of mass ($2m$). If mean square volocity of molecules of 'B' is v^2 and mean square velocity of x component of the velocity of 'A' type is given by 'ω^2' then ω^2/v^2 is:
(a) 2 (b) 1
(c) $\frac{1}{3}$ (d) $\frac{2}{3}$

14. When without change in temperature, a gas is forced in a smaller volume, its pressure increases because its molecules:
(a) strike the unit area of the container wall more often
(b) strike the unit area of the container wall at higher speed
(c) strike the unit area of container wall with greater force
(d) have more energy

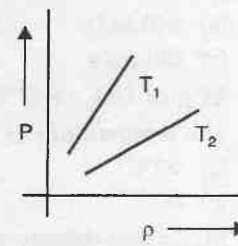
15. 'n' molecules of a gas are enclosed in a cubical vessel of edge length l, then pressure exerted by the gas if each molecule has mass 'm' and rms speed (v), is:
(a) $\frac{mnv^2}{l^3}$ (b) $\frac{nm^2r}{2l^3}$
(c) $\frac{nmv^2}{3l^3}$ (d) $\frac{nm^2r}{2l}$

16. The figure shows, the P-V diagram of two different masses m_1 and m_2 drawn at constant temperature T, then:



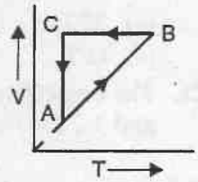
(a) $m_1 > m_2$
(b) $m_2 > m_1$
(c) $m_1 = m_2$
(d) insufficient data

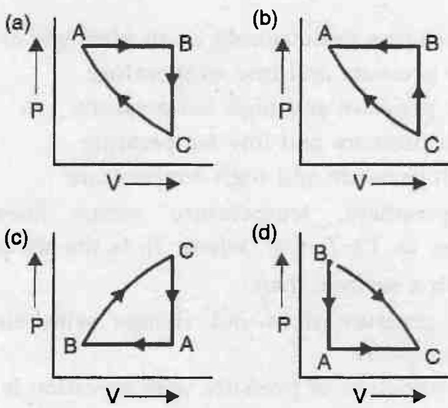
17. Figure shows graph of pressure versus density for an ideal gas at two temperatures T_1 and T_2. Then:



(a) $T_1 > T_2$
(b) $T_1 = T_2$
(c) $T_1 < T_2$
(d) any three is possible

18. A cyclic process $ABCA$ is shown in a V-T diagram, the corresponding P-V diagram is:





19. The pressure of an ideal gas is written as $P = \frac{2E}{3V}$, here E refers to:
(a) translational kinetic energy
(b) rotational kinetic energy
(c) vibrational kinetic energy
(d) total kinetic energy

20. A gas is contained in a closed vessel at 250K, then the percentage increase in pressure, if the gas is heated through 1°C, is:
(a) 0.4% (b) 0.6%
(c) 0.8% (d) 1.0%

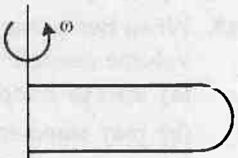
21. What volume will be occupied by the molecules contained in 4.5 kg water at STP, if the intermolecular forces vanish away?
(a) 5.6 m^3 (b) 4.5 m^3
(c) 11.2 m^3 (d) 5.6 L

22. The highest temperature of the gas, attained if the pressure of ideal gas varies according to the law, $P = P_0 - aV^2$, where P_0 and 'a' are constants, is :

(a) $T_{max} = \frac{3P_0}{2nR}\left(\frac{P_0}{3a}\right)^{1/2}$ (b) $T_{max} = \frac{2}{3}\frac{P_0}{nR}\left(\frac{P_0}{3a}\right)^{1/2}$

(c) $T_{max} = \frac{P_0}{3nR}\left(\frac{P_0}{3a}\right)^{1/2}$ (d) none of these

∗ 23. A horizontal cylinder open from one end and closed from the other, is rotated with a constant angular velocity 'ω' about a vertical axis passing through its open end. If outside air pressure is P_0, the temperature is T, and the molar mass of air is m, then find the air pressure as a function of the distance 'r' from the rotational axis, : (Assume molar mass is independent of r) :



(a) $P = P_0\, e^{(m\omega^2 r^2/2RT)}$ (b) $P = P_0 e^{(m\omega^2 r^2/RT)}$

(c) $P = P_0 e^{-m\omega^2 r^2/RT}$ (d) $P = P_0 e^{-m\omega^2 r^2/2RT}$

24. The pressure exerted by 6×10^{23} hydrogen molecules which will strike per second a wall of area 10^{-4} m^2 at 60° with normal if the mass of hydrogen molecules and speed are 3.32×10^{-27} kg and 10^3 m/s respectively is :

(a) 19.92×10^3 m/s (b) 18.2×10^3 m/s

(c) 1.992×10^3 m/s (d) 0.1992×10^3 m/s

25. Mark correct option/s :

(a) The root mean square speeds of the molecules of different ideal gases, maintained at the same temperature are the same

(b) Electrons in a conductor have no motion in the absence of a potential difference across it

(c) One mole of a monoatomic ideal gas is mixed with one mole of a diatomic ideal gas The molar specific heat of the mixture at constant volume is $2R$

(d) The pressure exerted by an enclosed ideal gas depends on the shape of the container

26. Four molecules of a gas have speeds 1, 2, 3 and 4 km/s. The value of the root-mean square speed of the gas molecules is :

(a) $\frac{1}{2}\sqrt{15}$ km/s (b) $\frac{1}{2}\sqrt{10}$ km/s

(c) 2.5 km/s (d) $\sqrt{\frac{15}{2}}$ km/s

27. The temperature of H_2 at which the rms velocity of its molecules is seven times the rms velocity of the molecules of nitrogen at 300 K, is

(a) 2100 K (b) 1700 K

(c) 1350 K (d) 1050 K

28. Choose the correct order of the root mean square velocity (v_{rms}), the average velocity (v_{av}) and the most probable velocity (v_{mp}) :

(a) $v_{mp} > v_{av} > v_{rms}$ (b) $v_{rms} > v_{av} > v_{mp}$

(c) $v_{av} > v_{mp} > v_{rms}$ (d) $v_{mp} > v_{rms} > v_{av}$

29. Five gas molecules chosen at random are found to have speeds of 500, 600, 700, 800 and 900 m/s. Then :

(a) the rms speed and the average speed are the same

(b) the rms speed is 14 m/s higher than the average speed

(c) the rms speed is 14 m/s lower than that the average speed

(d) the rms speed is $\sqrt{14}$ m/s higher than that the average speed.

30. In case of molecules of an ideal gas, which of the following, average velocities cannot be zero ?

(a) $<\bar{v}>$ (b) $<\bar{v}^3>$

(c) $<\bar{v}^4>$ (d) $<\bar{v}^5>$

31. Choose the correct relation between the rms speed (v_{rms}) of the gas molecules and the velocity of sound in that gas (v_s) in identical situations of pressure and temperature :

(a) $v_{rms} = v_s$ (b) $v_{rms} = \sqrt{\left(\frac{3}{\gamma}\right)}\, v_s$

(c) $v_{rms} = \sqrt{\left(\frac{\gamma}{3}\right)}\, v_s$ (d) $\gamma\, v_{rms} = 3v_s$

32. At what temperature is the effective speed of gaseous hydrogen molecules equal to that of oxygen molecules at 47°C ?

(a) 50 K (b) 20 K

(c) 40 K (d) 100 K

33. How many times the molecules of a diatomic gas is expanded to reduce the root mean square velocity of the molecules to 20/30 of the initial value?

(a) 2 times (b) 3 times

(c) 1.5 times (d) 2.5 times

34. Which of the following quantities is zero on an average for the molecules of an ideal gas in equilibrium?

(a) Kinetic energy (b) Momentum

(c) Density (d) Speed

35. On a fast moving train, a container is placed enclosing some gas at 300 K, while the train is in motion, the temperature of the gas

(a) rises above 300 K (b) falls below 300 K

(c) remains unchanged (d) becomes unsteady

36. If at a pressure of 10^6 dyne/cm^2, one gram mole of nitrogen occupies 2×10^4 c.c. volume, then the average energy of a nitrogen molecules in erg is :

(Given: Avogadro's number $= 6 \times 10^{23}$)

(a) 14×10^{-13} (b) 10×10^{-12}

(c) 10^6 (d) 2×10^6

37. The temperature at which average translational K.E. of a molecule is equal to the K.E. of an electron accelerated from rest through a potential difference of 1 V, is :

(a) $T = 7729$ K (b) $T = 8879$ K

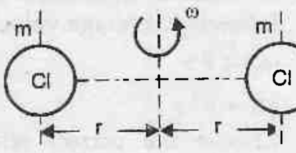
(c) $T = 7.72$ K (d) $T = 772.9$ K

38. The temperature of the mixture, if two perfectly monoatomic gases at absolute temperatures T_1 and T_2 and number of moles in the gases n_1 and n_2, respectively are mixed, is : (Assume no loss of energy)

(a) $T = \dfrac{n_1T_2 + n_2T_1}{n_1 + n_2}$ (b) $T = \dfrac{n_1T_2 - n_2T_1}{n_1 + n_2}$

(c) $T = \dfrac{n_1T_1 + n_2T_2}{n_1 + n_2}$ (d) $T = \dfrac{n_1T_1 - n_2T_2}{n_1 - n_2}$

39. In a model of chlorine (Cl_2), two Cl atoms are rotated about their centre of mass as shown. Here the two 'Cl' atoms are 2×10^{-10} m apart and angular speed $\omega = 2 \times 10^{12}$ rad/s. If the molar mass of chlorine is 70 g/mol, then what is the rotational kinetic energy of one Cl_2 molecule ?



(a) $2{\cdot}32 \times 10^{-20}$ J (b) $2{\cdot}32 \times 10^{-21}$ J

(c) $2{\cdot}32 \times 10^{-19}$ J (d) $2{\cdot}32 \times 10^{-22}$ J

40. If the temperature of 3 moles of helium gas is increased by 2 K., then the change in the internal energy of helium gas is :

(a) 70.0 J (b) 68.2 J

(c) 74.8 J (d) 78.2 J

41. At 20°C temperature, an argon gas at atmospheric pressure is confined in a vessel with a volume of 1 m^3. The effective hard-sphere diameter of argon atom is 3.10×10^{-10} m. Its mean free path is :

(a) 100 nm (b) 90 nm

(c) 93.6 nm (d) 95 nm

42. Increase of pressure :

(a) always increases the boiling point of a liquid

(b) always increases the melting point of a solid

(c) increases the melting point of solid which expand on melting

(d) always decreases the melting point of solid

43. When two gases combine in a chemical reaction, then the volume needed :

(a) always stand in simple integral proportion

(b) may stand in simple integral proportion

(c) always stand in fractional proportion

(d) may stand in fractional proportion

44. Unsaturated vapour obeys :

(a) Ideal gas law (b) van der Waal's law

(c) Boyle's law (d) Gay-Lussac law

45. In the case of saturated vapour :

(a) pressure depends upon volume at constant temperature

(b) pressure varies non-linearly with temperature at constant volume

(c) pressure becomes less than one atmosphere at boiling point

(d) pressure varies linearly with temperature at constant volume

Answers

Level-1

1. (c)	2. (b)	3. (d)	4. (a)	5. (b)	6. (b)	7. (d)	8. (c)	9. (d)	10. (c)
11. (c)	12. (d)	13. (b)	14. (d)	15. (d)	16. (c)	17. (a)	18. (c)	19. (c)	20. (a)
21. (b)	22. (d)	23. (c)	24. (a)	25. (c)	26. (d)				

Level-2

1. (b)	2. (c)	3. (c)	4. (a)	5. (b)	6. (b)	7. (a)	8. (a)	9. (c)	10. (a)
11. (b)	12. (c)	13. (d)	14. (a)	15. (c)	16. (b)	17. (a)	18. (a)	19. (a)	20. (a)
21. (a)	22. (b)	23. (a)	24. (a)	25. (c)	26. (d)	27. (d)	28. (b)	29. (b)	30. (c)
31. (b)	32. (b)	33. (a)	34. (b)	35. (a)	36. (a)	37. (a)	38. (c)	39. (b)	40. (c)
41. (c)	42. (c)	43. (a)	44. (a)	45. (b)					

Solutions

Level-1

7. $c = \sqrt{\dfrac{1^2 + 4^2 + 8^2 + 16^2}{4}}$ ms^{-1} $= 9.178 \approx 9.2$ ms^{-1}

9. $$PV = \mu RT = \frac{n}{N} kNT = nkT$$

or $$\frac{n}{V} = \frac{P}{kT} = \frac{10^6\, kT}{kT} = 10^6$$

10. Mean kinetic energy per mol $= \dfrac{3}{2}RT$

$$= \frac{3}{2} \times 8.3 \times 273 = 3.4 \times 10^3 \text{ J}$$

11. $$\frac{T}{300} = \frac{1}{2}$$

$\therefore$ $T = 150$ K

17

Laws of Thermodynamics

Syllabus: Specific heat of gases, relation between C_P and C_V for gases, first law of thermodynamics, thermodynamic processes, second law of thermodynamics, Carnot cycle, efficiency of heat engine.

Review of Concepts

1. Zeroth law of thermodynamics : When two bodies A and B are in thermal equilibrium with a third body C separately, then A as well as B are in thermal equilibrium mutually, *i.e.*, if $T_A = T_C$ and $T_B = T_C$, then $T_A = T_B$.

2. First law of thermodynamics :

$$\Delta H = \Delta U + \Delta W$$

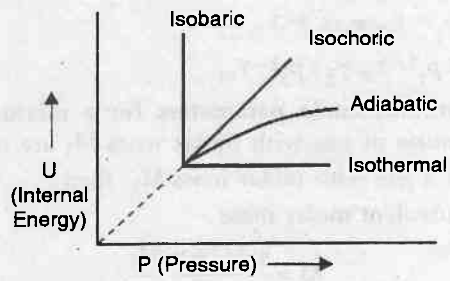
Here, ΔH = heat supplied to the system,

ΔU = change in internal energy

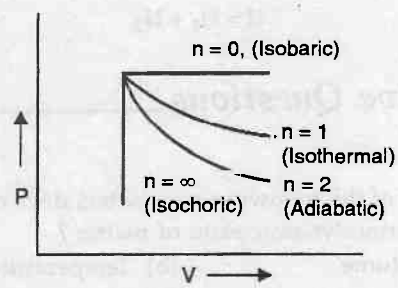
ΔW = work done by gas

Some important points :

- Work is path dependent in thermodynamics.
- Work is taken as positive when system expands against external force
- $W = \int PdV$
- The area of P-V diagram gives work done
- In cyclic process, work done is area of P-V diagram cycle. It is positive when process is clockwise. It is negative when process is anticlockwise.
- The change in internal energy is independent of path. It depends only on initial and final states.
- For ideal gas $\Delta U = nC_V \Delta T$



- If PV^n = constant.



3. Thermodynamic processes :

S. No.	Process	Law applicable	Quantity remains constant	ΔU	ΔW	$\Delta H = \Delta U + \Delta W$
1.	Isochoric	Gay-Lussac's law	Volume	$nC_V dT$	0	$nC_V dT$
2.	Isobaric	Charles' law	Pressure	$nC_V dT$	$P(V_2 - V_1)$	$nC_P dT$
3.	Free expansion	–	Temperature	0	0	0
4.	Throttling process	–	Temperature	0	0	0
5.	Isothermal process	Boyle's law	Temperature	0	$nRT \ln\left(\frac{V_2}{V_1}\right)$	$nRT \ln\left(\frac{V_2}{V_1}\right)$
6.	Adiabatic process	–	PV^γ = constant	$-\Delta W$	$\frac{nR(T_1 - T_2)}{\gamma - 1}$	0
7.	Polytropic process	×	PV^n = constant	$nC_V dT$	$\frac{P_1V_1 - P_2V_2}{(n-1)}$	×
8.	Cyclic process	×	×	0	Area of P-V diagram	ΔW

4. **Molar heat capacity :**

$$C = \frac{\Delta H}{n\Delta T}$$

(a) $C_P - C_V = R$ (b) $\frac{C_P}{C_V} = \gamma$

(c) $\gamma = 1 + \frac{2}{f}$

- For monoatomic, $f = 3$
- For diatomic, $f = 5$
- For polyatomic, $f = 6$

(d) $C_V = \frac{R}{\gamma - 1}$ (e) $C_P = \frac{\gamma R}{\gamma - 1}$

(f) In adiabatic process:

- $P_1V_1^{\gamma} = P_2V_2^{\gamma} = \ldots$
- $T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1} = \ldots$
- $T_1^{\gamma}P_1^{1-\gamma} = T_2^{\gamma}P_2^{1-\gamma} = \ldots$

5. **Thermodynamic parameters for a mixture of gas :** When n_1 moles of gas with molar mass M_1 are mixed with n_2 moles of a gas with molar mass M_2; then

(a) Equivalent molar mass

$$M = \frac{n_1M_1 + n_2M_2}{n_1 + n_2}$$

(b) Internal energy of the mixture

$$U = U_1 + U_2$$

(c) C_V of the mixture

$$C_V = \frac{n_1C_{V_1} + n_2C_{V_2}}{n_1 + n_2}$$

(d) C_P of the mixture

$$C_P = \frac{n_1C_{P_1} + n_2C_{P_2}}{n_1 + n_2}$$

(e) γ of the mixture

$$\frac{n_1 + n_2}{\gamma - 1} = \frac{n_1}{\gamma_1 - 1} + \frac{n_2}{\gamma_2 - 1}$$

6. **Second law of thermodynamics :**

(a) **Kelvin's statement :** It is impossible for a engine in a cyclic process to extract heat from a reservoir and convert it completely into work *i.e.*, a perfect heat engine can never be constructed.

(b) **Clausius statement :** It is impossible for a self-acting device unaided by any external agency to transfer heat from cold body to hot body *i.e.*, heat by itself cannot pass from a colder to hotter body.

7. **Heat engine :**

$$\text{Efficiency} = \eta = 1 - \frac{\Delta H_2}{\Delta H_1} = 1 - \frac{T_2}{T_1}$$

8. **Refrigerator :**

$$\text{Coefficient of performance} = \frac{\Delta H_2}{\Delta H_1 - \Delta H_2} = \frac{T_2}{T_1 - T_2}$$

Objective Questions

Level-1

1. Which of the following parameters does not characterize the thermodynamic state of matter ?
(a) Volume (b) Temperature
(c) Pressure (d) Work

2. Internal energy of ideal gas depends on :
(a) only pressure (b) only volume
(c) only temperature (d) none of these

3. In a thermodynamic system working substance is ideal gas, its internal energy is in the form of :
(a) kinetic energy only
(b) kinetic and potential energy
(c) potential energy
(d) none of the above

4. The first law of thermodynamics is essentially a statement :
(a) implying that heat cannot flow from a cold body to a hot body
(b) of conservation of energy
(c) that gives the mechanical equivalent of heat
(d) regarding isothermal process

5. If the door of a refrigerator is kept open, then which of following is true ?
(a) Room is cooled
(b) Room is heated
(c) Room is either cooled or heated
(d) Room is neither cooled nor heated

6. The process in which the heat is not transferred from one state to another, is :
(a) isothermal process (b) adiabatic process
(c) isobaric process (d) isochoric process

7. When the pressure of water is increased, the boiling temperature of water as compared to 100°C will be :
(a) lower (b) the same
(c) higher (d) on the critical temperature

8. During an adiabatic process, the pressure of a gas is found to be proportional to the cube of its absolute temperature. The ratio $\frac{C_P}{C_V}$ for the gas is :
(a) $\frac{3}{2}$ (b) $\frac{4}{3}$
(c) 2 (d) $\frac{5}{3}$

9. Compared to a burn due to water at 100°C a burn due to steam at 100°C is :
(a) more dangerous (b) less dangerous
(c) equally dangerous (d) none of these

10. For an isolated system :
(a) volume is constant
(b) pressure is constant
(c) temperature is constant
(d) all of the above

11. The change in internal energy of perfect gas will be :
(a) $C_V \times \Delta\theta$ (b) $C_P \times \Delta\theta$
(c) $(C_P - C_V)\,\Delta\theta$ (d) $(C_P + C_V)\,\Delta\theta$

12. Triple point of water is :
(a) 273.16 °F (b) 273.16 K
(c) 273.16 °C (d) 273.16 R

13. A thermodynamical system is changed from state (P_1, V_1) to (P_2, V_2) by two different processes, the quantity which will remain same will be :
(a) ΔQ (b) ΔQ
(c) $\Delta Q + \Delta W$ (d) $\Delta Q - \Delta W$

14. Work done in converting one gram of ice at – 10°C into steam at 100°C is :
(a) 3045 J (b) 6056 J
(c) 721 J (d) 616 J

15. An ideal gas undergoes an isothermal change in volume with pressure then :
(a) $P^{\gamma}V = \text{constant}$ (b) $PV^{\gamma} = \text{constant}$
(c) $(PV)^{\gamma} = \text{constant}$ (d) $PV = \text{constant}$

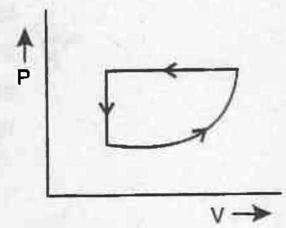
16. The isothermal Bulk modulus of perfect gas at pressure P is given by :
(a) P (b) $2P$
(c) $\frac{P}{2}$ (d) γP

17. In an adiabatic change, the pressure P and temperature T of a monoatomic gas are related by the relation $P \propto T^C$ where C equals :
(a) $\frac{5}{3}$ (b) $\frac{2}{5}$
(c) $\frac{3}{5}$ (d) $\frac{7}{2}$

18. A block of mass 100 g slides on a rough horizontal surface. If the speed of the block decreases from 10 m/s to 5 m/s, the thermal energy developed in the process is :
(a) 3.75 J (b) 37.5 J
(c) 0.375 J (d) 0.75 J

19. If the heat of 110 J is added to a gaseous system and change in internal energy is 40 J, then the amount of external work done is :
(a) 140 J (b) 70 J
(c) 110 J (d) 150 J

20. For one complete cycle of a thermodynamic process on a gas as shown in the P-V diagram, which of following is correct ?



(a) $\Delta E_{int} = 0, Q < 0$
(b) $\Delta E_{int} = 0, Q > 0$
(c) $\Delta E_{int} > 0, Q < 0$
(d) $\Delta E_{int} < 0, Q > 0$

21. Hailstone at 0°C falls from a height of 1 km on an insulating surface converting whole of its kinetic energy into heat. What part of it will melt ? ($g = 10\ \text{m/s}^2$)
(a) $\frac{1}{33}$ (b) $\frac{1}{8}$
(c) $\frac{1}{33} \times 10^{-4}$ (d) All of it will melt

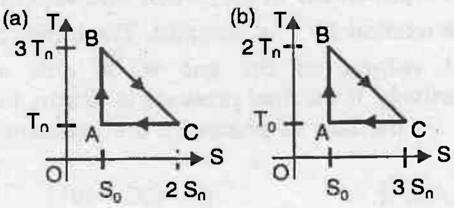
22. A gas expands under constant pressure P from volume V_1 to V_2, the work done by the gas is :
(a) $P\,(V_1 - V_2)$ (b) zero
(c) $P\,(V_1 - V_2)$ (d) $P\left(\frac{V_1 V_2}{V_2 - V_1}\right)$

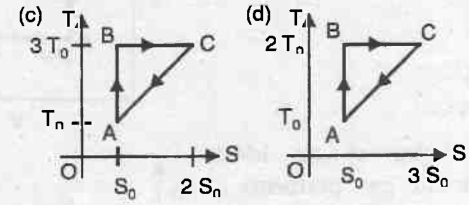
23. The adiabatic elasticity of hydrogen gas ($\gamma = 1.4$) at N.T.P. is :
(a) $1 \times 10^5\ \text{N/m}^2$ (b) $1 \times 10^{-8}\ \text{N/m}^2$
(c) $1.4\ \text{N/m}^2$ (d) $1.4 \times 10^5\ \text{N/m}^2$

Level-2

1. A boy weighing 50 kg eats bananas. The energy content of banana is 1000 cal, if this energy is used to lift the boy from ground, then the height through which he is lifted :
(a) 8.57 m (b) 10.57 m
(c) 6.57 m (d) 5.57 m

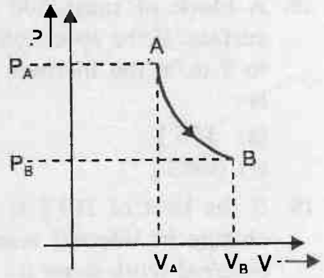
2. Which one of the following reversible cycles, represented by right angled triangles in a T-S diagram, is the least efficient ?





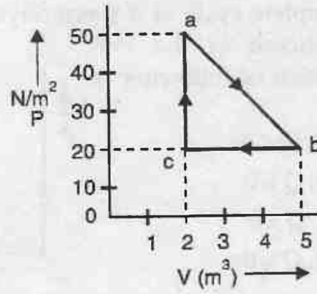
3. An ideal gas is heated at constant pressure and absorbs amount of heat Q. If the adiabatic exponent is γ, then the fraction of heat absorbed in raising the internal energy and performing the work, is :
(a) $1 - \frac{1}{\gamma}$ (b) $1 + \frac{1}{\gamma}$
(c) $1 - \frac{2}{\gamma}$ (d) $1 + \frac{2}{\gamma}$

4. The work done (W_{AB}) by the gas, if 5 moles of an ideal gas is carried by a quasi state isothermal process at 500 K to twice its volume, is :



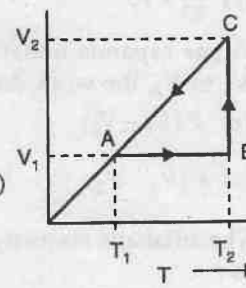
(a) 1500 J
(b) 14407 J
(c) 13380 J
(d) 14890 J

5. The work done for the cycle shown in given figure, will be :



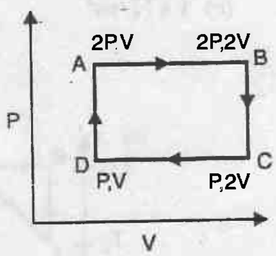
(a) 45 J (b) 54 J
(c) 22.5 J (d) 32.5 J

6. A cyclic process for 1 mole of an ideal gas is shown in the *V-T* diagram. The work done in *AB*, *BC* and *CA* respectively are :



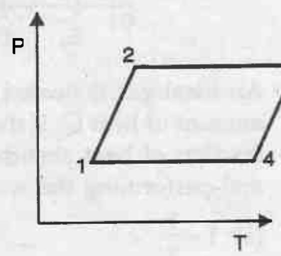
(a) $0, RT_1 \ln \left|\frac{V_1}{V_2}\right|, R(T_1 - T_2)$
(b) $R(T_1 - T_2), R, RT_1 \ln \left|\frac{V_1}{V_2}\right|$
(c) $0, RT_2 \ln \left|\frac{V_2}{V_1}\right|, \frac{RT_1}{V_1}(V_1 - V_2)$
(d) $0, RT_2 \ln \left|\frac{V_1}{V_2}\right|, R(T_2 - T_1)$

7. An ideal monoatomic gas is taken around the cycle *ABCDA* as shown in the *P-V* diagram. The work done during cycle is given by :



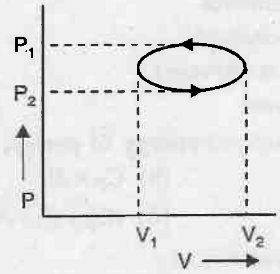
(a) $\frac{1}{2}PV$
(b) PV
(c) $2PV$
(d) $4PV$

8. Three moles of an ideal monoatomic gas performs a cycle as shown in the fig. The gas temperature in different states are $T_1 = 400\text{K}$, $T_2 = 800\text{K}$, $T_3 = 2400\text{K}$, $T_4 = 1200\text{K}$. What is the work done by the gas during the cycle ?



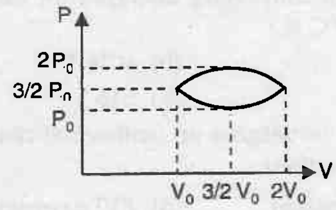
(a) 10 kJ (b) 20 kJ
(c) 5 kJ (d) 8.3 kJ

9. In the given elliptical *P-V* diagram :



(a) the work done is positive
(b) the change in internal energy is non- zero
(c) the work done $= -\frac{\pi}{4}(P_2 - P_1)(V_2 - V_1)$
(d) the work done $= \pi(V_2 - V_1)^2 = \pi(P_2 - P_1)^2$

10. A mass of monoatomic gas is taken through a cycle as indicated in the diagram. The efficiency of the cycle is :



(a) $\frac{2}{12 - \pi}$ (b) $\frac{2\pi}{12 + \pi}$
(c) $\frac{2\pi}{24 - \pi}$ (d) $\frac{1}{12 - \pi}$

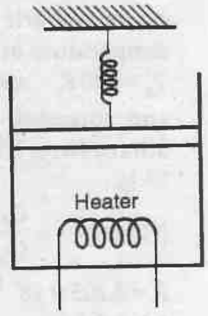
11. A balloon that is initially flat, is inflated by filling it from a tank of compressed air. The final volume of the balloon is 5 m^3. The barometer reads 95 kPa. The work done in this process is :
(a) 475×10^5 J (b) 4.75×10^7 J
(c) 4.75×10^3 J (d) 4.75×10^5 J

12. What work will be done, when 3 moles of an ideal gas are compressed to half the initial volume at a constant temperature of 300 K ?
(a) – 5188 J (b) 5000 J
(c) 5188 J (d) – 5000 J

13. Two moles of an ideal gas at a temperature of $T = 273$ K was isothermally expanded 4 times the initial volume and then heated isochorically, so that the final pressure becomes equal to the initial pressure. The ratio of molar specific heat capacities if total amount of heat imparted to the gas equals $Q = 27.7$ kJ, is :
(a) 1.63 (b) 1.66
(c) 2.63 (d) 1.49

14. A gas is contained in a cylinder and expands according to the relation $PV^{1.3} =$ constant. The initial pressure and initial volume of the gas is 30 atm and 30 mm^3 respectively. If the final pressure is 15 atm, then the work done on the face of piston by the pressure force of the gas, is :
(a) 5×10^4 J (b) 4.35×10^4 J
(c) 3×10^4 J (d) 4×10^4 J

*15. Two moles of an ideal monoatomic gas is confined in a cylinder by a spring loaded piston of cross-section area 4×10^{-3} m^2. Initially the spring of spring constant $k = 1920$ N/m is in its relaxed state. Now, the gas was heated by an electric heater, placed inside the cylinder, for some time and due to which gas expands and does 50 J of work in moving piston through a distance of 0.1 m. The temperature of the gas increases by 50 K. Assume piston and spring to be massless and there is no friction between the piston and the cylinder. Heat supplied by the heater:



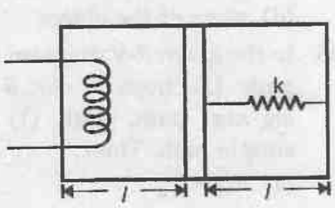
(a) 1295 J (b) 1200 J
(c) 1195 J (d) 1350 J

16. One mole of an ideal gas is enclosed in a conducting vertical cylinder under a light piston. If isothermally the volume of the gas is increased n times, then the work done in increasing the volume is: [Assume atmospheric pressure is P_0 and temperature is T_0]
(a) $RT_0 \log_e n$
(b) $-RT_0 \log_e n$
(c) $RT_0 \log_e n - (n-1) RT_0$
(d) $(n-1) RT_0 - RT_0 \log_e n$

17. If we consider molecules of an ideal gas in a box with a frictionless piston and now the box is heated and piston moves slowly outwards, then:
(a) the force on piston is due to molecular collision with piston
(b) the molecules collide with piston and return back with same speed
(c) the molecular collision with piston is inelastic
(d) both (a) and (b) are correct

18. A vertical cylinder is divided into two parts by a frictionless piston in the ratio of 5 : 4. The piston is free to slide along the length of the vessel and length of the vessel is 90 cm. Each of the two parts of the vessel contains 0.1 mole of an ideal gas and the temperature of gas is 300K. The mass of the piston is:
(a) 14 kg (b) 12.7 kg
(c) 16 kg (d) 15 kg

*19. An adiabatic cylinder closed at both ends consists of a freely moving non-coducting thin piston which divides the cylinder into two equal parts and each part contains 28 g of N_2. Initially 1/3rd molecules of nitrogen in the right part are dissociated into atoms. The length of the cylinder is 1 m and area of cross-section is 10^{-2} m^2. The natural length of the spring connected to the piston and right wall of the cylinder is $l = 50$ cm and $k = \sqrt{2} \times 10^3$ N/m. If the initial pressure in each part is $P_0 = \sqrt{2} \times 10^5$ N/m^2 that what work must be done by the gas in the right part?



(a) -1414 J (b) 1414 J
(c) -1515 J (d) 1515 J

20. When a gas is allowed to expand suddenly into a vacuum chamber, then:
(a) heat supplied is zero
(b) temperature remains constant
(c) volume does not change
(d) both (a) and (b) are correct

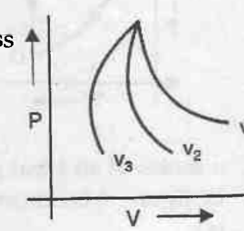
21. During an isothermal expansion of an ideal gas:
(a) its internal energy decreases
(b) its internal energy does not change
(c) the work done by the gas is equal to the quantity of heat absorbed by it
(d) both (b) and (c) are correct

22. If a gas is compressed adiabatically:
(a) the internal energy of gas increases
(b) the internal energy of gas decreases
(c) the internal energy of gas does not change
(d) the work done is positive

23. In a polytropic process, PV^n = constant:
(a) If $n = 1$, process is isothermal
(b) If $n = \infty$, process is isochoric
(c) If $n = 0$, process is isobaric
(d) all the above

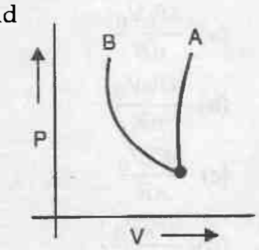
24. In a given process for ideal gas, $dW = 0$ and $dH > 0$. Then for the gas:
(a) the volume remains constant
(b) the volume will increase
(c) temperature will increase
(d) both (a) and (c) are correct

25. P-V diagram for adiabatic process is shown in the figure. Then:



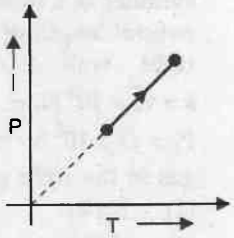
(a) $v_1 > v_2 > v_3$
(b) $v_1 < v_2 < v_3$
(c) $v_1 > v_3 > v_2$
(d) none of the above

26. In the given graph, adiabatic and isothermal curves are shown:

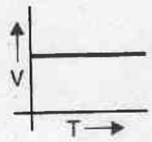


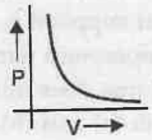
(a) the curve A is isothermal
(b) the curve B is isothermal
(c) the curve A is adiabatic
(d) the curve B is adiabatic
(e) both (b) and (c) are correct

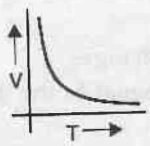
27. The process on an ideal gas, shown in figure is :
(a) isothermal
(b) isobaric
(c) isochoric
(d) none of the above



28. Which of the following best represents the process of above problem?

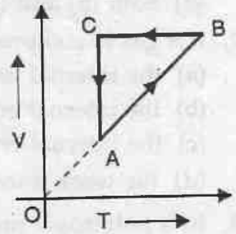
(a) 

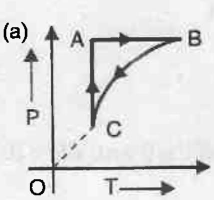
(b) 

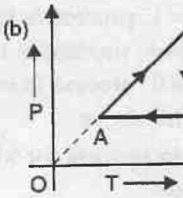
(c) 

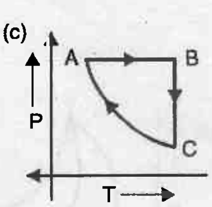
(d) All of these

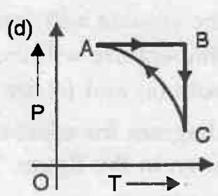
29. A thermodynamic cycle of an ideal gas is shown in the figure. Choose the correct option which represents the same cycle :



(a) 

(b) 

(c) 

(d) 

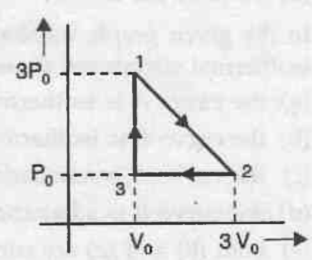
30. n moles of an ideal gas undergoes a process 1-2 as shown in figure. Maximum temperature of gas during process is :

(a) $\frac{3P_0V_0}{nR}$

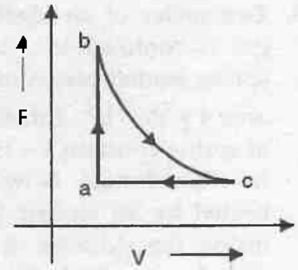
(b) $\frac{4P_0V_0}{nR}$

(c) $\frac{6P_0V_0}{nR}$

(d) $\frac{9P_0V_0}{nR}$



31. 0.2 moles of an ideal gas, is taken round the cycle abc as shown in the figure. The path b-c is adiabatic process, a-b is isovolumic process and c-a is isobaric process. The temperature at 'a' and 'b' are $T_a = 300$ K and $T_b = 500$ K and pressure at 'a' is 1 atmosphere. The volume at 'c' is :



(Given : $\gamma = \frac{C_P}{C_V} = \frac{5}{3}$, $R = 8.205 \times 10^{-2}$ litre/atm/mol-K)
(a) 6.9 L (b) 6.68 L
(c) 5.52 L (d) 5.82 L

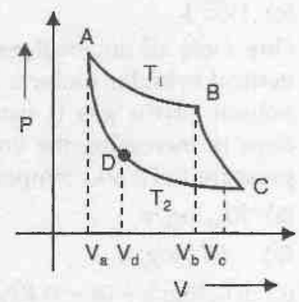
32. The P-V diagram shows that two adiabatic parts for the same gas intersect two isothermals at T_1 and T_2. How the ratio (V_a/V_d) and (V_b/V_c) are related to each other?

(a) $\left(\frac{V_a}{V_d}\right) = 2\left(\frac{V_b}{V_c}\right)$

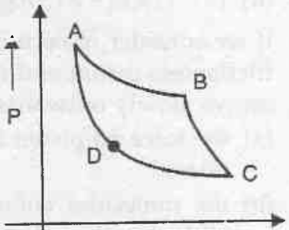
(b) $\left(\frac{V_a}{V_d}\right) = \left(\frac{V_b}{V_c}\right)$

(c) $\left(\frac{V_a}{V_c}\right) = \left(\frac{V_b}{V_d}\right)$

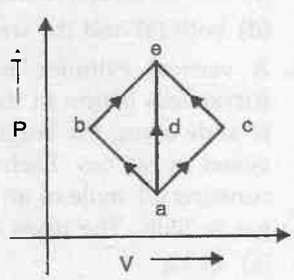
(d) $\left(\frac{V_a}{V_c}\right) = \left(\frac{V_b}{V_c}\right)^2$



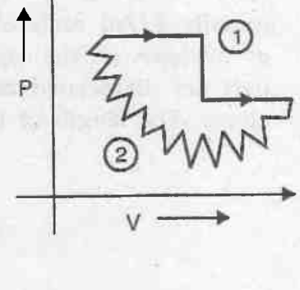
33. In P-V graph of an ideal gas, which describe the adiabatic process :
(a) AB and BC
(b) AB and CD
(c) AD and BC
(d) BC and CD



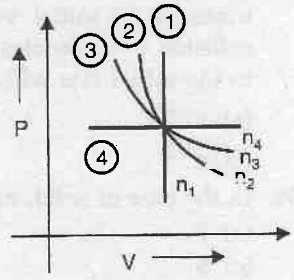
34. The initial state of an ideal gas is represented by the point a on the P-V diagram and its final state by the point e. The gas goes from the state a to the state e by :
(i) abe (ii) ace (iii) ade
The heat absorbed by the gas is :
(a) the same in all the three processes
(b) the same in processes (i) and (ii)
(c) greater in process (i) than in (iii)
(d) none of the above



35. In the given P-V diagram the path (2) from A to B is zig-zag path, but (1) is simple path. Then :
(a) $W_1 = W_2$
(b) $\Delta U_1 = \Delta U_2$
(c) $W_1 > W_2$
(d) both (b) and (c) are correct



36. A thermodynamic process is defined for an ideal gas. In this process PV^n = constant. Mark the correct options :



(a) $n_1 > n_2 > n_3 > n_4$
(b) $n_2 > n_1 > n_4 > n_3$
(c) $n_2 > n_4 > n_3 > n_1$
(d) None of the above

37. At 27°C, a motor car tyre has a pressure of 2 atmospheres. The temperature, if the tyre suddenly burst will be : (Given: $\gamma_{air} = 1.4$)

(a) 246.1 K (b) 250 K
(c) 246.1°C (d) 248 K

38. If 'V' is the volume of a vessel, which is to be evacuated by means of a piston air pump, then how many strokes are required to reduce the pressure in the vessel η times? One piston stroke captures the volume ΔV. Assume the process to be isothermal and the gas ideal :

(a) $n = \dfrac{\log \eta}{\log\left(1 - \dfrac{\Delta V}{V}\right)}$ (b) $n = \dfrac{\log \eta}{\log\left(1 + \dfrac{\Delta V}{V}\right)}$

(c) $n = \dfrac{\log \eta}{\log\left(\dfrac{\Delta V}{V}\right)}$ (d) None of these

*** 39.** A process on one mole of an ideal gas is defined as follow :

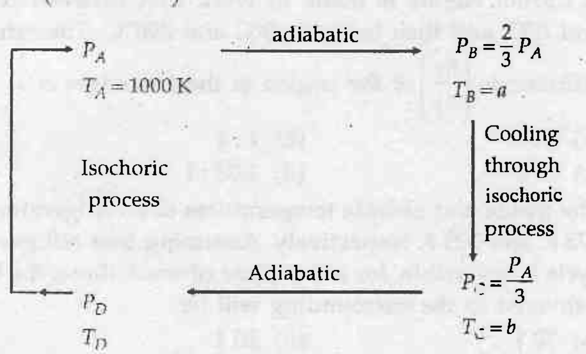
$$(P_A, V_A, T_A) \longrightarrow (P = a, V = 2V_A, T = T_A)$$
$$\longrightarrow (P_1 = P, V_1 = 2V_A, T_1 = b)$$
$$\longrightarrow (P_2 = P_A, V_2 = V_A, T_2 = c)$$

The values of a, b, and c are :

(a) $\left(\dfrac{P_A}{2}, \dfrac{T_A}{2}, T_A\right)$ (b) (P_A, T_A, T_A)

(c) $\left(\dfrac{P_A}{4}, \dfrac{T_A}{4}, \dfrac{T_A}{3}\right)$ (d) none of these

40.



The value of $\dfrac{T_B}{T_C}$ is :

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

*** 41.** The table given below shows two different processes. Calculate the unknown values with help of first law of thermodynamics. All the data are in joule :

Process	ΔQ	ΔW	U_i	U_f	$\Delta U = U_f - U_f$
1.	35	...	− 60	...	50
2.	− 15	...	80	60	...

(a) for process 1 → $\Delta W = -15$ J; $U_f = -10$ J
for process 2 → $\Delta W = 5$ J; $\Delta U = -20$ J
(b) for process 1 → $\Delta W = 15$ J; $U_f = 10$ J
for process 2 → $\Delta W = -5$ J; $\Delta U = -20$ J
(c) for process 1 → $\Delta W = -5$ J; $U_f = 20$ J
for process 2 → $\Delta W = 15$ J; $\Delta U = -10$ J
(d) data incomplete

42. In an adiabatic expansion, a gas does 25J of work while in an adiabatic compression 100J of work is done on a gas. The change of internal energy in the two processes respectively are :

(a) 25 J and − 100 J (b) − 25 J and 100 J
(c) − 25 J and − 100 J (d) 25 J and 100 J

43. A closed system undergoes a change of state by process 1 → 2 for which $Q_{12} = 10$ J and $W_{12} = -5$ J. The system is now returned to its initial state by a different path 2 → 1 for which Q_{21} is − 3 J. The total energy for the cycle is :

(a) − 8 J (b) zero
(c) − 2 J (d) + 5 J

44. Electrolysis is :

(a) reversible process
(b) irreversible process
(c) either reversible or irreversible
(d) neither reversible or irreversible

45. The molar heat capacity of oxygen gas at STP is nearly $2.5R$. As the temperature is increased, it gradually increases and approaches $3.5R$. The most appropriate reason for this behaviour is that at high temperature :

(a) oxygen does not behave as an ideal gas
(b) oxygen molecules dissociate in atoms
(c) the molecules collide more frequently
(d) molecular vibrations gradually become effective

46. During adiabatic change, specific heat is :

(a) zero (b) greater than zero
(c) less than zero (d) infinity

47. Molar heat capacity is directly related to :

(a) temperature (b) heat energy
(c) molecular structure (d) mass

48. If at NTP, velocity of sound in a gas is 1150 m/s, then the rms velocity of gas molecules at NTP is : (Given: $R = 8.3$ joule/mol/K, $C_P = 4.8$ cal/mol/K)

(a) 1600 m/s (b) 1532.19 m/s
(c) 160 m/s (d) 16 m/s

49. What is the molar heat capacity for the process, when 10 J of heat added to a monoatomic ideal gas in a process in which the gas performs a work of 5 J on its surrounding?

(a) $2R$ (b) $3R$
(c) $4R$ (d) $5R$

50. A gaseous mixture consists of 7g of nitrogen and 20 g of argon. Assume gases to be ideal. The specific heat capacities C_V and C_P in J/g-K for gaseous mixture are :
(a) $C_P = 0.66$ J/g-K, $C_V = 18.25$ J/g-K
(b) $C_P = 1.66$ J/g-K, $C_V = 1.82$ J/g-K
(c) $C_P = 0.421$ J/g-K, $C_V = 15.2$ J/g-K
(d) $C_P = 0.65$ J/g-K, $C_V = 0.421$ J/g-K

51. A gaseous mixture consists of $\mu_1 = 2$ moles of oxygen and $\mu_2 = 3$ moles of carbon di-oxide. Assume gases to be ideal. The value of $\gamma = \frac{C_P}{C_V}$ for the gaseous mixture is :
(a) 2.33 (b) 1.33
(c) 0.33 (d) 3.33

52. The molar specific heat of mixture at constant volume, if one mole of a monoatomic gas is mixed with three moles of a diatomic gas is :
(a) 3.33*R* (b) 2.25*R*
(c) 1.15*R* (d) 6.72*R*

53. If a gas is heated at constant pressure, then what percentage of total heat supplied is used up for external work ? (Given: γ for gas $= 4/3$)
(a) 25% (b) 50%
(c) 75% (d) 80%

54. One mole of a gas isobarically heated by 40K receives an amount of heat 1.162 kJ. What is the ratio of specific heats of the gas?
(a) 1.7 (b) 1.4
(c) 1.3 (d) 1.5

55. 3 moles of a gaseous mixture having volume V and temperature 'T' are compressed to (1/5)th of its initial volume. The change in its adiabatic compressibility, if gas obeys the equation $PV^{19/13} =$ constant, is :
($R = 8.3$ J/mol-K)
(a) $\Delta C = -0.0248 \frac{V}{T}$ m^2/N
(b) $\Delta C = -0.035 \frac{V}{T}$ m^2/N
(c) $\Delta C = -0.0426 \frac{V}{T}$ m^2/N
(d) $\Delta C = -0.0137 \frac{V}{T}$ m^2/N

56. In a process $PT =$ constant, if molar heat capacity of a gas is $C = 37.35$ J/mol-K, then the number of degrees of freedom of molecules in the gas is :
(a) $f = 10$ (b) $f = 5$
(c) $f = 6$ (d) $f = 7$

57. If in an adiabatic process, the pressure is increased by 2/3%, then volume decreases by $\left[\text{Assume } \frac{C_P}{C_V} = \frac{3}{2}\right]$:
(a) $\frac{4}{9}$ % (b) $\frac{2}{3}$ %
(c) 4% (d) $\frac{9}{4}$ %

58. A monoatomic ideal gas is expanded adiabatically to n times of its initial volume. The ratio of final rate of collision of molecules with unit area of container walls to the initial rate will be :
(a) $n^{-4/3}$ (b) $n^{4/3}$
(c) $n^{2/3}$ (d) $n^{-5/3}$

59. In the case of solid, number of degrees of freedom is :
(a) 3 (b) 5
(c) 6 (d) 7

60. A given quantity of an ideal gas is at the pressure P and the absolute temperature T. The isothermal bulk modulus of the gas is :
(a) $\frac{2}{3}P$ (b) P
(c) $\frac{3}{2}P$ (d) $2P$

61. If temperature of the atmosphere varies with height as $T = (T_0 - ah)$, where a and T_0 are positive constants, then find pressure as a function of height (h). Assume atmospheric pressure at sea level ($h = 0$) is P_0 and molecular mass M of the air and acceleration due to gravity g to be constant :
(a) $P = P_0\left(\frac{T_0 - ah}{T_0}\right)^{Mg/Ra}$ (b) $P = P_0\left(\frac{T_0 - ah}{T_0}\right)^{2Mg/Ra}$
(c) $P = P_0\left(\frac{T_0 - ah}{T_0}\right)^{3Mg/Ra}$ (d) $P = P_0\left(\frac{T_0 - ah}{T_0}\right)^{4Mg/Ra}$

62. At a temperature 't' the moment of inertia of a body is I. When the temperature of the body is increased from $t + \Delta t$, its moment of inertia also increases from I to $(I + \Delta I)$. If coefficient of linear expansion of the body is 'α', then the ratio $\frac{\Delta I}{I}$ is :
(a) $\frac{\Delta t}{t}$ (b) $\frac{2\Delta t}{t}$
(c) $\alpha \Delta t$ (d) $2\alpha \Delta t$

63. A Carnot engine is made to work first between 200°C and 0°C, and then between 0°C and 200°C. The ratio of efficiencies $\left(\frac{\eta_2}{\eta_1}\right)$ of the engine in the two cases is
(a) 1 : 15 (b) 1 : 1
(c) 1 : 2 (d) 1.73 : 1

64. The inside and outside temperatures of a refrigerator are 273 K and 303 K respectively. Assuming that refrigerator cycle is reversible, for every joule of work done, the heat delivered to the surrounding will be :
(a) 10 J (b) 20 J
(c) 30 J (d) 50 J

65. The coefficient of performance, if in a mechanical refrigerator, the lower temperature coils of a evaporator are -23°C, and compressed gas in the condenser has a temperature of 77°C, is :
(a) 70% (b) 20%
(c) 0.23% (d) 2.5%

Answers

Level-1

1. (d)	2. (c)	3. (b)	4. (b)	5. (b)	6. (b)	7. (c)	8. (a)	9. (a)	10. (d)
11. (a)	12. (b)	13. (d)	14. (a)	15. (d)	16. (a)	17. (d)	18. (a)	19. (b)	20. (a)
21. (a)	22. (a)	23. (d)							

Level-2

1. (a)	2. (d)	3. (a)	4. (b)	5. (a)	6. (c)	7. (b)	8. (b)	9. (c)	10. (b)
11. (d)	12. (a)	13. (a)	14. (b)	15. (a)	16. (d)	17. (d)	18. (b)	19. (a)	20. (b)
21. (d)	22. (a)	23. (d)	24. (d)	25. (b)	26. (e)	27. (c)	28. (d)	29. (c)	30. (b)
31. (b)	32. (b)	33. (c)	34. (c)	35. (d)	36. (a)	37. (a)	38. (b)	39. (a)	40. (b)
41. (a)	42. (b)	43. (b)	44. (a)	45. (d)	46. (a)	47. (c)	48. (b)	49. (b)	50. (d)
51. (b)	52. (b)	53. (a)	54. (b)	55. (a)	56. (b)	57. (a)	58. (d)	59. (c)	60. (b)
61. (a)	62. (d)	63. (d)	64. (a)	65. (d)					

Solutions

Level-1

14. $W = JQ = 4.2\,(0.5 \times 10 + 1 \times 80 + 1 \times 100 + 1 \times 540)$

$= 3045\ \text{J}$

18. Thermal energy = loss in kinetic energy

$$= \frac{1}{2}\, m(v_1^2 - v_2^2)$$

$$= \frac{1}{2}\, 100 \times 10^{-3}\,(10^2 - 5^2) = 3.75\ \text{J}$$

21. $$mgh = KmL$$

$$\Rightarrow \quad K = \frac{gh}{L}$$

$$= \frac{10 \times 1000}{3.36 \times 10^5} \sim \frac{1}{33}$$

$\because$ Latent heat of ice $= 3.36 \times 10^5$ J/kg

Level-2

1. Energy used by boy is

$E = 1000 \times 4.2\ \text{J} = mgh = 50 \times 9.8 \times h$

$h = 8.57$ m

3. Heat absorbed by the system at constant pressure $Q = nC_P\,\Delta T$ and

change in internal energy

$$\Delta U = nC_V\,\Delta T$$

$$W = Q - \Delta U$$

$$\text{fraction} = \frac{W}{Q} = \frac{Q - \Delta U}{Q} = 1 - \frac{\Delta U}{Q}$$

$$= 1 - \frac{\Delta U}{Q} = \left(1 - \frac{1}{\gamma}\right)$$

4. Work done in isothermal expansion

$$= nRT \ln\left(\frac{V_B}{V_A}\right)$$

$$= (5)\,(8.314)\,(500)\,(\ln 2)$$

$$= 14407\ \text{J}$$

5. The area of P-V diagram gives work.

The area of Δabc is $A = \frac{1}{2} \times 30 \times 3$

$= 45$ J = work done

6. During AB, process is isochoric

$\therefore \quad \Delta V = 0$

$\therefore \quad W = 0$

During BC, process is isothermal.

$\therefore \quad \Delta T = 0$

$$W = RT_2 \ln \frac{V_2}{V_1}$$

During CA, process is isobaric. So, pressure is constant

$\therefore \quad W = P(V_1 - V_2)$

But $\quad PV_1 = RT_1$

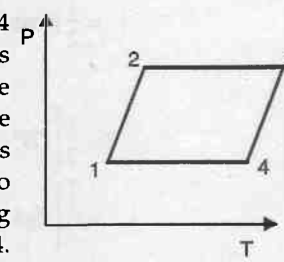
$$\therefore \quad P = \frac{RT_1}{V_1} = \frac{RT_2}{V_2}$$

$$\therefore \quad W = \frac{RT_1}{V_1}(V_1 - V_2) = \frac{RT_2}{V_2}(V_1 - V_2)$$

7. The area of P-V diagram gives work done

$\therefore \quad W = (2V - V)\,(2P - P) = PV$

8. The segments 1 – 2 and 3 – 4 indicate that pressure is directly proportional to the temperature. Hence, the volume of gas remains unchanged. We have to calculate the work done during isobaric process 2 – 3 and 1 – 4.



$$W_{2-3} = P_2\,(V_3 - V_2)$$

$$W_{4-1} = P_1\,(V_1 - V_4)$$

18

Heat Transfer

Syllabus: Modes of heat transfer, thermal conductivity, black body radiation, Wein's displacement law, Stefan's law of radiation and Newton's law of cooling.

Review of Concepts

1. Definition of heat transfer : Heat can be transferred from one place to the other by any of three possible ways : conduction, convection and radiation. In the first two processes, a medium is necessary for the heat transfer. Radiation, however, does not have this restriction. This is also the fastest mode of heat transfer in which heat is transferred from one place to other in the form of electromagnetic radiation.

2. Heat conduction :

(a) The rate of flow of heat in steady state is

$$\frac{\Delta H}{\Delta t} = \frac{KA(\theta_1 - \theta_2)}{L}$$

(b) $\frac{dH}{dt} = -KA\frac{d\theta}{dx}$

Here, $\frac{d\theta}{dx}$ = temperature gradient,

K = thermal conductivity

Unit of K is watt per metre per Kelvin.

(c) Thermal diffusivity $= \frac{\text{thermal conductivity}}{\text{heat capacity per unit volume}}$

(d) Thermal resistance $= \frac{l}{KA}$

Some important points :

- In steady state, the temperature of a point remains constant with respect to time.
- Thermal conduction in metal takes place due to free electrons.
- Heat transfer in mercury takes place by conduction not by convection.
- A substance which is good conductor of heat is also good conductor of electricity.
- If thermal resistances are in parallel,
$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$$
- When thermal resistances are in series,
$$R = R_1 + R_2 + \ldots$$
- **Growth of ice on ponds:** The time taken to double and triple the thickness of ice will be in ratio of $t_1 : t_2 : t_3 = 1^2 : 2^2 : 3^2$.
Time taken for thickness of ice growing from x_1 to x_2 is given by
$$t = \frac{\rho L}{2K\theta}(x_2^2 - x_1^2)$$
where, ρ is density of ice, L be the latent heat of ice, K be the conductivity.
- Out of all gases, H_2 is good conductor of heat

3. Radiation :

(a) Stefan's law:

$$\frac{\Delta H}{A\,\Delta t} = e\sigma T^4$$

Here, $\frac{\Delta H}{A\,\Delta t}$ = rate of radiated energy per unit area

σ = Stefan's constant $= 5.67 \times 10^{-8}$ Wm^{-2}K^{-4}

e = emissivity

T = temperature of body in kelvin

(b) If a body of temperature T is placed in environment of temperature T_0 $(T_0 < T)$, then the rate of lossing of energy is:

$$\frac{\Delta H}{A\,\Delta t} = e\sigma(T^4 - T_0^4)$$

(c) $\frac{\Delta H}{A\,\Delta t} = \frac{ms}{A}\frac{dT}{dt}$

(d) Kirchhoff's law:

If a = absorptive power, e_0 = emissive power

then $\frac{e}{a}$ = emissive power of black body

Here, $a = \int_0^\infty a_\lambda d\lambda$, Here a_λ = spectral absorptive power

$e_0 = \int_0^\infty e_\lambda d\lambda$. Here e_λ = spectral emissive power

Some important points :

- Good absorber is good emitter.
- Propagation of heat in vacuum only takes place by radiation.
- At 0 K, radiation stops.
- Heat radiation obeys all laws of light.
- For black body, $e = 1$.
- $0 < e < 1$
- e has neither unit nor dimensions.
- The value of e depends upon nature of surface.
- More surface, more radiation.

4. **Wein's displacement law :**

$$\lambda_m T = \text{constant} = 2.892 \times 10^{-3}\text{mK}$$

(a) Blue star is hotter than red star.

(b) Solar constant $= 1.34 \times 10^4$ Jm^{-2}s^{-1}.

(c) When a black body is heated, λ_m decreases with rise of temperature.

5. **Newton's law of cooling :**

(a) $\frac{d\theta}{dt} = K(\theta - \theta_0)$

Here, θ = temperature of body, θ_0 = temperature of surroundings

(b) If a body cools from θ_1°C to θ_2°C in time t, then

$$\frac{\theta_1 - \theta_2}{t} = K\left(\frac{\theta_1 + \theta_2}{2} - \theta_0\right)$$

Some important points :

- Newton's law of cooling is special case of Stefan's law.
- It is only applicable for small temperature difference.
- If two liquids of equal mass, equal surface area are cooled from initial temperature θ_1°C to θ_2°C in same environment temperature, then

$$\frac{S_1}{S_2} = \frac{t_1}{t_2}$$

Here, t_1 and t_2 are times of cooling for respective liquids.

Objective Questions

Level-1

1. If the wavelength of maximum intensity of radiation emitted by sun and moon are 0.5×10^{-6} m and 10^{-4} m respectively, the ratio of their temperatures is :

(a) $\frac{1}{100}$ (b) $\frac{1}{200}$

(c) 100 (d) 200

2. A red glass piece is heated until it glows in dark. The colour of the glow will be :

(a) red (b) orange

(c) green (d) violet

3. An object is at temperature of 400°C. At what temperature would it radiate energy twice as fast ? The temperature of the surrounding may be assumed to be negligible :

(a) 200°C (b) 200 K

(c) 800°C (d) 800 K

4. The maximum wavelength of radiation emitted at 200 K is 4 μm what will be the maximum wavelength of radiation emitted at 2400 K ?

(a) 3.33 μm (b) 0.66 μm

(c) 1 μm (d) 1 m

5. For the measurement of temperature of the order of 400°C, the preferred thermometer will be :

(a) Hg thermometer (b) alcohol thermometer

(c) radiation thermometer (d) thermocouple

6. For measuring temperature near absolute zero the thermometer used is :

(a) thermoelectric thermometer

(b) radiation thermometer

(c) magnetic thermometer

(d) resistance thermometer

7. The mode of transfer of heat which requires no medium, is called as :

(a) radiation (b) conduction

(c) combusion (d) convection

8. If K and σ respectively are the thermal and electrical conductivities of a metal at absolute temperature T then :

(a) $\frac{K}{\sigma T}$ = constant (b) $\frac{K}{\sigma}$ = constant

(c) $\frac{K}{T}$ = constant (d) $\frac{\sigma}{KT}$ = constant

9. The thermal conductivity of copper is :

(a) less than that of iron

(b) less than that of aluminium

(c) less than that of wood

(d) more than that of all the three given above

10. Though air is bad conductor yet a body kept in air losses heat quickly this is due to :

(a) conduction (b) convection

(c) radiation (d) none of these

11. A bucket full of hot water is kept in a room and it cools from 75°C to 70°C in T_1 minutes, from 70°C to 65°C in T_2 minutes and from 65°C to 60°C in T_3 minutes then :

(a) $T_1 = T_2 = T_3$ (b) $T_1 < T_2 < T_3$

(c) $T_1 > T_2 > T_3$ (d) $T_1 < T_2 > T_3$

12. In a closed room, heat transfer takes place by :

(a) conduction (b) convection

(c) radiation (d) all of these

13. A body of length 1 m having cross-sectional area 0.75 m^2 has thermal conductivity 6000 J/s then the temperature difference if $K = 200$ Jm^{-1}K^{-1}, will be :

(a) 20°C (b) 40°C

(c) 80°C (d) 100°C

14. The volume of block of metal changes by 0.12% when heated through 20°C then α is :

(a) 2.0×10^{-5} (°C)$^{-1}$ (b) 4.0×10^{-5} (°C)$^{-1}$

(c) 6.0×10^{-5} (°C)$^{-1}$ (d) 8.0×10^{-5} (°C)$^{-1}$

15. 1 g of ice at 0°C is mixed with 1 g of steam at 100°C. After thermal equilibrium is attained, the temperature of mixture will be :

(a) 1°C (b) 50°C

(c) 81°C (d) 100°C

16. Woollen clothes keep the body warm because wool :
(a) is a bad conductor
(b) increases the temperature of the body
(c) decreases the temperature of the body
(d) all of the above

17. In a composite rod, when two rods of different lengths and of the same area of cross-section, are joined end to end then if K is the effective coefficient of thermal conductivity $\frac{l_1 + l_2}{K}$ is equal to :
(a) $\frac{l_1}{K_1} - \frac{l_2}{K_2}$ (b) $\frac{l_1}{K_2} = \frac{l_2}{K_1}$
(c) $\frac{l_1}{K_1} + \frac{l_2}{K_2}$ (d) $\frac{l_1}{K_2} + \frac{l_2}{K_1}$

18. A black body is maintained at 27°C and 927°C. What will be the ratio of radiation emitted ?
(a) 1 : 4
(b) 1 : 16
(c) 1 : 64
(d) 1 : 256

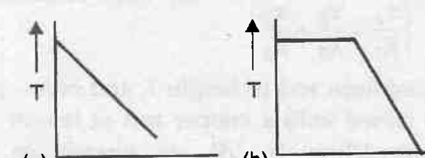
19. Thermal radiation are :
(a) electromagnetic wave
(b) mechanical transverse wave
(c) mechanical longitudinal wave
(d) none of the above

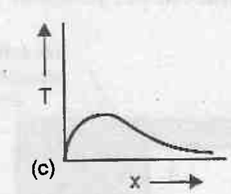
Level-2

1. If a rod is in a variable state (not in steady state), then :
(a) temperature gradient remains constant
(b) temperature of rod is function of time and distance from one of end
(c) temperature of rod is only function of distance from one of end
(d) temperature of rod is only function of time

2. One end of a metal rod is kept in steam. In steady state, the temperature gradient $\left(\frac{d\theta}{dx}\right)$:
(a) may be variable (b) must be constant
(c) must be variable (d) none of these

3. End A of a copper rod is maintained in steam chamber and other end is maintained at 0°C.
Assume $x = 0$ at A. The T-x graph for the rod in steady state is :

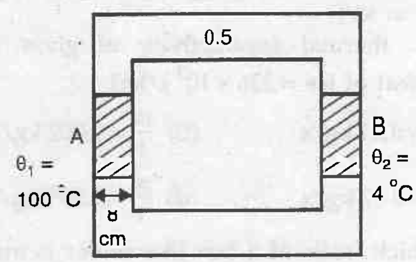




(c) none of these

4. The daily loss of energy by the earth if the temperature gradient in the earth's crust is 32°C per km and mean conductivity of the rock is 0.008 of C.G.S. unit, is :
(Given : radius of earth = 6400 km)
(a) 10^{40} cal (b) 10^{30} cal
(c) 10^{18} cal (d) 10^{10} cal

*5. A 8 cm thick walled closed cubical block made up of perfectly insulating material and the only way for heat to enter or leave the box is through two solid cylindrical metallic plugs each of cross-sectional area 12 cm^2 and length 8 cm fixed in the opposite walls of the box. The thermal conductivity of the material of the plug is 0.5 cal/s/cm/°C. If outer surface A is kept at 100°C while outer surface B of the other plug is maintained at 4°C and a source of energy generating 36 cal/s is enclosed inside the box, then find the equilibrium temperature of the inner surface of the box, assuming that it is same at all points of the inner surface :



(a) $\theta = 71$°C (b) $\theta = 76$°C
(c) $\theta = 83$°C (d) $\theta = 64$°C

6. Cylindrical rod of copper of length 2 m and cross-sectional area 2 cm^2 is insulated at its curved surface. The one end of rod is maintained in steam chamber and other is maintained in ice at 0°C.
(The thermal conductivity of copper is 386 J/m-s-°C).
The temperature at a point which is at a distance of 120 cm from the colder end is :
(a) 80°C (b) 50°C
(c) 60°C (d) none of these

7. In previous problem, the temperature gradient is :
(a) 0.5°C/m (b) 1°C/m
(c) 2°C/m (d) none of these

8. In the previous problem, the amount of ice melts per second is :
(a) 48.25 g (b) 80 g
(c) 20.8 g (d) none of these

9. Cylindrical copper rod of length 1 m and a cylindrical steel rod of length 1.5 m are joined together end to end. The cross-sectional area of each rod is 3.14 cm^2. The free ends of steel rod and copper rods are maintained at 0°C and 100°C respectively. The surfaces of rods are thermally insulated.

The temperature of copper-steel junction is: (Thermal conductivity of steel $=46$ J/m-s-°C and the thermal conductivity of copper $=386$ J/m-s-°C)

(a) 40°C (b) 60°C
(c) 93°C (d) 80.64°C

10. In previous problem, the rate of loss of heat at free end of copper is:

(a) 2 J/s (b) 0.89 J/s
(c) 1.07 J/s (d) none of these

11. A block of ice at 0°C rests on the upper surface of the slab of stone of area 3600 cm^2 and thickness of 10 cm. The slab is exposed on the lower surface to steam at 100°C. If 4800 g of ice is melted in one hour, then the thermal conductivity of stone is:

(Given: The latent heat of fusion of ice = 80 cal/gm)

(a) $K=2.96\times10^{-3}$ cal/cm s°C
(b) $K=1.96\times10^{-3}$ cal/cm s°C
(c) $K=0.96\times10^{-3}$ cal/cm s°C
(d) none of the above

12. The ice is filled in a hollow glass sphere of thickness 2 mm and external radius 10 cm. This hollow glass sphere with ice now placed in a bath containing boiling water at 100°C. The rate at which ice melts, is: (Neglect volume change in ice)

(Given: thermal conductivity of glass 1.1 W/m/K, latent heat of ice $=336\times10^3$ J/kg)

(a) $\frac{m}{t}=0.01$ kg/s (b) $\frac{m}{t}=0.002$ kg/s
(c) $\frac{m}{t}=0.02$ kg/s (d) $\frac{m}{t}=0.001$ kg/s

13. 5 cm thick walls of a box like cooler is made of plastic foam. Its total surface area is 1.5 m^2. If outside temperature is 30°C, then how much ice melts each hour inside the cooler to hold its temperature at 0°C?

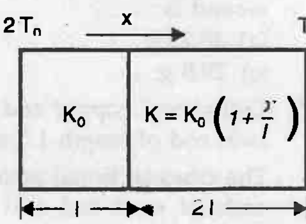
(Given: K for plastic $=0.04$ W/mK $L_0=80$ cal/g and 1 kcal $=4.184$ kJ/kcal)

(a) 4 kg (b) 0.39 kg
(c) 3.9 kg (d) 0.2 kg

14. If in two identical containers, equal quantity of ice melts completely in 30 and 20 minutes respectively, then the ratio of the thermal conductivities of the material of two containers is:

(a) 1 : 1 (b) 1 : 2
(c) 3 : 2 (d) 2 : 3

***15.** Find the temperature at the interface for steady flow of heat through the slab, if heat conductivity of first slab of length 'l' is K_0 and is uniform every where but the conductivity of second slab of length '$2l$' varies with the distance 'x' measured from the interface according to the law $K=K_0\left(1+\frac{x}{l}\right)$ The temperature at the boundries of the composite slab are $2T_0$ and T_0:



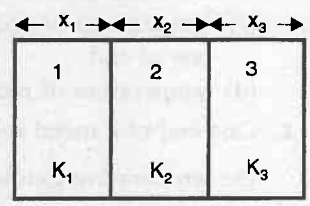
(a) $T'=\left(\frac{2\ln 2+1}{\ln 2+1}\right)T_0$ (b) $T'=\left(\frac{2\ln 3+1}{\ln 3+1}\right)T_0$
(c) $T'=\left(\frac{2\ln 3+1}{2\ln 3+1}\right)T_0$ (d) $T'=\left(\frac{4\ln 3+1}{\ln 3+1}\right)T_0$

16. A compound rod is formed of a steel core of diameter 1cm and outer casing is of copper, whose outer diameter is 2 cm. The length of this compound rod is 2 m and one end is maintained as 100°C, and the end is at 0°C. If the outer surface of the rod is thermally insulated, then heat current in the rod will be:

(Given: Thermal conductivity of steel $=12$ cal/m-K-s, thermal conductivity of copper $=92$ cal/m-K-s)

(a) 2 cal/s (b) 1.13 cal/s
(c) 1.42 cal/s (d) 2.68 cal/s

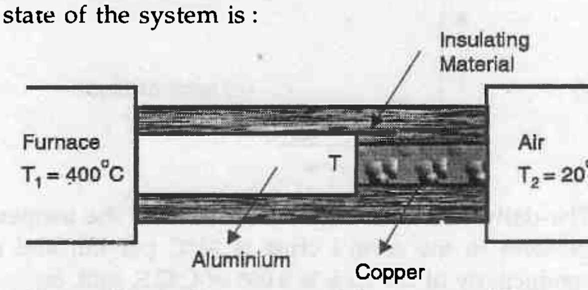
17. Three slabs, are placed in contact in order 1, 2 and 3 as shown in figure. The thickness of the slabs are x_1, x_2 and x_3 and made of materials of thermal conductivities K_1, K_2 and K_3 respectively. Assume that there is no loss of heat due to radiation. At steady state the combination will behave as a single material, if thermal conductivity K will be:



(a) $K=\frac{(x_1+x_2+x_3)}{\left(\frac{x_1}{K_1}+\frac{x_2}{K_2}+\frac{x_3}{K_3}\right)}$ (b) $K=\frac{2(x_1+x_2+x_3)}{\left(\frac{x_1}{K_1}+\frac{x_2}{K_2}+\frac{x_3}{K_3}\right)}$

(c) $K=\frac{(x_1+x_2+x_3)}{\left(\frac{x_1}{K_1}-\frac{x_2}{K_2}+\frac{x_3}{K_3}\right)}$ (d) none of these

***18.** An aluminium rod of length L and cross- sectional area '$2A$' is joined with a copper rod of length '$2L$' and area of cross-section is 'A', as shown in figure. The temperature of aluminium-copper junction in the steady state of the system is:



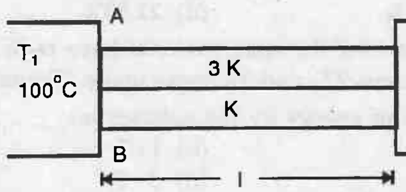
(Given: Thermal conductivity $K_{Al}=240$ J/m-sec-°C, $K_{Cu}=400$ J/m-sec-°C

(a) 300°C (b) 400°C
(c) 288.24°C (d) 275.4°C

19. A uniform metal ring with centre C have two points A and B, such that angle ACB is θ. A and B are maintained at two different constant temperatures. If the angle between A and B, *i.e.* $\theta = 180°$, the rate of heat flow from A to B is 1.2 W, then what will be the rate, when $\theta = 90°$?

(a) 0.6 W (b) 0.9 W
(c) 1.6 W (d) 1.8 W

20. Two rods A and B of same length and cross-sectional area are connected in parallel and a temperature difference of 100°C is maintained across the combination as shown in the figure. If the thermal conductivity of the rod A is $3K$ and that of rod B is K, then what is the equivalent thermal resistance ?



(a) $R = \dfrac{l}{4KA}$ (b) $R = \dfrac{1}{2KA}$

(c) $R = \dfrac{2l}{KA}$ (d) $R = \dfrac{3l}{2KA}$

21. A metallic sphere having inner and outer radii a and b respectively has thermal con- ductivity

$$K = \frac{K_0}{r} \qquad (a < r < b)$$

The thermal resistance between inner surface and outer surface is :

(a) $\dfrac{(b-a)}{4\pi K_0}$ (b) $\dfrac{(b^2-a^2)}{4\pi K_0\, ab}$

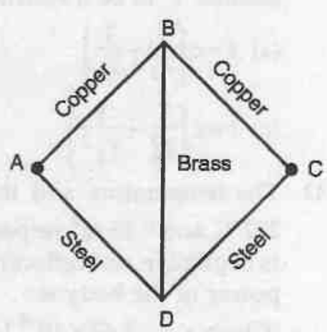
(c) $\dfrac{4\pi K_0}{(b-a)}$ (d) none of these

22. In above problem if the temperature of inner and outer surfaces are $\theta_1°$ and θ_2°C $(\theta_1 > \theta_2)$. The rate of flow of heat in steady state is :

(a) $\dfrac{4\pi K_0\,(\theta_1-\theta_2)}{(b-a)}$ (b) $\dfrac{4\pi K_0\,(b-a)}{(\theta_1-\theta_2)}$

(c) $\dfrac{4\pi K_0\, ab\,(\theta_1-\theta_2)}{(b^2-a^2)}$ (d) none of these

23. Five wires each of cross-sectional area A and length l are combined as shown in figure.
The thermal conductivity of copper and steel are K_1 and K_2 respectively.
The equivalent thermal resistance between points A and C is :



(a) $\dfrac{l}{(K_1+K_2)A}$ (b) $\dfrac{2l}{(K_1+K_2)A}$

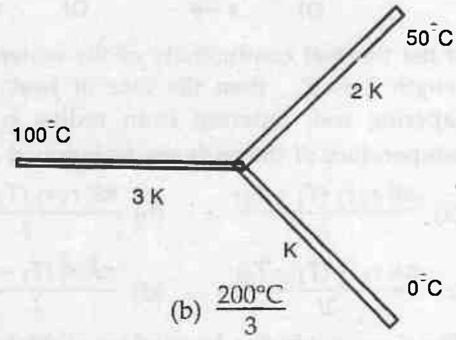
(c) $\dfrac{l\,(K_1+K_2)}{K_1 K_2 A}$ (d) none of these

24. In previous problem if A is maintained at 100°C and C is maintained at 0°C. The rate emitted at C is : (assume the curve surfaces of rods are thermally insulated)

(a) $\dfrac{50A\,(K_1+K_2)}{l}$ (b) $\dfrac{100A\,(K_1+K_2)}{l}$

(c) $\dfrac{A\,(K_1+K_2)}{l}$ (d) none of these

25. Three rods are arranged as a letter Y. The rods have same dimensions and have thermal conductivities $3K$, $2K$ and K. If the ends of the rods are at a temperature of 100°C, 50°C and 0°C, then temperature of the junction O is :



(a) 75°C (b) $\dfrac{200°\text{C}}{3}$

(c) 40°C (d) $\dfrac{100°\text{C}}{3}$

26. A metal rod of length L and cross-sectional area A converts a large tank of water at temperature θ_0 and a small vessel containing mass m of water at initial temperature of $\theta_1 (< \theta_0)$. If the thermal conductivity of rod is K, then the time taken for the temperature of water in smaller vessel to become $\theta_2 (\theta_1 < \theta_2 < \theta_0)$ is :

(Given : Specific heat capacity of water is s and all other heat capacities are neglected)

(a) $T = \dfrac{ms}{KA} \log \dfrac{(\theta_0-\theta_1)}{(\theta_0-\theta_2)}$

(b) $T = \dfrac{Lms}{KA} \log \left(\dfrac{\theta_0-\theta_1}{\theta_0-\theta_2}\right)$

(c) $T = \dfrac{2mLs}{KA} \left(\log \dfrac{(\theta_0-\theta_1)}{\theta_0-\theta_2}\right)$

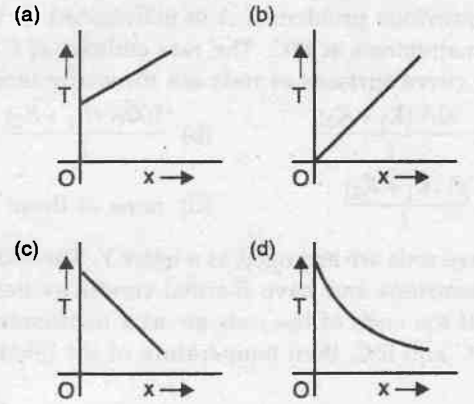
(d) none of the above

27. The thermal conductivity of a material of a cylinder of radius R is K_1, which is surrounded by a cylindrical shell of inner radius R and outer radius $2R$ made of the material of thermal conductivity K_2. The two ends of the combined system are maintained at two different temperatures. Assume, that 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 :

(a) $K_1 + K_2$ (b) $\dfrac{K_1 K_2}{(K_1+K_2)}$

(c) $\dfrac{(K_1+3K_2)}{4}$ (d) $\dfrac{(3K_1+K_2)}{4}$

28. Choose the correct option, if heat is flowing through a conductor of length l from $x = 0$ to $x = l$. Assume thermal resistance per unit length is uniform :



29. If the thermal conductivity of the material of the rod of length l, is K , then the rate of heat flow through a tapering rod, tapering from radius r_1 and r_2, if the temperature of the ends are maintained at T_1 and T_2, is :
(a) $\frac{\pi K r_1 r_2 (T_1 + T_2)}{l}$ (b) $\frac{\pi K r_1 r_2 (T_1 - T_2)}{l}$
(c) $\frac{\pi K r_1 r_2 (T_1 - T_2)}{2l}$ (d) $\frac{\pi K r_1^2 (T_1 - T_2)}{l}$

30. The time in which a layer of ice of thickness h will grow on the surface of the pond of surface area A, when the surrounding temperature falls to $-T$°C is :
(Assume K = thermal conductivity of ice, ρ = density fo water, L = latent heat of fusion)
(a) $t = \frac{\rho L}{2KT} h^2$ (b) $t = \frac{\rho L}{KT} h^2$
(c) $t = \frac{\rho L h^2}{3KT}$ (d) $t = \frac{\rho L h^2}{4KT}$

31. Which process has maximum rate of heat transfer ?
(a) Conduction
(b) Convection
(c) Radiation
(d) In all the above heat is transferred with the same velocity.

32. The propagation of heat in air takes place by :
(a) conduction (b) convection
(c) radiation (d) all of these

33. The propagation of heat in vacuum takes place by :
(a) conduction (b) convection
(c) radiation (d) none of these

34. The thermal radiation emitted by a body per second per unit area is $\frac{\Delta H}{A \Delta t} = kT^4$.
If σ is Stefan's constant, then body :
(a) may be polished
(b) may be black body
(c) must be black body
(d) must not be black body

35. Read the following statements carefully
(A) Black body radiation is white
(B) Emissivity of a body is equal to its absorptive power
Mark correct option :
(a) Statement (A) is correct
(b) Statement (B) is correct
(c) Both are correct
(d) Both are wrong

36. The power 'P' is received by a surface at temperature $T_0 K$ from a small sphere at temperature T ($T >> T_0$) and at a distance 'd'. If both 'T' and 'd' are doubled, then power received by surface will become :
(a) P (b) $2P$
(c) $4P$ (d) $16P$

37. What will be the increment in heat energy radiated when the temperature of hot body is raised by 5% ?
(a) 5% (b) 6%
(c) 11.65% (d) 21.55%

38. Two spheres of the same material have radii r and $4r$ and temperatures $2T_0$ and T_0 respectively. The ratio of rate of radiation of energy by the spheres is :
(a) 1 : 1 (b) 1 : 2
(c) 2 : 1 (d) 3 : 1

39. A sphere, a cube and a thin circular plate all of same material having same mass are initially heated to 200°C. Which of these will cool fastest ?
(a) Circular plate (b) Sphere
(c) Cube (d) All of these

40. A sphere and a cube of the same material and same total surface area are placed in the same evacuated space turn by turn, after they are heated to the same temperature. Let initial rate of cooling of sphere and cube are R_1 and R_2, respectively, then compare their initial rate of cooling :
(a) $R_1 > R_2$ (b) $R_1 < R_2$
(c) $R_1 = R_2$ (d) none of these

41. A body at a temperature of 727°C and has surface area 5 cm^2, radiates 300 J of energy each minute. The emissivity is :
(Given: Boltzmann constant = 5.67×10^{-8} watt m^2(K)^4)
(a) $e = 0.18$ (b) $e = 0.02$
(c) $e = 0.2$ (d) $e = 0.15$

42. Choose the correct relation, when the temperature of an isolated black body falls from T_1 to T_2 in time 't', and assume 'c' to be a constant :
(a) $t = c\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$ (b) $t = c\left(\frac{1}{T_2^2} - \frac{1}{T_1^2}\right)$
(c) $t = c\left(\frac{1}{T_2^3} - \frac{1}{T_1^3}\right)$ (d) $t = c\left(\frac{1}{T_2^4} - \frac{1}{T_1^4}\right)$

43. The temperature and the surface area of the body are 227°C and 0.15 m^2 respectively. If its transmitting power is negligible and reflecting power is 0.5, then the thermal power of the body is :
(Given : $\sigma = 5.67 \times 10^{-8}$ J/m^2 s K)
(a) 300 watt (b) 265.78 watt
(c) 201 watt (d) 320.89 watt

44. The surface temperature of the sun is 'T'K and the solar constant for a plate is 's'. The sun subtends an angle θ at the planet. Then :

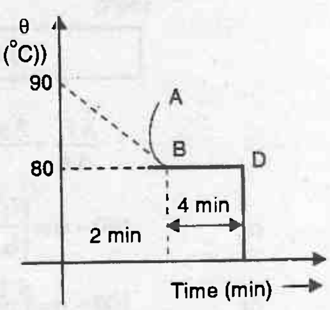
(a) $s \propto T^4$ (b) $s \propto T^2$
(c) $s \propto \theta^2$ (d) $s \propto \theta$

45. Newton's law of cooling is derived from
(a) Wien's displacement law
(b) Kirchhoff's law of radiation
(c) Stefan's law
(d) Planck's law

46. Read the following statements
(A) Water can be boiled inside the artificial satellite by convection.
(B) Heavy liquid can be boiled in artificial satellite by convection.
Mark correct option/s :
(a) Both statements are correct
(b) Both statements are wrong
(c) A is correct but B is wrong
(d) B is correct but A is wrong

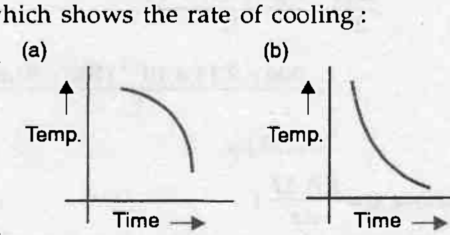
47. What amount of ice at – 14°C, required to cool 200 g of water from 25°C to 10°C ?
(Given : $C_{ice} = 0.5$ cal/g°C, L for ice = 80cal/g)
(a) 31 g (b) 41 g
(c) 51 g (d) 21 g

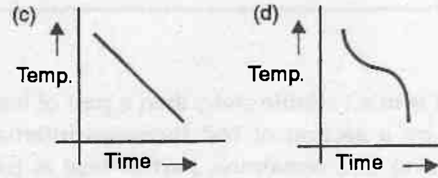
48. The cooling curve of pure wax material after heating is shown in the figure. It first cools from A to B and solidifies along BD. The ratio of L/C, if L and C are respective values of specific latent heat of fusion and specific heat capacity of the liquid wax is : (Assume rate of heat loss remain constant)



(a) 40 (b) 80
(c) 100 (d) 20

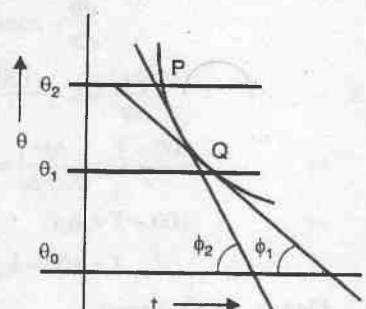
49. A metal block is heated well above the room temperature and then left to cool in the room. Choose the correct graph which shows the rate of cooling :





50. A body initially at 60°C cools to 50°C in 10 minutes. What will be its temperature at the end of next 10 minutes, if the room temperature is 25°C. Assume Newton's law of cooling :
(a) 42.85°C (b) 45°C
(c) 40.46°C (d) 44.23°C

51. A body starts cooling in a surrounding which is at a temperature of θ_0. A graph is plotted between temperature θ and time t. Assume Newton's law of cooling is obeyed. Tangents are drawn to the curve at point P and Q at temperatures of θ_2 and θ_1 respectively. If tangent meet the time axis at angle of ϕ_2 and ϕ_1, then :



(a) $\dfrac{\tan\phi_2}{\tan\phi_1} = \dfrac{\theta_1 - \theta_0}{\theta_2 - \theta_0}$ (b) $\dfrac{\tan\phi_2}{\tan\phi_1} = \dfrac{\theta_2 - \theta_0}{\theta_1 - \theta_0}$

(c) $\dfrac{\tan\phi_2}{\tan\phi_1} = \dfrac{\theta_1}{\theta_2}$ (d) $\dfrac{\tan\phi_2}{\tan\phi_1} = \dfrac{\theta_2}{\theta_1}$

52. When a blackened platinum wire is heated gradually, it appears ?
(a) first blue, then red and finally white
(b) first red, then blue and finally white
(c) first white, then blue and finally red
(d) first red, then white and finally blue

53. Surface temperature of the sun as estimated is 6032.25 K. The wavelength at which sun radiates maximum energy, is : (Given : Wein's constant = 0.2898 cm-K
(a) $\lambda_m = 5000$ Å (b) $\lambda_m = 4804.2$ Å
(c) $\lambda_m = 3809.5$ Å (d) $\lambda_m = 2891.6$ Å

Answers

Level-1

1. (d)	**2.** (c)	**3.** (d)	**4.** (a)	**5.** (d)	**6.** (c)	**7.** (a)	**8.** (a)	**9.** (d)	**10.** (b)
11. (b)	**12.** (b)	**13.** (b)	**14.** (a)	**15.** (d)	**16.** (a)	**17.** (c)	**18.** (d)	**19.** (a)	

Level-2

1. (b)	**2.** (b)	**3.** (a)	**4.** (c)	**5.** (b)	**6.** (c)	**7.** (a)	**8.** (a)	**9.** (c)	**10.** (b)
11. (a)	**12.** (c)	**13.** (b)	**14.** (d)	**15.** (b)	**16.** (b)	**17.** (a)	**18.** (c)	**19.** (c)	**20.** (a)
21. (a)	**22.** (a)	**23.** (b)	**24.** (a)	**25.** (b)	**26.** (b)	**27.** (c)	**28.** (c)	**29.** (b)	**30.** (a)
31. (c)	**32.** (d)	**33.** (c)	**34.** (c)	**35.** (c)	**36.** (c)	**37.** (d)	**38.** (a)	**39.** (a)	**40.** (a)
41. (a)	**42.** (c)	**43.** (b)	**44.** (a)	**45.** (c)	**46.** (b)	**47.** (a)	**48.** (d)	**49.** (b)	**50.** (a)
51. (b)	**52.** (b)	**53.** (b)							

19

Reflection of Light

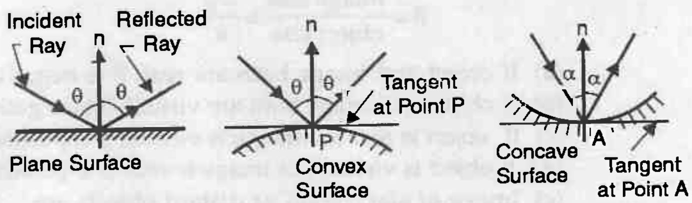
Syllabus: Reflection of light at plane and curved surfaces.

Review of Concepts

1. Reflection of light: When waves of any type strike the interface between two optical materials, new waves are generated which move away from the barrier. Experimentally it is found that the rays corresponding to the incident and reflected waves make equal angles with the normal to the interface and that the reflected ray lies in the plane of incidence formed by the line of incidence and the normal. Thus, the two laws of reflection can be summarised as under :

(i) Incident ray, reflected ray and normal on incident point are coplanar.

(ii) The angle of incidence is equal to angle of reflection.



Some important points: In case of plane mirror :

(i) For real object, image is virtual.

(ii) For virtual object, image is real.

(iii) Image size = Object size.

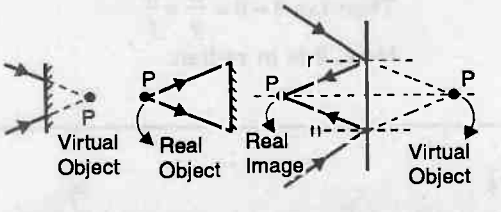
(iv) The converging point of incident beam behaves as object.

(v) If incident beam on optical instrument (mirror, lens etc) is converging in nature, object is virtual.

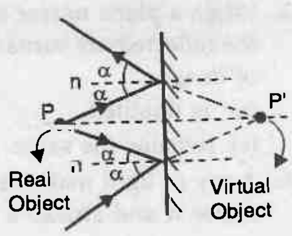
(vi) If incident beam on the optical instrument is diverging in nature, the object is real.

(vii) The converging point of reflected or refracted beam from an optical instrument behaves as image.

(viii) If reflected beam or refracted beam from an optical instrument is converging in nature, image is real.



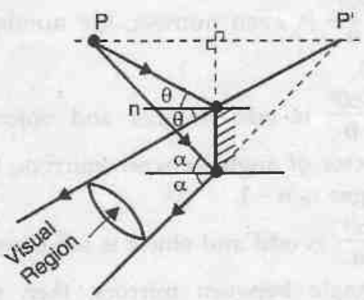
(ix) If reflected beam or refracted beam from an optical instrument is diverging in nature, image is virtual.



(x) For solving the problem, the reference frame is chosen in which optical instrument (mirror, lens, etc.) is in rest.

(xi) The formation of image and size of image are independent of size of mirror.

(xii) Visual region and intensity of image depend on size of mirror.

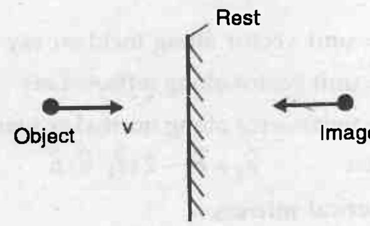


(xiii) If the plane mirror is rotated through an angle θ, the reflected ray and image is rotated through an angle 2θ in the same sense.

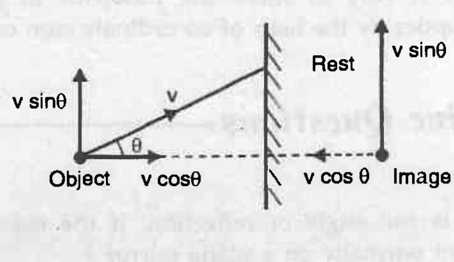
(xiv) If plane mirror is cut into a number of pieces, then the focal length does not change.

(xv) The minimum height of mirror required to see the full image of a man of height h is $h/2$.

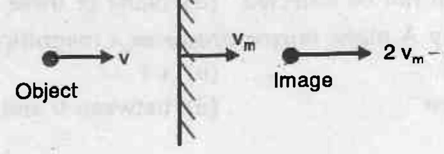
(xvi)



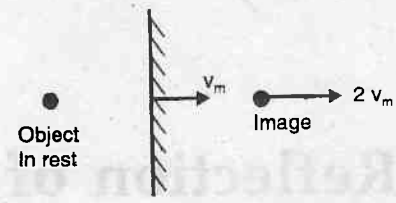
(xvii)



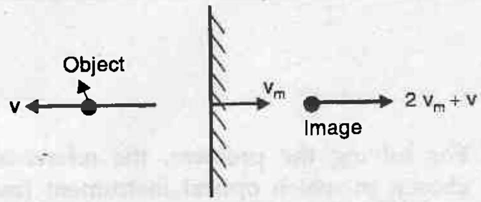
(xviii)



(xix)



(xx)



2. Number of images formed by combination of two plane mirrors : The images formed by combination of two plane mirrors are lying on a circle whose centre is at the meeting point of mirrors. Also, object is lying on that circle.

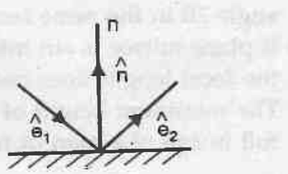
Let θ = angle between mirrors, then

(i) If $\frac{360^\circ}{\theta}$ is even number, the number of images is $n-1$.

(ii) If $\frac{360^\circ}{\theta}$ is odd number and object is placed on bisector of angle between mirrors, then number of images is $n-1$.

(iii) If $\frac{360^\circ}{\theta}$ is odd and object is not situated on bisector of angle between mirrors, then the number of images is equal to n.

3. Law of reflection in vector form :



Let $\hat{e}_1$ = unit vector along incident ray.

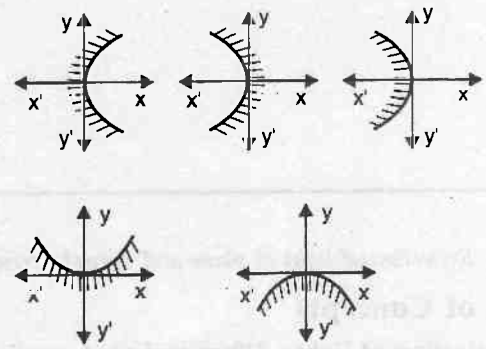
$\hat{e}_2$ = unit vector along reflected ray

$\hat{n}$ = unit vector along normal or point of incidence

Then, $\hat{e}_2 = \hat{e}_1 - 2(\hat{e}_1 \cdot \hat{n})\hat{n}$

4. Spherical mirrors :

(i) It is easy to solve the problems in geometrical optics by the help of co-ordinate sign convention.



(ii) The mirror formula is $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

Also, $R = 2f$

These formulae are only applicable for paraxial rays.

(iii) All distances are measured from optical centre. It means optical centre is taken as origin.

(iv) The sign conventions are only applicable in given values.

(v) The transverse magnification is

$$\beta = \frac{\text{image size}}{\text{object size}} = \frac{-v}{u}$$

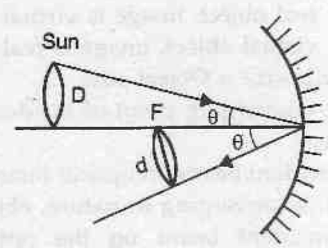
(a) If object and image both are real, β is negative.

(b) If object and image both are virtual, β is negative

(c) If object is real but image is virtual; β is positive.

(d) If object is virtual but image is real, β is positive.

(e) Image of star; moon or distant objects are formed at focus of mirror.



If y = the distance of sun or moon from earth.

D = diameter of moon or sun's disc.

f = focal length of the mirror

d = diameter of the image

Then $\tan\theta \approx \theta = \frac{D}{y} = \frac{d}{f}$

Here, θ is in radian.

Objective Questions

Level-1

1. What is the angle of reflection, if the ray of light is incident normally on a plane mirror ?
   (a) 0° (b) 90°
   (c) will not be reflected (d) None of these

2. The ray A plane mirror produces a magnification of :
   (a) −1 (b) +1
   (c) zero (d) between 0 and ∞

3. When a plane mirror is rotated through an angle θ, then the reflected ray turns through the angle 2θ, then the size of image :
   (a) is doubled (b) is halved
   (c) remains the same (d) becomes infinity

4. A ray of light makes an angle of 10° with the horizontal above it and strikes a plane mirror which is inclined at

an angle θ to the horizontal. The angle θ for which the reflected ray becomes vertical is :

(a) 40° (b) 50°
(c) 80° (d) 100°

5. A ray is reflected in turn by three plane mirrors mutually at right angles to each other. The angle between the incident and the reflected rays is :

(a) 90° (b) 60°
(c) 180° (d) none of these

6. The change in reflected wave, when light wave suffers reflection at the interface from air to glass is :

(a) 0 (b) $\frac{\pi}{2}$
(c) π (d) 2π

7. What will be the deviation produced in the ray, if a ray of light incidents on a plane mirror at an angle of 30° ?

(a) 30° (b) 60°
(c) 90° (d) 120°

8. If for angle of incidence, the incident ray and reflected ray from two mirrors be parallel to each other, then angle between two plane mirrors will be :

(a) 60° (b) 90°
(c) 120° (d) 175°

9. A plane mirror is infront of you in which you can see your image. It is approaching towards you at a speed of 10 cm/s, then at what speed will your image approach you ?

(a) 10 cm/s (b) 5 cm/s
(c) 20 cm/s (d) 15 cm/s

10. At an instant a watch shows time 3 : 25. When seen through a mirror, time appeared will be :

(a) 8 : 35 (b) 9 : 35
(c) 7 : 35 (d) 8 : 25

11. Calculate the velocity of image with respect to observer if an observer is walking away from the plane mirror with 6 m/s :

(a) 6 m/s (b) – 6 m/s
(c) 12 m/s (d) 3 m/s

12. Convergence of concave mirror can be decreased by dipping in :

(a) water (b) oil
(c) both (a) and (b) (d) none of these

13. Diminished virtual image can be formed only in :

(a) plane mirror
(b) a concave mirror
(c) a convex mirror
(d) concave-parabolic mirror

14. Image formed by convex mirror is :

(a) virtual
(b) real
(c) enlarged
(d) inverted

15. Mark the correct option.
An object is placed 40 cm away from a concave mirror of focal length 20 cm. The image formed is :

(a) real, inverted and same in size
(b) real, inverted and smaller
(c) virtual, erect and larger
(d) virtual, erect and smaller

16. A boy of length 10 m, to see his own complete image, requires a mirror of length at least equal to :

(a) 10/4 (b) 10/3
(c) 10/2 (d) 10

17. The size of the image, if an object of 2.5 m height is placed at a distance of 10 cm from a cancave mirror is : (Take radius of curvature of concave mirror = 30 cm)

(a) 10.5 cm (b) 9.2 cm
(c) 7.5 cm (d) 5.6 cm

18. A virtual image larger than the object can be obtained by :

(a) concave mirror
(b) convex mirror
(c) plane mirror
(d) concave lens

19. Which mirror should a boy use, if he stands straight infront of a mirror at a distance of 30 cm away from it and sees his erect image whose height is $\frac{1}{6}$th of his real height, is :

(a) plane mirror
(b) convex mirror
(c) concave mirror
(d) plano-convex mirror

20. The focal length of convex mirror is 20 cm, its radius of curvature will be :

(a) 10 cm (b) 20 cm
(c) 30 cm (d) 40 cm

Level-2

1. Mark correct option :

(a) The laws of reflection of light hold only for plane surfaces
(b) The size of virtual image can be measured by receiving it on screen
(c) Plane mirror alongs form an erect image
(d) Plane mirror may form inverted image

2. A plane mirror :

(i) can form real image of a real object
(ii) neither converges nor diverges the rays
(iii) cannot form real image of a real object

Choose the correct option or options :

(a) (i) is correct
(b) (i) and (ii) are correct
(c) (ii) and (iii) are correct
(d) none of the above

3. A hair dresser stands with her nose 20 cm infront of a plane mirror for what distance must she focus her eyes in order to see her nose in the mirror?
(a) 40 cm (b) 50 cm
(c) 30 cm (d) 60 cm

4. A plane mirror is placed along positive x-axis facing along positive y-axis. The equation of a linear object is $x = y$. The equation of its image is:
(a) $x = y$ (b) $x + y = 0$
(c) $2x + y = 0$ (d) none of these

5. A man of height 1.8 m stands infront of a large vertical plane mirror. The distance of the image from the man if he stands at a distance of 1.5 m from the mirror is:
(a) 1 m (b) 2 m
(c) 3 m (d) 4 m

6. A clock fixed on a wall shows time 04 : 25 : 37. What time will its image in a plane mirror show?
(a) 07 : 43 : 32 (b) 07 : 43 : 32
(c) 07 : 35 : 23 (d) 43 : 27 : 36

7. A car is moving towards a plane mirror at a speed of 30 m/s. Then the relative speed of its image with respect to the car will be:
(a) 30 m/s (b) 60 m/s
(c) 15 m/s (d) 45 m/s

8. A man is running towards a plane mirror with some velocity. If the relative velocity of his image with respect to him is 4 m/s, then the velocity of a man is:
(a) 2 m/s (b) 4 m/s
(c) 8 m/s (d) 16 m/s

9. A plane mirror is placed in y-z plane. A point object approaches the plane mirror with velocity $3\hat{i} + 4\hat{j}$. The velocity of image with respect to mirror is:
(a) $-3\hat{i} + 4\hat{j}$ (b) $3\hat{i} - 4\hat{j}$
(c) $-3\hat{i} - 4\hat{j}$ (d) none of these

10. A plane mirror is placed along the y-axis as such x-axis is normal to the plane of the mirror. The reflecting surface of the mirror is towards negative x-axis. The mirror moves in positive x-direction with uniform speed of 5 m/s and a point object P is moving with constant speed 3 m/s in negative x-direction. The speed of image with respect to mirror is:
(a) 8 m/s (b) 16 m/s
(c) 5 m/s (d) 10 m/s

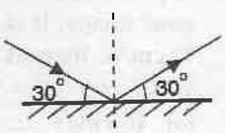
11. A plane mirror is placed in y-z plane facing towards negative x-axis. The mirror is moving parallel to y-axis with a speed of 5 cm/s. A point object P is moving infront of the mirror with a velocity $3\hat{i} + 4\hat{j}$. The velocity of image is:
(a) $-3\hat{i} + 4\hat{j}$ (b) $3\hat{i} - 4\hat{j}$
(c) $-3\hat{i}$ (d) $3\hat{i} + 4\hat{j}$

12. A plane mirror is placed in y-z plane facing towards negative x-axis. The mirror is moving parallel to y-axis with a speed of 5 cm/s. A point object P is moving infront of the mirror with a velocity $(3\text{ cm/s})\hat{i} + (4\text{ cm/s})\hat{j} + (5\text{ cm/s})\hat{k}$. The velocity of image with respect to mirror is:
(a) $(-3\text{ cm/s})\hat{i} + (4\text{ cm/s})\hat{j} + (5\text{ cm/s})\hat{k}$
(b) $(3\text{ cm/s})\hat{i} + (4\text{ cm/s})\hat{j} - 5\text{ (cm/s)}\hat{k}$
(c) $-(3\text{ cm/s})\hat{i} - (4\text{ cm/s})\hat{j} - (5\text{ cm/s})\hat{k}$
(d) none of the above

13. A bullet of mass m_2 is fired from a gun of mass m_1 with horizontal velocity v. A plane mirror is fixed at gun facing towards bullet. The velocity of the image of bullet formed by the plane mirror with respect to bullet is:
(a) $\left(1 + \frac{m_2}{m_1}\right)$ (b) $\left(\frac{m_1 + m_2}{m_1}\right)v$
(c) $\frac{2(m_1 + m_2)}{m_1}v$ (d) none of these

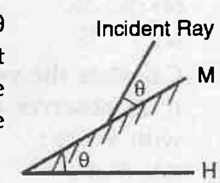
14. A cubical room is formed with 6 plane mirrors. An insect moves along diagonal of the floor with uniform speed. The velocity of its image in two adjacent walls are $20\sqrt{2}$ cm/s. Then the velocity of image formed by the roof is:
(a) 20 cm/s (b) 40 cm/s
(c) $20\sqrt{2}$ cm/s (d) $10\sqrt{2}$ cm/s

15. On a plane mirror, a ray of light is incident at an angle of 30° with horizontal. To make the reflected ray vertical, at what angle with horizontal must a plane mirror be placed?



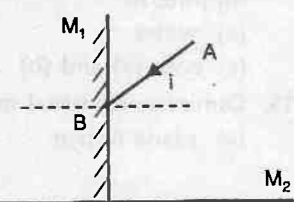
(a) 30° (b) 60°
(c) 45° (d) 54°

16. A mirror is inclined at an angle of θ with the horizontal. If a ray of light is incident at an angle of incidence θ, then the reflected ray makes the following angle with horizontal:



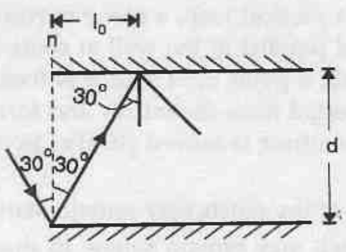
(a) θ (b) 2θ
(c) θ/2 (d) none of these

17 The mirrors are perpendicular to each other as shown in fig. A light ray AB is incident on the mirror M_1. Then the reflected ray will also suffer a reflection from the mirror M_2. Then the final ray after reflection from M_2 will be parallel to the incident ray, if:



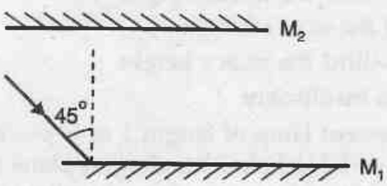
(a) $i = 45°$ (b) $i = 60°$
(c) $i < 30°$ (d) for any i between 0° and 90°

18. Two mirrors each 1.6 m long are facing each other. The distance between the mirrors is 20 cm. A light ray is incident on one end of the mirror at an angle of incidence of 30°. How many times is the ray reflected before it reaches the other end?



(a) There are 15 reflections counting the first one
(b) There are 13 reflections counting the first one
(c) There are 12 reflections counting the first one
(d) None of the above

19. Two plane mirrors M_1 and M_2 each have length 1 m are separated by 1 cm. A ray of light is incident on one end of mirror M_1 at angle 45°. How many reflections the ray will have before going at from the other end ?



(a) 50 (b) 51
(c) 100 (d) 101

20. A pole 5 m high is situated on a horizontal surface. Sun rays are incident at an angle 30° with the vertical. The size of shadow on horizontal surface is :

(a) 5 m (b) $\frac{5}{\sqrt{3}}$ m
(c) $\frac{10}{\sqrt{3}}$ m (d) none of these

21. A man wants to distinguish between two pillars located at a distance of 11 km. What should be the minimum distance between pillars ?

(a) 3.2 m (b) 1.2 m
(c) 1.1 m (d) 1.8 m

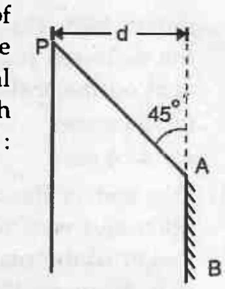
22. If distance between the wheel and mirror is 'd' then the velocity of light is : (Given that m be the number of teeth and 'n' the number of revolutions made in one second).

(a) mnd (b) $2\,mnd$
(c) $3\,mnd$ (d) $4\,mnd$

23. A ray is incident on a plane surface. If $\hat{i}+\hat{j}-\hat{k}$ represents a vector along the direction of incident ray. $\hat{i}+\hat{j}$ is a vector along normal on incident point in the plane of incident and reflected ray. Then vector along the direction of reflected ray is :

(a) $-\frac{1}{\sqrt{19}}(-3\hat{i}+3\hat{j}+\hat{k})$
(b) $\frac{1}{\sqrt{19}}(3\hat{i}+3\hat{j}-\hat{k})$
(c) $-\frac{1}{\sqrt{3}}(\hat{i}+\hat{j}+\hat{k})$
(d) $\hat{k}$

24. A point object P is situated infront of plane mirror shown in figure. The width of mirror AB is d. The visual region on a line passing through point P and parallel to the mirror is :



(a) d
(b) $2d$
(c) $3d$
(d) none of the above

25. A point source S is centred infront of a 70 cm wide plane mirror. A man starts walking from the source along a line parallel to the mirror. The maximum distance that can be walked by man without losing sight of the image of source is :

(a) 80 cm (b) 60 cm
(c) 70 cm (d) 90 cm

26. A beautiful girl with two normal eyes wants to see full width of her face by a plane mirror. The eye to eye and ear to ear distances of her face are 4 inch and 6 inch respectively. The minimum width of the required mirror is :

(a) 1 inch (b) 2 inch
(c) 3 inch (d) 4 inch

27. The size of the face of a dancer is $24\,cm \times 16\,cm$. The minimum size of a plane mirror required to see the face of dancer completely by :
(i) one eyed dancer.
(ii) two eyed dancer.
(Distance between the eyes is 4 cm.)

(a) (i) $12\times 8\,cm^2$ (ii) $12\times 6\,cm^2$
(b) (i) $8\times 10\,cm^2$ (ii) $12\times 2\,cm^2$
(c) (i) $10\times 12\,cm^2$ (ii) $9\times 8\,cm^2$
(d) (i) $12\times 2\,cm^2$ (ii) $6\times 13\,cm^2$

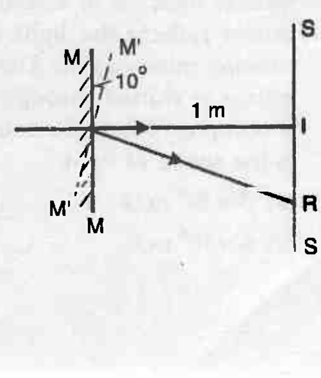
28. A narrow beam of light after reflection by a plane mirror falls on a scale 100 cm from the mirror. When the mirror is rotated a little the spot moves through 2 cm, the angle, through which the mirror is rotated is :

(a) 0.02 rad (b) 0.01 rad
(c) 200 rad (d) $\frac{0.01}{180}\pi$ rad

29. A ray of light falls on a plane mirror. When the mirror is turned, about an axis at right angle to the plane of the mirror through 20°, the angle between the incident ray and new reflected ray is 45°. The angle between the incident ray and original reflected ray is :

(a) 15° (b) 30°
(c) 45° (d) 60°

30. A lamp and scale arrangement, used to measure small deflection is shown in the figure. SS' is the glass scale placed at a distance of 1 m from the plane mirror. MM and I is the position of the light spot formed after reflection from the underdeflected



mirror MM. The mirror is deflected by 10° and comes to the deflected position $M'M'$. The distance moved by the spot on the scale (IR) is :

(a) 24.6 cm (b) 36.4 cm
(c) 46.4 cm (d) 34.9 cm

31. One end of the strip of a plane mirror is fixed and the other end rests on the top of the small vertical rod. The length of the plane mirror strip is 25 cm. A ray of light is incident on the mirror and reflected from the mirror and forms a spot on a screen 3 m away from the mirror. Now, if the top of the rod is moved upwards 0.1 mm, then what will be movement of the spot ?

(a) 0.24 cm (b) 3.4 cm
(c) 5 cm (d) 4.5 cm

32. A plane mirror is mounted parallel to a vertical wall at the distance 'd' from light fixed on the wall gets reflected by the mirror to form a path of light on the wall. When the mirror is moved parallel to itself towards the wall, the path of light on the wall :

(a) remains unchanged in position and vertical height
(b) moves along the wall away from the source without changing in vertical length
(c) will increase in vertical length with the lower end fixed
(d) moves along the wall away from the source and is increasing in vertical length.

33. The shape of spot light produced when bright sunshine passes perpendicular through a hole of very small size, is :

(a) square because hole is square
(b) round because it is an image of the sun
(c) round with a small pinumbra around it
(d) square with a small pinumbra

34. Images in spherical mirrors suffer from several defects. Some of which is/are :

(a) diffraction effect
(b) the magnification varies with the distance of the object from mirror
(c) a point source will not produce a point image
(d) all of the above

35. A flat mirror revolves at a constant angular velocity making 2 revolutions/sec. With what velocity will a light spot move along a spherical screen with a radius of 10 m, if the mirror is at a centre of curvature of the screen ?

(a) 251.2 m/s (b) 261.2 m/s
(c) 271.2 m/s (d) 241.2 m/s

36. A plane mirror which rotates 10^4 times per minute reflects light on to a stationary mirror 50 m away. This mirror reflects the light normally so that it strikes the rotating mirror again. The image observed in the rotating mirror is shifted through 2.4 minutes from the position it occupies. When the rotating mirror is stationary, what is the speed of light ?

(a) 3×10^8 m/s (b) 4×10^8 m/s
(c) 5×10^8 m/s (d) 6×10^8 m/s

37. Infront of a vertical wall, a plane mirror of square shape is mounted parallel to the wall at some distance from it. On the wall, a point light source is fixed and light from it gets reflected from the mirror and forms a path on the wall. If the mirror is moved parallel to itself towards the wall, then

(i) centre of the patch may remain stationary
(ii) the patch may remain square in shape
(iii) area of patch decreases

Choose correct statement :

(a) (i) and (ii) are correct
(b) (i) and (iii) are correct
(c) (ii) and (iii) are correct
(d) none of the above

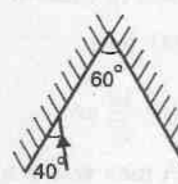
38. The shortest height of a vertical mirror required to see the entire image of a man, will be

(a) one-third the man's height
(b) half the man's height
(c) two-third the man's height
(d) data insufficient

39. A fluorescent lamp of length 1 m is placed horizontal at a depth of 1.2 m below a ceiling. A plane mirror of length 0.6 m is placed below the lamp parallel to and symmetric to the lamp at a distance 2.4 m from it. The length of the reflected patch of light on the ceiling is :

(a) 3 m (b) 4 m
(c) 7 m (d) none of these

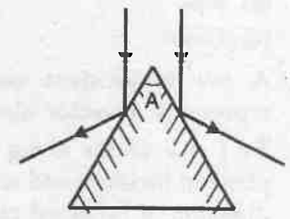
***40.** In figure shown, a ray of light is incident at 50° on the middle of one of a pair of mirrors arranged at 60° :



(i) Calculate the image at which the ray is incident on the second mirror
(ii) Calculate the angle at which the ray is incident on the first mirror after being reflected from the second mirror.

(a) (i) 45° (ii) 10° (b) (i) 30° (ii) 45°
(c) (i) 10° (ii) 70° (d) (i) 20° (ii) 50°

41. In the given figure, the angle between reflected rays is equal to :

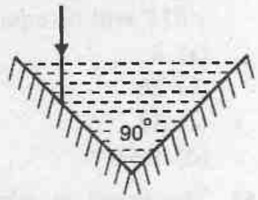


(a) A
(b) 2 A
(c) 3 A
(d) 4 A

42. Two plane mirrors are perpendicular to each other. A ray after suffering reflection from the two mirrors will be

(a) perpendicular to the original ray
(b) parallel to the original ray
(c) parallel to the first mirror
(d) at 45° to the original ray

43. A vessel consists of two plane mirrors at right angles (as shown in figure). The vessel is filled with water. The total deviation in incident ray is :

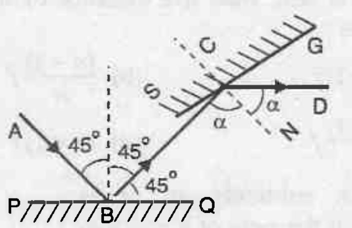


(a) 0°
(b) 90°
(c) 180°
(d) none of the above

44. Two plane mirrors are inclined at an angle θ. A ray of light is reflected from the first mirror and is then incident on the second mirror from which it is again reflected. What is deviation of incident ray ?

(a) $360° + 2\theta$ (b) $360° - \theta$
(c) $360° - 2\theta$ (d) $360° + \theta$

45. A light ray is incident on a horizontal plane mirror at an angle of 45°. At what angle should a second plane mirror be placed in order that the reflected ray finally be reflected horizontally from the second mirror, as shown in figure :



(a) $\theta = 30°$ (b) $\theta = 24°$
(c) $\theta = 22.5°$ (d) $\theta = 67.5°$

46. A number of images of a bright bulb can be seen in a thick mirror. The image is seen at a large angle of reflection. The brightest image is :

(a) the first one (b) the second one
(c) the third one (d) the fourth one

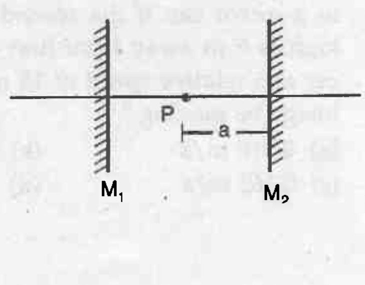
47. Two plane mirrors are combined to each other as such one is in y-z plane and other is in x-z plane. A ray of light along vector $\hat{i} + \hat{j} + \hat{k}$ is incident on the first mirror. The unit vector in the direction of emergence ray after successive reflections through the mirror is :

(a) $-\frac{1}{\sqrt{3}}\hat{i} - \frac{1}{\sqrt{3}}\hat{j} + \frac{1}{\sqrt{3}}\hat{k}$ (b) $-\frac{1}{\sqrt{3}}\hat{i} - \frac{1}{\sqrt{3}}\hat{j} - \frac{1}{\sqrt{3}}\hat{k}$
(c) $-\hat{i} - \hat{j} + \hat{k}$ (d) none of these

48. A source of light lies on the angle bisector of two plane mirrors inclined at an angle θ. The values of θ, so that the light reflected from one mirror does not reach the other mirror will be :

(a) $\theta > 120°$ (b) $\theta > 90°$
(c) $\theta \le 120°$ (d) none of these

49. Two plane mirrors are placed parallel to each other. A point object is placed between them. The distance of image formed in one of the mirror is in :

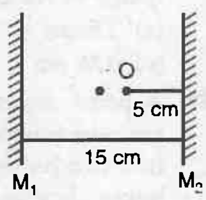


(a) harmonic progression
(b) arithmetic progression
(c) geometric progression
(d) both harmonic and arithmetic progression

50. Two plane mirrors are parallel to each other and spaced 20 cm apart. A luminous point object is placed between them and 5 cm from one mirror. What are the distances from each mirror of the three nearest images in each ?

(a) For Ist mirror, $-5, 35$ and 45 cm
For 2nd mirror, $-15, 25$ and 55 cm
(b) For 1st mirror, $-2, 23$ and 54 cm
For 2nd mirror, $-3, 35$ and 50 cm
(c) For Ist mirror, $-35, 40$ and 30 cm
For 2nd mirror, $-3, 50$ and 40 cm
(d) None of the above

51. Two plane mirrors are placed parallel to each other as shown in the figure. There is an object 'O' placed between the mirrors, at 5 cm from mirror M_2. What are the distance of first three images from the M_2 ?



(a) 5, 10, 15 (b) 5, 15, 30
(c) 5, 25, 25 (d) 5, 15, 25

52. If an object is placed between two plane mirrors a distance $2b$ apart, the object is situated at mid-point between mirrors, the position of n^{th} image formed by one of the mirrors with respect to the object is :

(a) nb (b) $2nb$
(c) $3nb$ (d) $4nb$

53. If two mirrors are inclined at some angle and an object is placed between the mirrors and there are 7 images formed for an object. Then what is angle between the mirrors?

(a) 54° (b) 50°
(c) 60° (d) 64°

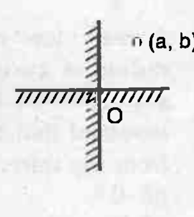
54. Two plane mirrors are placed at some angle. There are five images formed, when an object is placed symmetrically between them, the angle between the mirrors is :

(a) 60° (b) 65°
(c) 30° (d) 45°

55. Two plane mirrors are inclined at an angle such that a ray incident on a mirror undergoes a total deviation of 240° after two reflections. The angle between mirrors. Also discuss the formation of image :

(a) 60°, 5 (b) 5°, 60
(c) 45°, 5 (d) 30°, 6

***56.** Two plane mirrors are inclined at 90°. An object is placed between them whose coordinates are (a, b). Find the position vectors of all the images formed : (Take $\hat{i}, \hat{j}$ are unit vectors along x-y axis)

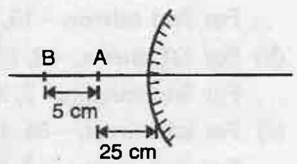


(a) $-a\hat{i} - b\hat{j}, a\hat{i} - b\hat{j}, -a\hat{i} + b\hat{j}$

(b) $-a\hat{\mathbf{i}}+b\hat{\mathbf{j}},\ -a\hat{\mathbf{i}}-b\hat{\mathbf{j}},\ a\hat{\mathbf{i}}-b\hat{\mathbf{j}}$
(c) $a\hat{\mathbf{i}}+b\hat{\mathbf{j}},\ -a\hat{\mathbf{i}}-b\hat{\mathbf{j}},\ +a\hat{\mathbf{i}}-b\hat{\mathbf{j}}$
(d) none of the above

57. If two adjacent walls and the ceiling of a rectangular room are mirror surfaced, then how many images of himself, a man can see ?
(a) 3 (b) 5
(c) 6 (d) 9

58. A convex mirror of focal length 10 cm is shown in figure. A linear object $AB = 5$ cm is placed along the optical axis. Point B is at distance 25 cm from the pole of mirror. The size of image of AB is :



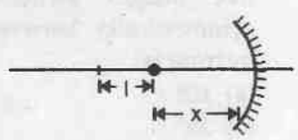
(a) 2.5 cm (b) 0.64 cm
(c) 0.36 cm (d) none of these

59. A point object P is placed at centre of curvature of a concave mirror of focal length 25 cm. The mirror is cut into two halves and shifted symmetrically 1 cm apart in perpendicular to the optical axis. The distance between images formed by both parts is :
(a) 2 cm (b) 1 cm
(c) 3 cm (d) 4 cm

60. In the measurement of the focal length f of a concave mirror, the object distance $u = 40 \pm 0.1$ cm and image distance $v = 20 \pm 0.2$ cm. The maximum % error in the measure of f is :
(a) 1.75 (b) 0.75
(c) 0.3 (d) 2.25

61. If u represents object distance from pole of spherical mirror and v represents image distance from pole of mirror and f is the focal length of the mirror, then a straight line $u = v$ will cut u versus v graph at :
(a) (f, f) (b) $(2f, 2f)$
(c) $(f, 2f)$ (d) $(0, 0)$

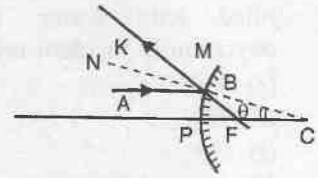
62. A short linear object of length l lies on the axis of a spherical mirror of focal length f, at a distance x from the mirror. Then the length of the image (P) so obtained will be :



(a) $\dfrac{lf}{(x-f)}$ (b) $\dfrac{lf^2}{(x-f)^2}$
(c) $\dfrac{lf}{x}$ (d) $\dfrac{l(x-f)}{x}$

63. A rear view mirror of a vehicle is cylindrical having radius of curvature 5 cm and length of arc of curved surface is 10 cm. The field of view in radian, if it is assumed that the eye of the driver is at a large distance from the mirror, is :
(a) 0.5 (b) 1
(c) 2 (d) 4

64. In the figure, AB and BK represent incident and reflected rays. If angle $BCF = \theta$, then $\angle BFP$ will be equal to :

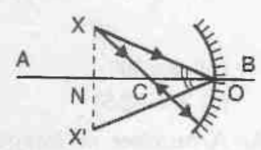


(a) θ
(b) 2θ
(c) 3θ
(d) $3.5\,\theta$

65. The speed at which the image of the luminous point object is moving, if the luminous point object is moving at speed v_0 towards a spherical mirror, along its axis, is :
(Given : R = radius of curvature, u = object distance)
(a) $v_i = -v_0$ (b) $v_i = -v_0\left(\dfrac{R}{2u-R}\right)$
(c) $v_i = -v_0\left(\dfrac{2u-R}{R}\right)$ (d) $v_i = -v_0\left(\dfrac{R}{2u-R}\right)^2$

66. A concave mirror produces an image n times the size of an object. If the focal length of the mirror is 'f' and image formed is real, then the distance of the object from the mirror is :
(a) $(n-1)f$ (b) $\dfrac{(n-1)}{n}f$
(c) $\dfrac{(n+1)}{n}f$ (d) $(n+1)f$

67. The sun subtends an angle $\alpha = 0.5°$ at the pole of a concave mirror. The radius of curvature of concave mirror is $R\,(=1.5\text{ m})$. The size of image formed by the concave mirror is :



(a) 0.785 cm (b) 0.654 cm
(c) 0.755 cm (d) 0.622cm

68. An observer is sitting 20 cm away from a circular convex mirror, with his eyes on the axis of the mirror. The mirror has diameter of 6 cm and focal length 30 cm is fixed with its principal axis horizontal. The image is formed at distance 12 cm from the mirror and the distance of mid-point of diameter from the pole is 0.75 cm. The angular field of view in the horizontal plane seen in the mirror by the observer is :
(a) $\tan\theta = 0.5672$ (b) $\tan = 0.3014$
(c) $\tan\theta = 0.5279$ (d) $\tan\theta = 0.2516$

69. The position of 1 cm tall object which is placed 8 cm infront of a concave mirror of radius of curvature 24 cm is :
(a) 24 cm (b) 25 cm
(c) 26 cm (d) 27 cm

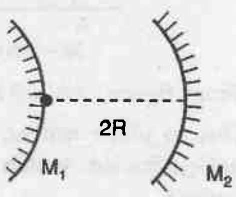
70. A convex driving mirror of focal length 20 cm, is fitted in a motor car. If the second car 2 m broad and 1.6 m high is 6 m away from first car and overtakes the first car at a relative speed of 15 m/s, then how fast will the image be moving ?
(a) 0.016 m/s (b) 0.0257 m/s
(c) 0.162 m/s (d) 0.0073 m/s

71. When an object is placed at a distance of 25 cm from a mirror, the magnification is m_1. But the magnification becomes m_2, when the object is moved 15 cm farther away with respect to the earlier position. If $\frac{m_1}{m_2} = 4$, then find the focal length of the mirror and what type of mirror it is ?
(a) 20 cm, convex (b) 20 cm, concave
(c) 10 cm, convex (d) 10 cm, concave

72. Two objects 'A' and 'B' when placed in turns infront of a concave mirror, give images of equal size. The focal length of the concave mirror is 7.5 cm and size of object A is three times the size of object B. The distance of B from the mirror, if A is placed 30 cm from the mirror, is :
(a) 18 cm (b) 15 cm
(c) 20 cm (d) 25 cm

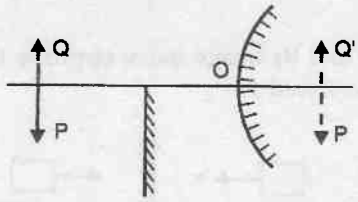
73. An object of height 5 cm is placed in midway between a concave mirror of radius of curvature 30 cm and a convex mirror of radius of curvature 30 cm. The mirrors are placed opposite to each other and are 60 cm apart. The position of the image formed by reflection at convex mirror is :
(a) 10 cm (b) 20 cm
(c) 15 cm (d) 13 cm

74. Two spherical mirrors, one convex and other concave are placed coaxially at a distance 2R from each other. Both the mirrors have same radius of curvature R. What is the radius of 3rd image from first three images of the circle, if a small circle of radius a is drawn on the convex mirror shown in the figure ?



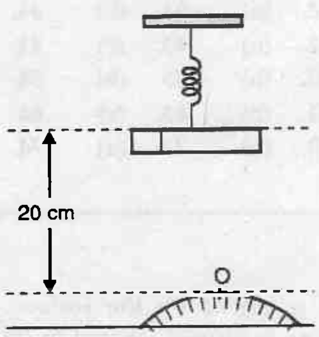
(a) $\frac{a}{43}$ (b) $\frac{a}{41}$
(c) $\frac{a}{39}$ (d) $\frac{a}{56}$

75. An object is placed at a distance of 40 cm from a convex spherical mirror as shown in figure. The radius of curvature of the convex mirror is 20 cm. At what distance from the object a plane mirror should be placed so that the image in the spherical mirror and plane mirror may be in one plane ?



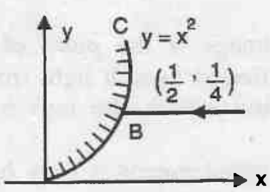
(a) 20 cm (b) 24 cm
(c) 28 cm (d) 32 cm

* 76. A body of mass 100 g is tied to one end of spring of constant 20 N/m. The distance between pole of mirror and mean position of the body is 20 cm. The focal length of convex mirror is 10 cm. The amplitude of vibration of image is :



(a) 10 cm (b) 50 cm
(c) 0.67 cm (d) 0.33 cm

77. In the given figure, the angle of reflection is :



(a) 30° (b) 60°
(c) 45° (d) none of these

78. The reflective surface is given by $y = 2 \sin x$. The reflective surface is facing positive axis. What is the least values of co-ordinate of the point where a ray parallel to positive x-axis becomes parallel to positive y-axis after reflection ?
(a) $\left(\frac{\pi}{3}, \sqrt{3}\right)$ (b) $\left(\frac{\pi}{2}, \sqrt{2}\right)$
(c) $\left(\frac{\pi}{3}, \sqrt{2}\right)$ (d) $\left(\frac{\pi}{4}, \sqrt{3}\right)$

Answers

Level-1

1. (b)	2. (b)	3. (c)	4. (a)	5. (c)	6. (c)	7. (d)	8. (b)	9. (c)	10. (a)
11. (c)	12. (d)	13. (c)	14. (a)	15. (a)	16. (c)	17. (c)	18. (a)	19. (b)	20. (d)

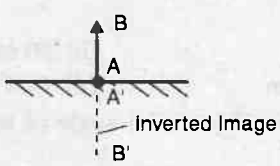
Level-2

1. (d)	2. (c)	3. (a)	4. (b)	5. (c)	6. (c)	7. (b)	8. (a)	9. (a)	10. (a)
11. (a)	12. (a)	13. (c)	14. (b)	15. (a)	16. (d)	17. (d)	18. (a)	19. (d)	20. (b)
21. (a)	22. (d)	23. (c)	24. (b)	25. (c)	26. (a)	27. (a)	28. (b)	29. (c)	30. (d)
31. (a)	32. (a)	33. (b)	34. (d)	35. (a)	36. (a)	37. (a)	38. (b)	39. (a)	40. (c)
41. (b)	42. (b)	43. (c)	44. (c)	45. (c)	46. (b)	47. (a)	48. (a)	49. (c)	50. (a)
51. (c)	52. (b)	53. (b)	54. (a)	55. (a)	56. (b)	57. (c)	58. (c)	59. (a)	60. (a)
61. (b)	62. (b)	63. (c)	64. (b)	65. (d)	66. (c)	67. (b)	68. (d)	69. (a)	70. (a)
71. (b)	72. (b)	73. (a)	74. (b)	75. (b)	76. (c)	77. (c)	78. (a)		

Solutions

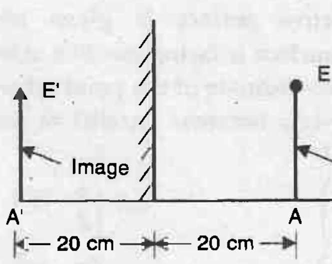
Level-2

1. If an object is placed on the surface of plane mirror, inverted image is formed (shown in fig.)

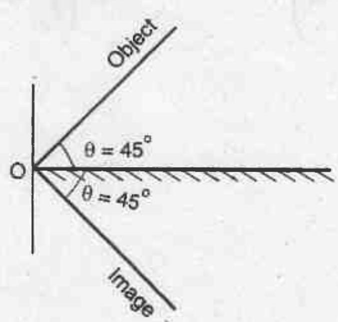


2. The position of image is the point of divergence or convergence of reflected rays. If light from a real object incident on a plane mirror, the rays incident will be diverging.
As power of the plane mirror is zero, hence, it neither converges nor diverges the rays.

3. From the figure, image is situated at 40 cm from eye. Hence, (a) is correct.



4.



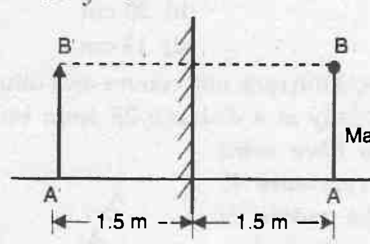
The slope of image is $m = \tan(-45°) = -1$

$\therefore \quad y = mx$ (As crossing from origin)

$\therefore \quad y = -x$

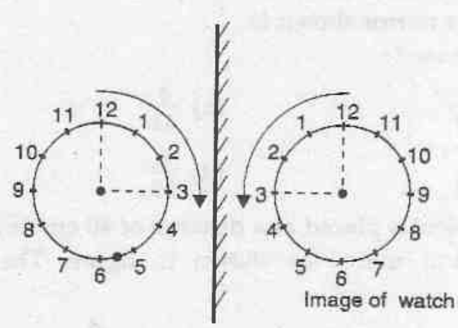
$\therefore \quad x + y = 0$

5.

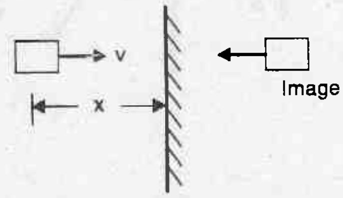


From figure, $AA' = 3$ m.

6. Due to plane mirror, clockwise watch is converted into anticlockwise watch (shown in figure). Here, (c) is correct.



7. The car and its image move opposite to each other with the same speed v.



$$\therefore \quad v_{rel} = 2v = 60 \text{ m/s}$$

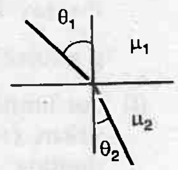
$\therefore$ Hence, (b) is correct.

20
Refraction of Light

Syllabus: Refraction of light at plane and curved surfaces, total internal reflection, optical fibre, deviation and dispersion of light by a prism, lens formula, magnification and resolving power, microscope and telescope.

Review of Concepts

1. Laws of refraction : When light passes from one medium, say air, to another, say glass, a part is reflected back into the first medium and the rest passes into the second medium. When it passes into the second medium, its direction of travel is changed. It either bends towards the normal or bends away from the normal. This phenomenon is known as refraction. There are two laws of refraction.



(a) The incident ray, the refracted ray and normal on incidence point are coplanar.

(b) $\mu_1 \sin\theta_1 = \mu_2 \sin\theta_2 = \ldots =$ constant.

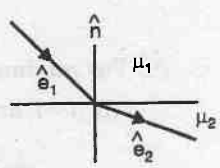
This is known as Snell's law.

Snell's law in vector form :

Let, $\hat{e}_1$ = unit vector along incident ray

$\hat{e}_2$ = unit vector along refracted ray.

$\hat{n}$ = unit vector along normal on incidence point.



Then $\mu_1 (\hat{e}_1 \times \hat{n}) = \mu_2 (\hat{e}_2 \times \hat{n})$

Some important points :

(i) The value of absolute refractive index μ is always greater or equal to one.

(ii) The value of refractive index depends upon material of medium, colour of light and temperature of medium.

(iii) When temperature increases, refractive index decreases.

(iv) Optical path is defined as product of geometrical path and refractive index.

i.e., optical path $= \mu x$

(v) For a given time, optical path remains constant.

i.e., $\mu_1 x_1 = \mu_2 x_2 = \ldots$ constant

$\therefore \quad \mu_1 \dfrac{dx_1}{dt} = \mu_2 \dfrac{dx_2}{dt}$

$\therefore \quad \mu_1 c_1 = \mu_2 c_2$

$\therefore \quad \dfrac{\mu_2}{\mu_1} = \dfrac{c_1}{c_2}$

i.e., $\mu \propto \dfrac{1}{c}$

(vi) The frequency of light does not depend upon medium.

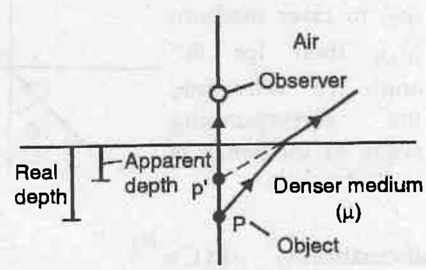
$\therefore \quad c_1 = f\lambda_1, \quad c_2 = f\lambda_2$

$\therefore \quad \dfrac{\mu_1}{\mu_2} = \dfrac{c_2}{c_1} = \dfrac{\lambda_2}{\lambda_1}$

$\therefore \quad \mu \propto \dfrac{1}{\lambda}$

2. (a) When observer is in rarer medium and object is in denser medium:

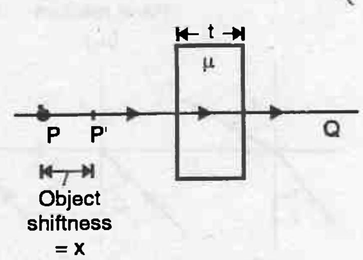
$$\mu = \frac{\text{real depth}}{\text{apparent depth}}$$



(b) When object is in air and observer is in denser medium:

$$\mu = \frac{\text{apparent position}}{\text{real position}}$$

(c) The shift of object due to slab is $x = t\left(1 - \dfrac{1}{\mu}\right)$



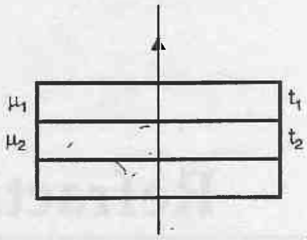
(i) This formula is only applicable when observer is in rarer medium.

(ii) The object shiftness does not depend upon the position of object.

(iii) Object shiftness takes place in the direction of incident ray.

(d) The equivalent refractive index of a combination of a number of slabs for normal incidence is

$$\mu = \frac{\Sigma t_i}{\Sigma \frac{t_i}{\mu_i}}$$

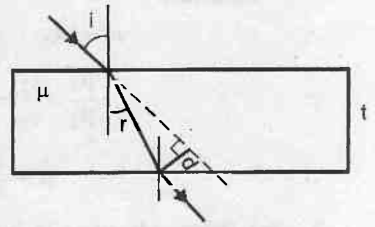


Here, $\Sigma t_i = t_1 + t_2 + \ldots$

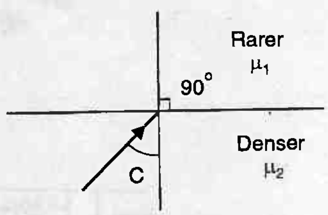
$$\Sigma \frac{t_i}{\mu_i} = \frac{t_1}{\mu_1} + \frac{t_2}{\mu_2} + \ldots$$

(e) The apparent depth due to a number of media is $\Sigma \frac{t_i}{\mu_i}$

(f) The lateral shifting due to a slab is $d = t \sec r \sin (i - r)$.



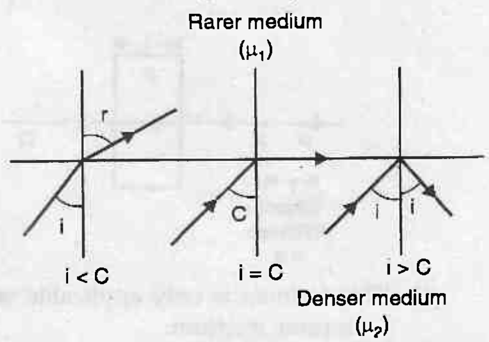
3. (a) **Critical angle :** When a ray passes from denser medium (μ_2) to rarer medium (μ_1), then for 90° angle of refraction, the corresponding angle of incidence is critical angle.



Mathematically, $\sin C = \frac{\mu_1}{\mu_2}$

(b) (i) When angle of incidence is lesser than critical angle, refraction takes place. The corresponding deviation is

$$\delta = \sin^{-1}\left(\frac{\mu_2}{\mu_1} \sin i\right) - i \qquad \text{for } i < C$$



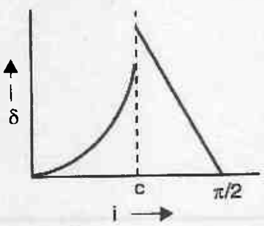
(ii) When angle of incidence is greater than critical angle, total internal reflection takes place. The corresponding deviation is

$$\delta = \pi - 2i \qquad \text{when } i < C$$

4. The $\delta - i$ graph is

(i) Critical angle depends upon colour of light, material of medium, and temperature of medium.

(ii) Critical angle does not depend upon angle of incidence.



Prism

(a) Deviation produced by prism is $\delta = i + i' - A$.

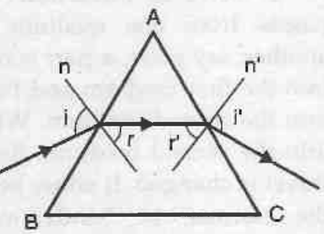
(b) $r + r' = A$

(c) For grazing incidence, $i = 90°$

(d) For grazing emergence, $i' = 90°$

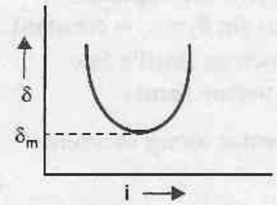
(e) For not transmitting the ray from prism,

$$\mu > \operatorname{cosec} \frac{A}{2}$$



(f) For limiting angle of prism, $i = i' = 90°$, the limiting angle of prism $= 2C$ where C is critical angle. If angle of prism exceeds the limiting values, then the rays are totally reflected.

(g) δ–i graph for prism:



(h) For minimum deviation,

(i) $i = i'$ and $r = r'$

(ii) $$\mu = \frac{\sin\left(\frac{\delta_m + A}{2}\right)}{\sin \frac{A}{2}}$$

In the case of minimum deviation, ray is passing through prism symmetrically.

(i) For maximum deviation (δ_{max}).

$$i = 90° \text{ or } i' = 90°$$

(j) For thin prism, $\delta = (\mu - 1) A$

(k) Angular dispersion, $D = (\mu_v - \mu_r) A$

(l) Angular deviation, $\delta_y = (\mu_y - 1) A$

(m) Dispersive power $= \omega = \left(\frac{\mu_v - \mu_r}{\mu_y - 1}\right)$

(n) $\mu_y = \frac{\mu_v + \mu_r}{2}$

(o) For dispersion without deviation,

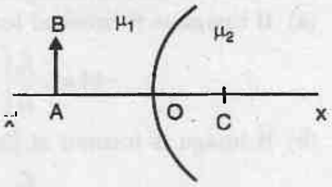
$$\Sigma \delta_y = 0$$

(p) For deviation without dispersion,

$$\Sigma D = 0$$

Refractive Surface Formula,

$$\frac{\mu_2}{v}-\frac{\mu_1}{u}=\frac{\mu_2-\mu_1}{r}$$



Here,
v = image distance,
u = object distance,
r = radius of curvature of spherical surface.

(a) For plane surface, $r=\infty$

(b) Transverse magnification,

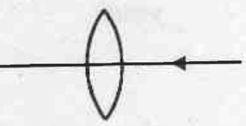
$$m=\frac{\text{image size}}{\text{object size}}=\frac{\mu_1 v}{\mu_2 u}$$

(c) Refractive surface formula is only applicable for paraxial ray.

Lens

1. **Lens formula :**

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$$



(a) Lens formula is only applicable for thin lens.

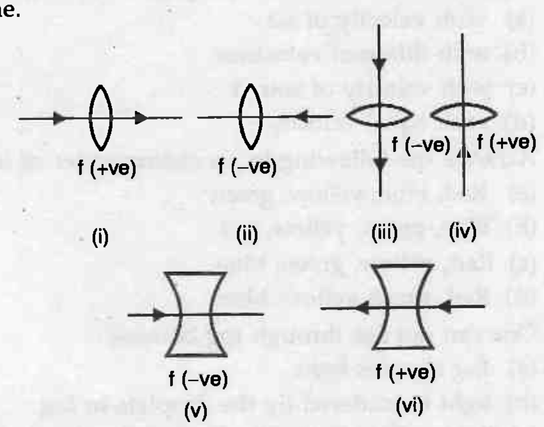
(b) $r=2f$ formula is not applicable for lens.

(c) $m=\frac{\text{image size}}{\text{object size}}=\frac{v}{u}$

(d) Magnification formula is only applicable when object is perpendicular to optical axis.

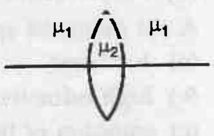
(e) Lens formula and the magnification formula is only applicable when medium on both sides of lenses are same.

(f)



(g) Thin lens formula is applicable for converging as well diverging lens.
Thin lens maker's formula :

$$\frac{1}{f}=\left(\frac{\mu_2-\mu_1}{\mu_1}\right)\left(\frac{1}{r_1}-\frac{1}{r_2}\right)$$



2. (a) Thin lens formula is only applicable for paraxial ray.

(b) This formula is only applicable when medium on both sides of lens are same.

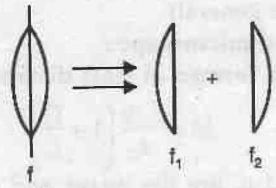
(c) Intensity is proportional to square of aperture.

(d) When lens is placed in a medium whose refractive index is greater than that of lens. *i.e.,* $\mu_1>\mu_2$, then converging lens behaves as diverging lens and vice versa.

(e) When medium on both sides of lens are not same, then both focal lengths are not same to each other.

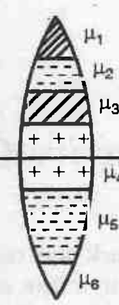
(f) If a lens is cut along the diameter, focal length does not change.

(g) If lens is cut by a vertical, it converts into two lenses of different focal lengths.



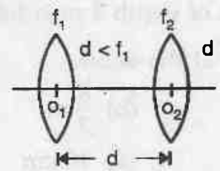
i.e., $\frac{1}{f}=\frac{1}{f_1}+\frac{1}{f_2}$

(h) If a lens is made of a number of layers of different refractive indices (shown in figure), then number of images of an object formed by the lens is equal to number of different media.



(i) The minimum distance between real object and real image in the case of thin lens is $4f$.

(j) The equivalent focal length of co-axial combination of two lenses is given by



$$\frac{1}{F}=\frac{1}{f_1}+\frac{1}{f_2}-\frac{d}{f_1 f_2}$$

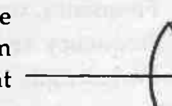
(k) If a number of lenses are in contact, then

$$\frac{1}{F}=\frac{1}{f_1}+\frac{1}{f_2}+\dots$$

(l) (i) Power of thin lens, $P=\frac{1}{F}$

(ii) Power of mirror, $P=-\frac{1}{F}$

(m) If a lens is silvered at one surface, then the system behaves as an equivalent mirror, whose power $P=2P_L+P_m$



Here, P_L = Power of lens $=\left(\frac{\mu_2-\mu_1}{\mu_1}\right)\left(\frac{1}{r_1}-\frac{1}{r_2}\right)$

P_m = Power of silvered surface $=-\frac{1}{F_m}$

Here, $F_m=\frac{r_2}{2}$, where r_2 = radius of silvered surface.

$$P=-\frac{1}{F}$$

Here, F = focal length of equivalent mirror.

Optical Instrument

1. Simple microscope: Magnifying power of a simple microscope is $M = 1 + \frac{D}{f}$, where D = least distance of distinct vision = 25 cm (in general)

2. Compound microscope:

(a) If image is formed at least distance of distinct vision

$$M = \frac{-v_o}{u_o}\left(1 + \frac{D}{f_e}\right)$$

where, v_o and u_o are the image and object distances for the objective.

f_e = focal length of eye piece.

(b) If final image is formed at infinity:

$$M = \frac{-v_o D}{u_o f_e}$$

3. Astronomical telescope:

(a) If image is formed at least distance of distinct vision

$$M = -\frac{f_o}{f_e}\left[1 + \frac{f_e}{D}\right]$$

(b) If image is formed at infinity (normal adjustment)

$$M = -\frac{f_o}{f_e}$$

4. Galilean telescope:

(a) For normal adjustment:

$$M = \frac{f_o}{f_e}$$

(b) If final image is formed at least distance of distinct vision:

$$M = \frac{f_o}{f_e}\left[1 - \frac{f_e}{D}\right]$$

Objective Questions

Level-1

1. Mark the correct option of source which is associated with a line emission spectrum:
(a) Electric fire (b) Neon street sign
(c) Red traffic light (d) Sun

2. A rectangular tank of depth 8 m is full of water $\left(\mu = \frac{4}{3}\right)$, the bottom is seen at the depth:
(a) 6 m (b) $\frac{8}{3}$ m
(c) 8 cm (d) 10 cm

3. Ray optics fails when the size of the obstacle is:
(a) 5 cm
(b) 3 cm
(c) less than the wavelength of light
(d) (a) and (b) both

4. If light travels from one medium to the other of which the refractive index is different, then which of the following will change?
(a) Frequency, wavelength and velocity
(b) Frequency, wavelength
(c) Frequency and velocity
(d) Wavelength and velocity

5. If the wavelength of light is increased, the angle of minimum deviation δ_m, the refractive index μ and the frequency ν:
(a) will decrease
(b) will increase
(c) will remain unchanged
(d) do not depend upon the wavelength

6. The angle of refraction, when a light ray approaches a glass-air interface from the glass side at the critical angle, will be:
(a) 0°
(b) 45°
(c) 90°
(d) equal to the angle of incidence

7. Light of different colours propagates through air:
(a) with velocity of air
(b) with different velocities
(c) with velocity of sound
(d) with equal velocity

8. Arrange the following in ascending order of frequency:
(a) Red, blue, yellow, green
(b) Blue, green, yellow, red
(c) Red, yellow, green, blue
(d) Red, green yellow, blue

9. One can not see through fog because:
(a) fog absorbs light
(b) light is scattered by the droplets in fog
(c) light suffers total reflection by the droplets in fog
(d) the refractive index of fog is in infinity

10. A cut diamond sparkles because of its:
(a) hardness
(b) high refractive index
(c) emission of light by the diamond
(d) absorption of light by the diamond

11. The combination of convex lens and concave lens each of focal length 10 cm when combines, behaves as:
(a) convex lens (b) concave lens
(c) as a slab of glass (d) as convex mirror

12. The refractive index of the medium, if a light wave has a frequency of 4×10^{14} Hz and a wavelength of 5×10^{-7} metres in a medium, will be:
(a) 1.5 (b) 1.33
(c) 1.0 (d) 0.66

13. The number of wavelengths in the visible spectrum is :
(a) 4000 (b) 6000
(c) 2000 (d) inifinite

14. The spectrum of molecular form of the substance is called :
(a) band spectrum (b) line spectrum
(c) absorption spectrum (d) continuous spectrum

15. Mark the correct option in impure spectrum :
(a) Order of colours is reverse
(b) Order of colours is irregular
(c) Colours are overlapped
(d) No colours is present

16. It is given that refractive index of water is 1.33. A diver in water will see the setting sun, at an angle of :
(a) 0° (b) 41°
(c) 90° (d) 60°

17. The mirage in desert is caused because :
(a) the refractive index of atmosphere does not change with height
(b) there is effect of height on refractive index
(c) light is reflected by the sand particles
(d) none of the above

18. Select the correct alternative, in case of dispersion without deviation :
(a) The emergent ray's of all the colours are parallel to the incident ray
(b) Only yellow coloured ray is parallel to the incident ray
(c) Only red coloured ray is parallel to the incident ray
(d) All the rays are parallel, but not parallel to the incident ray

19. Find the length of the optical path of two media in contact of lengths d_1 and d_2 of refractive indices μ_1 and μ_2 respectively :
(a) $\mu_1 d_1 + \mu_2 d_2$ (b) $\mu_1 d_2 + \mu_2 d_1$
(c) $\frac{d_1 d_2}{\mu_1 \mu_2}$ (d) $\frac{d_1 + d_2}{\mu_1 \mu_2}$

20. Calculate the refractive index of glass with respect to water. It is given that refractive indices of glass and water with respect to air are $\frac{3}{2}$ and $\frac{4}{3}$ respectively.
(a) $\frac{8}{9}$ (b) $\frac{9}{8}$
(c) $\frac{7}{6}$ (d) none of these

21. The dispersive power, if the refractive indices for the material of the prism are $\mu_v = 1.6$ and $\mu_r = 1.4$, is
(a) 3 (b) 1.6
(c) 0.4 (d) 1

22. If angle of prism is 10° and refractive indices of violet and red light are 1.54 and 1.52 respectively, then the angular dispersion is :
(a) 0.02 (b) 0.2
(c) 3.06 (d) 30.6

23. When a prism is dipped in water then the angle of minimum deviation of a prism with respect to air will be : $\left({}_a\mu_g = \frac{3}{2}, {}_a\mu_w = \frac{4}{3} \right)$
(a) $\frac{1}{8}$ (b) $\frac{1}{2}$
(c) $\frac{3}{4}$ (d) $\frac{1}{4}$

24. Angle of minimum deviation for a prism of refractive index 1.5 is equal to the angle of prism. The angle of prism is ($\cos 41° = 0.75$)
(a) 62° (b) 41°
(c) 82° (d) 31°

25. When a ray of light falls on a prism, light gets dispersed because :
(a) it is made of glass
(b) it is triangular
(c) refractive index of the prism material is different for different colours
(d) light is of seven colours

26. The false statement is :
(a) $A = r_1 + r_2$ (b) $\delta = 2i - A$
(c) $i = \frac{A + \delta_m}{2}$ (d) $\delta = (i - r_1) + (e - r_2)$

{where, $\angle i$ = incidence angle, $\angle r$ = angle of refraction, $\angle e$ = emergent angle, A = angle of prism, δ_m = angle of minimum deviation}

Level-2

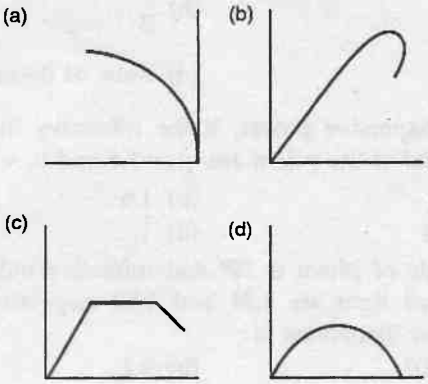
1. Due to increase of temperature of medium, refractive index will be :
(a) decreased (b) increased
(c) unchanged (d) none of these

2. In the case of refraction :
(a) the frequency of light changes
(b) the phase changes
(c) the wave length changes
(d) all the above

3. The rising and setting of sun appear red because of :
(a) refraction (b) reflection
(c) diffraction (d) scattering

4. The electric permittivity and magnetic permeability of free space are ε_0 and μ_0, respectively. The index of refraction of the medium, if ε and μ are the electric permittivity and magnetic permeability in a medium is :
(a) $\frac{\varepsilon\mu}{\varepsilon_0\mu_0}$ (b) $\left(\frac{\varepsilon\mu}{\varepsilon_0\mu_0}\right)^{1/2}$
(c) $\frac{\varepsilon_0\mu_0}{\varepsilon\mu}$ (d) $\left(\frac{\varepsilon_0\mu_0}{\varepsilon\mu}\right)^{1/2}$

5. Which of the following graphs represents the variation of longitudinal spherical aberration with the radius of the lens aperture for lenses of the same focal length and refractive index?

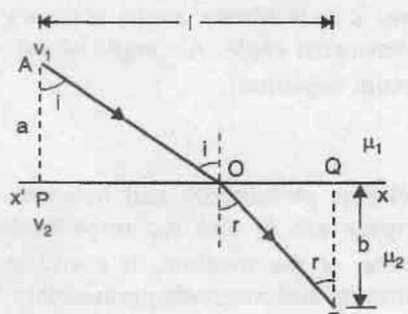


6. The maximum possible deviation of the ray, when a ray of light travels from an optically denser to rarer medium and the critical angle for the two medium is C, is :
(a) $(\pi - C)$ (b) $(\pi - 2C)$
(c) $2C$ (d) $\left(\frac{\pi}{2} + C\right)$

7. A ray of light falls on a transparent glass slab of refractive index 1.62. What is the angle of incidence, if the reflected ray and refracted ray are mutually perpendicular ?
(a) $\tan^{-1}(1.62)$ (b) $\tan^{-1}\left(\frac{1}{1.62}\right)$
(c) $\frac{1}{\tan^{-1}(1.62)}$ (d) None of these

8. A ray of light travelling in glass having refractive index ${}_a\mu_g = 3/2$, is incident at a critical angle C on the glass-air interface. If a thin layer of water is poured on glass air interface, then what will be the angle of emergence of this ray in air when it emerges from water-air interface ?
(a) 180° (b) 0°
(c) 90° (d) 45°

9. The time required for the light to go from A to B, when a ray of light goes from point A in a medium where the speed of light is v_1 to a point B in a medium where the speed of light is v_2 as shown in figure, is :



(a) $t = \frac{a \sec i}{v_1} + \frac{b \sec r}{v_2}$ (b) $t = \frac{a \sec i}{v_2} + \frac{b \sec r}{v_1}$
(c) $t = \frac{a \sec i}{v_1} - \frac{b \sec r}{v_2}$ (d) $t = \frac{a \sec i}{v_2} - \frac{b \sec r}{v_1}$

10. The time taken by the light to travel a distance of 500 metre in water of refractive index of 4/3 is :
(Given : velocity of light in vacuum = 3×10^8 m/s.)
(a) 3×10^{-10} sec (b) $2{\cdot}22 \times 10^{-6}$ sec
(c) $4{\cdot}3 \times 10^{-5}$ sec (d) 3×10^{-6} sec

11. In a medium of refractive index n_1, a monochromatic light of wavelength λ_1 is travelling. When it enters in a denser medium of refractive index n_2, the wavelength of the light in the second medium is :
(a) $\lambda_1\left(\frac{n_1}{n_2}\right)$ (b) $\lambda_1\left(\frac{n_2}{n_1}\right)$
(c) $\frac{\lambda_1(n_2 - n_1)}{n_2}$ (d) $\frac{\lambda_1(n_2 - n_1)}{n_1}$

12. If 'c' is the velocity of light in vacuum, then the time taken by the light to travel through a glass plate of thickness 't' and having refractive index μ is :
(a) $\left(\frac{t}{\mu c}\right)$ (b) $t\mu c$
(c) $\frac{\mu t}{c}$ (d) $\frac{tc}{\mu}$

13. The focal lengths of a thin convex lens for red and violet colours are 44.6 cm and 42.5 cm. The focal length for the mean colour and dispersive power of the lens are respectively :
(a) focal length = 43.53 cm
dispersive power = 0.048
(b) focal length = 28.53
dispersive power = 0.048
(c) focal length = 63.53 cm
dispersive power = 8.48
(d) focal length = 30.43
dispersive power = 4.8

14. A beam of parallel rays of width 6 cm propagates in glass at an angle θ to its plane face. What would the beam width b_1, be after it goes over to air through this face? (The refractive index of the glass is μ.)
(a) $b\mu$ (b) $b\mu \cot\theta$
(c) $\frac{b(1 - \mu^2\cos^2\theta)^{1/2}}{\sin\theta}$ (d) $\frac{b(1 - \mu^2\sin^2\theta)^{1/2}}{\cos\theta}$

15. Solar rays are incident at 45° on the surface of water ($\mu = 4/3$). What is the length of the shadow of a pole of length 1.2 m erected at the bottom of the pond, if the pole is vertical assuming that 0.2 m of the pole is above the water surface ?
(a) 1 m (b) 0.75 m
(c) 0.825 m (d) 1.2 m

* 16. x-y plane separates two media. $z > 0$ contains a medium of refractive index 1 and $z < 0$ contains a medium of refractive index 2. A ray of light is incident from first medium along a vector $\hat{i} + \hat{j} - \hat{k}$, the unit vector along refracted ray is :
(a) $\frac{1}{2\sqrt{3}}\hat{i} + \frac{1}{2\sqrt{3}}\hat{j} - \sqrt{\frac{5}{6}}\hat{k}$
(b) $\frac{1}{2\sqrt{3}}\hat{i} + \frac{1}{2\sqrt{3}}\hat{i} - \frac{1}{2\sqrt{3}}\hat{k}$
(c) $\hat{i} + \hat{j} - \hat{k}$
(d) none of the above

17. A light ray strikes a flat glass plate, at a small angle 'θ'. The glass plate has thickness 't' and refractive index 'μ'. What is the lateral displacement 'd' ?

(a) $\frac{t\theta(\mu+1)}{\mu}$ (b) $\frac{t\theta(\mu-1)}{\mu}$

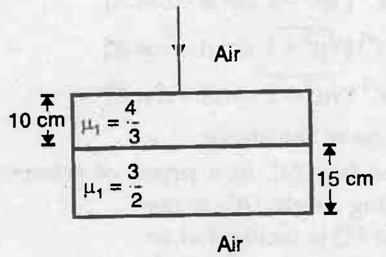
(c) $\frac{t}{\theta\mu}(\mu-1)$ (d) $\frac{\mu}{t\theta}(\mu+1)$

18. A glass slab has thickness 't' and refractive index μ. If a ray of light from air is incident on a glass slab, at an angle of incidence equal to the angle of total internal refraction of glass, then the displacement of the ray due to this slab in terms of thickness and refractive index of glass μ is :

(a) $\frac{t}{\mu}\left[1-\frac{1}{\sqrt{\mu^2-1}}\right]$ (b) $\frac{t}{\mu}\left[1+\frac{1}{\sqrt{\mu^2+1}}\right]$

(c) $\frac{t}{\mu}\left[1-\frac{1}{\sqrt{\mu^2+1}}\right]$ (d) $\frac{t}{\mu}\left[1+\frac{1}{\sqrt{\mu^2-1}}\right]$

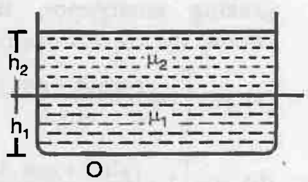
19. Considering normal incidence of ray, the equivalent refractive index of combination of two slabs shown in figure is :



(a) 1.8 (b) 1.43

(c) 2 (d) none of these

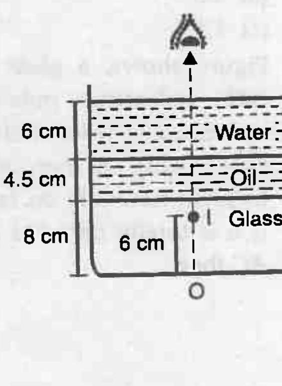
*20. A tank contains two different liquids which do not mix with each other. The lower and upper liquids are at depth h_2 and h_1 respectively and of refractive indices μ_2 and μ_1. An object 'O' is located at the bottom, when seen vertically from above. Locate the position of image of the object O as seen from above :



(a) $\frac{h_1}{\mu_1}-\frac{h_2}{\mu_2}$ (b) $\frac{h_1}{\mu_1}+\frac{h_2}{\mu_2}$

(c) $\frac{h_1}{\mu_2}+\frac{h_2}{\mu_1}$ (d) $\frac{h_1}{\mu_2}-\frac{h_2}{\mu_1}$

21. A vessel contains a slab of glass 8 cm thick and of refractive index 1.6. Over the slab, the vessel is filled by oil of refractive index μ upto height 4.5 cm and also by another liquid *i.e.*, water of refractive index 4/3 and height 6 cm as shown in figure. An observer looking down from above, observes that, a mark at the bottom of the glass slab appears to be raised up to position 6 cm from the bottom of the slab. The refractive index of oil (μ) is :



(a) 1.5 (b) 2.5

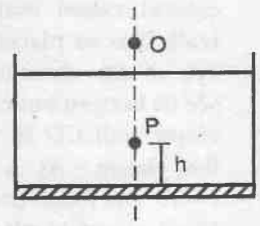
(c) 0.5 (d) 1.2

22. n transparent slabs of refractive index 1.5 each having thickness 1 cm, 2 cm, ... to n cm are arranged one over another. A point object is seen through this combination with near perpendicular light. If the shift of object by the combination is 1 cm then the value of n is :

(a) either 2 or 3 (b) 2

(c) 3 (d) 0.3

23. In the figure, a point source 'P' is placed at a height h above the plane mirror in a medium of refractive index μ. An observer O, vertically above P, outside the liquid, sees P and its image in the mirror. The apparent distance between these two is :



(a) $2\mu h$ (b) $\frac{2h}{\mu}$

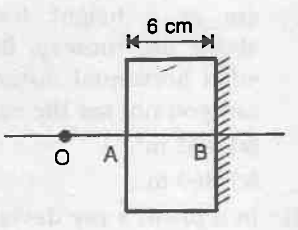
(c) $\frac{2h}{\mu-1}$ (d) $h\left(1+\frac{1}{\mu}\right)$

*24. In a lake, a fish rising vertically to the surface of water uniformly at the rate of 3 m/s, observes a bird diving vertically towards the water at a rate of 9 m/s vertically above it. The actual velocity of the dive of the bird is : (Given: refractive index of water = 4/3)

(a) 9.2 m/s (b) 4.5 m/s

(c) 9.0 m/s (d) 3.2 m/s

25. An object O is placed at 8 cm infront of a glass slab, whose one face is silvered as shown in the figure. The thickness of the slab is 6 cm. If the image formed 10 cm behind the silvered face, the refractive index of glass is :



(a) $\mu = 1.8$ (b) $\mu = 1.2$

(c) $\mu = 1.5$ (d) $\mu = 1.3$

26. A concave mirror with its optic axis vertical and mirror facing upward is placed at the bottom of the water tank. The radius of curvature of mirror is 40 cm and refractive index for water $\mu = 4/3$. The tank is 20 cm deep and if a bird is flying over the tank at a height 60 cm above the surface of water, the position of image of a bird is :

(a) 3.75 cm (b) 4.23 cm

(c) 5.2 cm (d) 3.2 cm

27. Word 'Newton' is printed on a paper and is placed on a horizontal surface below a cubical glass. The minimum value of refractive index of a cubical glass for which

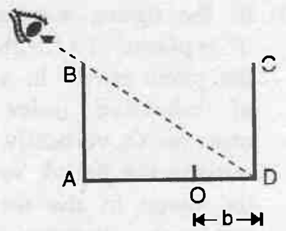
letters are not visible from any of vertical faces of the glass, is :

(a) $\sqrt{3}$ (b) 0.5
(c) 1 (d) $\sqrt{2}$

28. In a tank filled with water of refractive index 5/3, a point source of light is placed 4 m below the surface of water. To cut-off all light coming out of water from the source, what should be the minimum diameter of a disc, which should be placed over the source on the surface of water ?

(a) 1 m (b) 4 m
(c) 3 m (d) 6 m

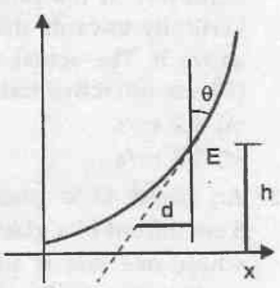
29. A person is looking into a cubical vessel with opaque wall. It is so placed that the eye of an observer cannot see its bottom but can see the entire wall CD as shown in the figure. At a distance $b = 10$ cm from corner D, a small object is placed at O.



Upto how much height should the vessel must be filled with water ($\mu = 4/3$), so the observer can see the object ?

(a) $x = 2.67$ cm (b) $x = 267$ cm
(c) $x = 26.7$ cm (d) $x = 0.267$ cm

***30.** You stand at one end of a long airport runway. A vertical temperature gradient in the air has resulted in the index of refraction of the air above the runway to vary with the height y according to $n = n_0(1 + ay)$ where n_0 is refractive index at the runway surface and $a = 1.5 \times 10^{-6}\ m^{-1}$. Your eyes are at a height $h = 1.7$ m above the runway. Beyond what horizontal distance 'd' can you not see the runway (shown in figure) ?



(a) 652 m (b) 752 m
(c) 460 m (d) 370 m

31. In a prism a ray deviates towards :

(a) base of prism
(b) refracting edge of a prism
(c) normal to the base
(d) second phase of the prism

32. In the condition of minimum deviation position, a ray travels within the prism :

(a) symmetrically (b) assymmetrically
(c) normally (d) transversally

33. The maximum refractive index of a prism which permits the passage of light through it, when the refracting angle of the prism is 90°, is :

(a) $\sqrt{3}$ (b) $\sqrt{2}$
(c) $\sqrt{\frac{3}{2}}$ (d) $\frac{3}{2}$

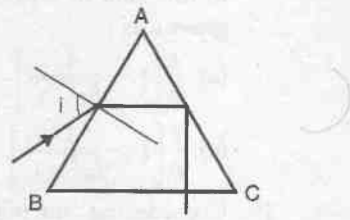
34. A glass prism of refractive index 8/5 is immersed in a liquid of refractive index 4/3. A ray of light incident at grazing angle on one face emerges at grazing angle on the other face of the prism. The angle of the prism is :

(a) 30° (b) 60°
(c) 37° (d) none of these

35. An equilateral prism deviates a ray through 45° for the two angle of incidence differing by 20°. The angle of incidence is :

(a) 60° (b) 40°
(c) 120° (d) none of these

36. There is a glass prism of refractive index μ and angle of prism is A. A ray of light enter the side AB face of the prism at an angle of incidence i. The value of angle of incidence i so, that no ray emerges from the face AC of the prism, is :



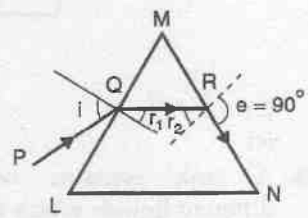
(a) $\sin^{-1}[\sqrt{\mu^2 - 1}\sin A - \cos A]$

(b) $\sin^{-1}[\sqrt{\mu^2 + 1}\sin A - \cos A]$

(c) $\sin^{-1}[\sqrt{\mu^2 + 1}\sin A + \cos A]$

(d) none of the above

37. On one face ML of a prism of refractive index 'μ' and refracting angle 'A', a ray of light PQ is incident at an angle i, and refracted along QR, as shown in figure. If after refraction from MN, this ray travels along RN at grazing emergence, then choose the correct option :



(a) $\mu = \left[1 + \left(\frac{\sin A + \cos i}{\sin A}\right)^2\right]^{1/2}$

(b) $\mu = \left[1 + \left(\frac{\sin i + \cos A}{\sin A}\right)^2\right]^{1/2}$

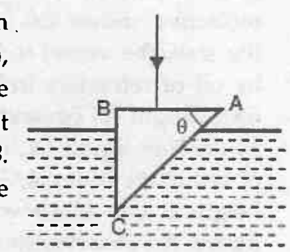
(c) $\mu = \left[1 - \left(\frac{\sin i + \cos A}{\sin A}\right)^2\right]^{1/2}$

(d) $\mu = \left[1 + \left(\frac{\sin i - \cos A}{\sin i}\right)^2\right]^{1/2}$

38. The refractive index of the material of prism, if a thin prism of angle $A = 6°$, produces a deviation $\delta = 3°$, is :

(a) 1.5 (b) 1.2
(c) 1.1 (d) 1.25

39. Figure shows, a glass prism ABC (refractive index 1.5), immersed in water (refractive index 4/3). A ray of light incident normally on face AB. If it is totally reflected at face AC then :



(a) $\sin\theta > \frac{8}{9}$ (b) $\sin\theta > \frac{2}{3}$

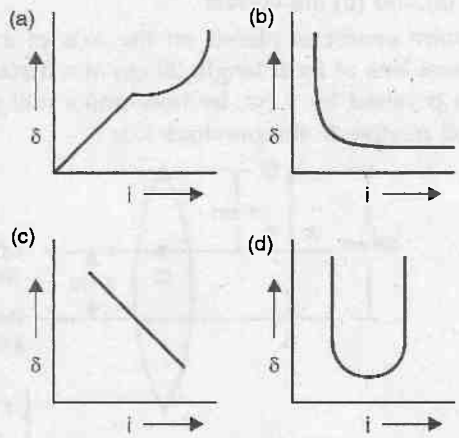
(c) $\sin\theta = \frac{\sqrt{3}}{2}$ (d) $\frac{2}{3} < \sin\theta < \frac{8}{9}$

40. The refractive index of the material, if a prism having an angle $A = 60°$ which produces a minimum deviation of $30°$?

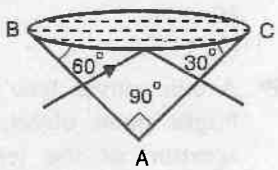
(a) $\sqrt{3}$ (b) $\sqrt{2}$

(c) $\sqrt{5}$ (d) $1/\sqrt{2}$

41. Which of the following graphs will represent the angle of deviation δ by a prism versus angle of incidence i for a monochromatic light?



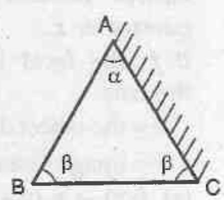
42. A drop of liquid is spread on the hypotenuse of $30°–60°–90°$ prism as shown and a ray of light incident normally on face AB of the prism. If the refractive index of liquid is 1.3, then the refractive index of prism, so that total internal reflection take place, is:



(a) 1.2 (b) 1.4

(c) 1.3 (d) 1.5

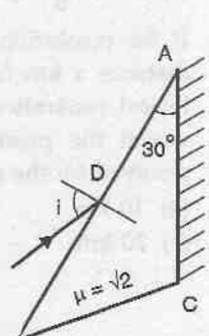
43. One face AC of the glass prism is silvered as shown and the principal section of a glass prism is an isosceles triangle ABC with $AB = AC$. The $\angle BAC$, if the ray incident normally on face AB and after two reflections, it emerges from the base BC, perpendicular to it, is:



(a) $70°$ (b) $36°$

(c) $72°$ (d) $44°$

44. The prism shown in the figure has one side silvered. The angle of the prism is $30°$ and $\mu = \sqrt{2}$. What should be angle of incidence, if the incident ray retraces its initial path?



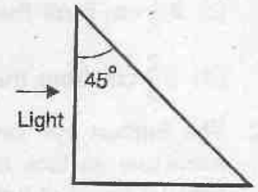
(a) $50°$

(b) $45°$

(c) $60°$

(d) $75°$

45. A beam of light consisting of red, green and blue colour is incident on a right angled prism as shown in the figure. Light of red, green and blue colour travel in prism with velocities respectively 5/7, 20/29 and 2/3 times that in the air. The prism will:



(a) separate all three colours from one another

(b) not separate even partially any colour from the other two colours

(c) separate the blue colour partially by transmission from red and green colours

(d) separate the part of the red colour from the green and the blue colour

46. In a glass prism, spectrum is produced due to:

(a) refraction (b) dispersion

(c) scattering (d) diffraction

47. If a crown glass prism of refracting angle $10°$ have refractive indices for red and violet rays 1.514 and 1.523 respectively, then the dispersion caused by a crown glass prism is:

(a) $0.07°$ (b) $0.08°$

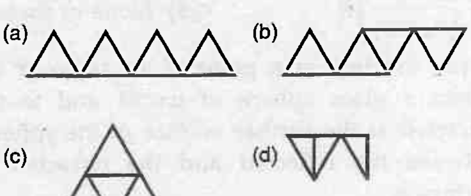
(c) $0.09°$ (d) $0.10°$

48. A thin prism of angle $7°$ made of glass of refractive index 1.5 is combined with another prism made of glass of $\mu = 1.75$ to produce dispersion without deviation. The angle of second prism is:

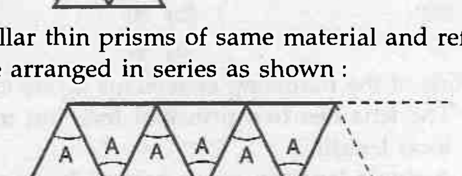
(a) $7°$ (b) $4.67°$

(c) $9°$ (d) $5°$

49. Four similar prisms of same material having same angle of prism are arranged. Which of the following arrangements give no net angular deviation?



50. In n simillar thin prisms of same material and refractive index are arranged in series as shown:



(a) if n is even number, no net deviation and no net dispersion

(b) if n is odd, no net deviation and no net dispersion

(c) it depends upon angle of prism

(d) no sufficient information

51. A small object is enclosed in a sphere of solid glass 8 cm in radius. It is situated 2 cm from the centre and is viewed from the side to which it is nearer. Where will it appear to be if μ of glass = 1.5?

(a) 6 cm from the centre

(b) 4 cm from the nearer surface

(c) $3\frac{1}{5}$ cm from the nearer surface

(d) $3\frac{2}{3}$ cm from the centre

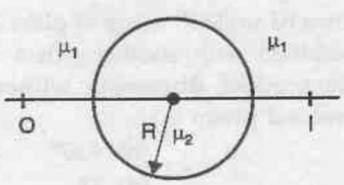
52. The human eye can be regarded as a single spherical refractive surface of curvature of cornea 7.8 mm. If a parallel beam of light comes to focus at 3.075 cm behind the refractive surface, the refractive index of the eye is :

(a) 1.34 (b) 1
(c) 1.5 (d) 1.33

53. In a glass sphere, there is a small bubble 2×10^{-2} m from its centre. If the bubble is viewed along a diameter of the sphere, from the side on which it lies, how far from the surface will it appear ? The radius of glass sphere is 5×10^{-2} m and refractive index of glass is 1.5 :

(a) 2.5×10^{-2} m (b) 3.2×10^{-2} m
(c) 6.5×10^{-2} m (d) 0.2×10^{-2} m

54. Where would an object be placed in a medium of refractive index μ_1, so that its real image is formed at equidistant from the sphere of radius R and refractive index μ_2, which is also placed in the medium of refractive index μ_1 as shown in figure ?



(a) $\left(\frac{\mu_2 - \mu_1}{\mu_2 + \mu_1}\right) R$ (b) $\left(\frac{\mu_2}{\mu_2 - \mu_1}\right) R$

(c) $\left(\frac{\mu_1}{\mu_2 - \mu_1}\right) R$ (d) None of these

55. A ray incident at a point at an angle of incidence 60° enters a glass sphere of $\mu = \sqrt{3}$ and is reflected and refracted at the further surface of the sphere. The angle between the reflected and the refracted rays at this surface is :

(a) 50° (b) 90°
(c) 60° (d) 40°

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

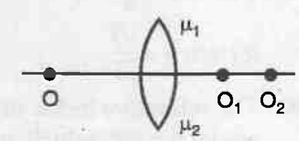
(a) The lens has two principal foci, but may have one focal length

(b) A single lens can never bring a beam of white light to a point focus

(c) A burning glass brings light rays to same focus as heat radiation

(d) Both (a) and (b) are correct

57. Consider three converging lenses L_1, L_2 and L_3 having identical geometrical construction. The index of refraction of L_1 and L_2 are μ_1 and μ_2 respectively. The upper half of the lens L_3 has a refractive index μ_1 and the lower half has μ_2 (shown). A point object O has an image at O_1 by the lens L_1 and at O_2 by the lens L_2 placed in the same position. If L_3 is placed at the same place :



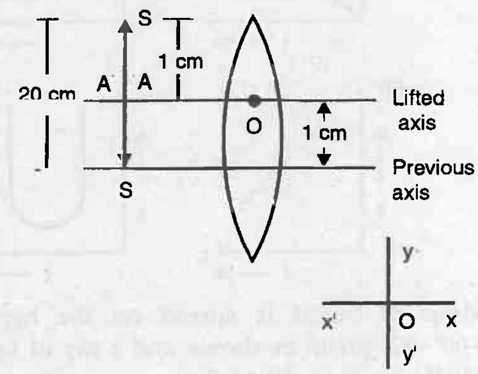
(a) there will be an image at O_1

(b) there will be an image at O_2

(c) the only image will forms somewhere between O_1' and O_2

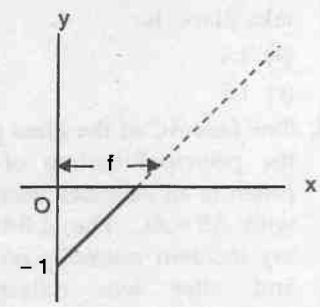
(d) (a) and (b) are correct

*58. A point source is placed on the axis of a symmetrical convex lens of focal length 20 cm at a distance 40 cm. If lens is raised by 1 cm, by how much will the image be lifted relative to the previous axis ?



(a) 1 cm (b) 3 cm
(c) 2 cm (d) 4 cm

*59. A thin convex lens is used to form a real image of a bright point object. The aperture of the lens is small. A graph shown is obtained by plotting, a suitable parameter y against another suitable parameter x.



If f = the focal length of the lens

u = the object distance

v = image distance

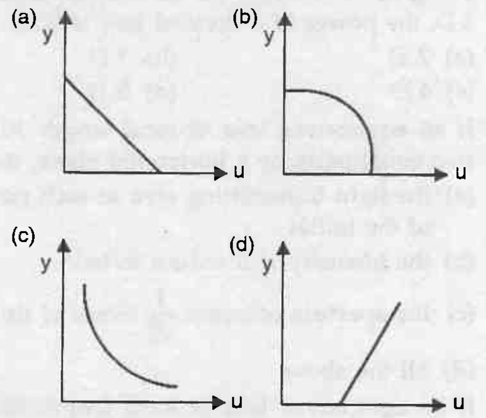
(a) $(uv) \to x, (u+v) \to y$ (b) $u+v \to x, uv \to y$

(c) $u \to x, \frac{u}{v} \to y$ (d) $\frac{1}{u} \to x, \frac{1}{v} \to y$

60. If the resolution limit of the eye is 1 minute and at a distance x km from the eye, two persons stand with a leteral separation of 3 metre, then the value of x for which the positions of the two persons can be just resolved by the nacked eye, is :

(a) 10 km (b) 15 km
(c) 20 km (d) 30 km

61. Which of the following best represents object distance u versus image distance v-graph for a convex lens ?



62. Mark correct option or options :
   (a) The minimum distance between a real image and the real object in concave mirror is zero
   (b) The minimum distance between a real object and real image in concave mirror is greater than $4f$, where f is focal length of the lens
   (c) The focal length of concave mirror depends upon the wavelength of light incident on it
   (d) The focal length of mirror depends upon medium infront of the mirror

63. Select the correct alternative(s) :
   (a) A convex lens may form a real image
   (b) $R = 2f$ formula is applicable to only paraxial ray
   (c) A convex lens becomes less convergent when it is immersed in water
   (d) All of the above

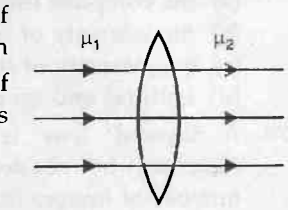
64. From an air craft flying at an altitude of 2000 m, photograph of the ground are taken from a camera, whose size of the film is $18\ \text{cm} \times 18\ \text{cm}$ and the focal length of camera is 50 cm. The area of the ground can be photographed by the camera is :
   (a) $648910\ \text{m}^2$ (b) $721879\ \text{m}^2$
   (c) $518400\ \text{m}^2$ (d) $482529\ \text{m}^2$

65. The distance between the object and screen is x and a convex lens is placed somewhere in between an object and a screen. The focal length (f) of the lens, if the numerical value of magnification produced by the lens is m is :
   (a) $\dfrac{mx}{(m+1)^2}$ (b) $\dfrac{mx}{(m-1)^2}$
   (c) $\dfrac{(m+1)^2}{m} \cdot x$ (d) $\dfrac{(m-1)^2}{m} \cdot x$

66. On the axis of a spherical mirror of focal length f, a short linear object of length L lies on the axis at a distance u from the mirror. Its image has an axial length L' equal to :
   (a) $L\left[\dfrac{f}{(u-f)}\right]^{1/2}$ (b) $L\left[\dfrac{(u+f)}{f}\right]^{1/2}$
   (c) $L\left[\dfrac{(u-f)}{f}\right]^2$ (d) $L\left[\dfrac{f}{(u-f)}\right]^2$

67. A light source is placed at a distance b from a screen. The power of the lens required to obtain k-fold magnified image is :
   (a) $\dfrac{k+1}{kb}$ (b) $\dfrac{(k+1)^2}{kb}$
   (c) $\dfrac{kb}{k+1}$ (d) $\dfrac{kb}{(k-1)^2}$

68. In the given arrangement, a lens of refractive index 1.5 is placed having media of refractive indices μ_1 and μ_2 in either sides. Then the value of μ_1 and μ_2 with respect to lens are :



   (a) 1.5 and 1.5
   (b) less than 1.5
   (c) greater than 1.5 and less than 1.5
   (d) 1 and 1

69. The refractive index of a lens material is μ and focal length f. Due to some chemical changes in the material, its refractive index has increased by 2%. The percentage decrease, in focal length for $\mu = 1.5$ will be :
   (a) 4% (b) 2%
   (c) 6% (d) 8%

70. The focal length of a convex lens when placed in air and then in water will :
   (a) increase in water with respect to air
   (b) increase in air with respect to water
   (c) decrease in water with respect to air
   (d) remain the same

71. A lens forms a sharp image of a real object on a screen. On inserting a parallel slide between the lens and the screen with its thickness along the principal axis of the lens, it is found necessary to shift the screen parallel to itself distance d away from the lens for getting image sharply focussed on it. If the refractive index of the glass relative to air is μ, the thickness of the slab is :
   (a) $\dfrac{d}{\mu}$ (b) μd
   (c) $\dfrac{\mu d}{\mu-1}$ (d) $(\mu-1)\dfrac{d}{\mu}$

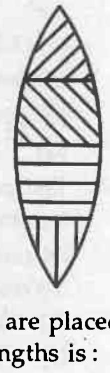
72. The radius of curvature of the face of planoconvex lens is 12 cm and its refractive index is 1.5. If the plane surface of the lens is now silvered, then the focal length of the lens is :
   (a) 26 cm (b) 22 cm
   (c) 24 cm (d) 20 cm

73. When a thin convergent glass lens ($\mu_g = 1.5$) and has power of $+5.0$ D, is immersed in a liquid of refractive index μ_l, it acts as a divergent lens of focal length 100 cm. The value of μ_l is :
   (a) $\dfrac{4}{3}$ (b) $\dfrac{5}{3}$
   (c) $\dfrac{5}{4}$ (d) $\dfrac{6}{5}$

74. The change in the focal length of the lens, if a convex lens of focal length 20 cm and refractive index 1.5, is immersed in water having refractive index 1.33, is:
(a) 62.2 cm (b) 5.82 cm
(c) 58.2 cm (d) 6.22 cm

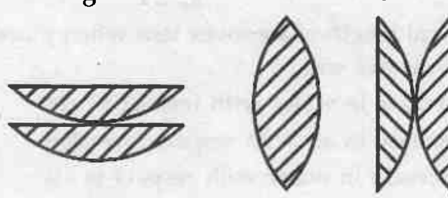
75. A converging lens is used to form an image on a screen. When the upper half of the lens is covered by an opaque screen:
(a) the complete image will be formed
(b) the intensity of image will increase
(c) the intensity of image will decrease
(d) both (a) and (c) are correct

76. A layered lens is made of materials indicated by shades in the figure. The number of images formed is:



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

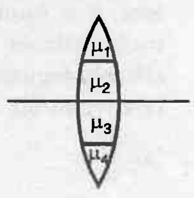
77. Two plano-convex lens each of focal length f are placed as shown in figure. The ratio of their focal lengths is:



(i) (ii) (iii)

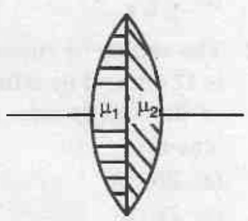
(a) 1 : 2 : 3 (b) 1 : 1 : 1
(c) 1 : 2 : 1 (d) 3 : 2 : 1

78. The number of images formed by the lens, if an object is placed on the axis of the lens is:



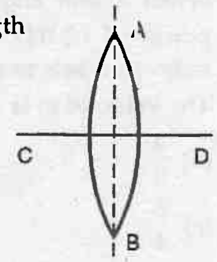
(a) one
(b) two
(c) three
(d) four

79. How many images are formed by the lens shown, if an object is kept on its axis?



(a) One
(b) Two
(c) Three
(d) Four

80. The focal length of each half, if the symmetrical lens of focal length f cut along AB is:



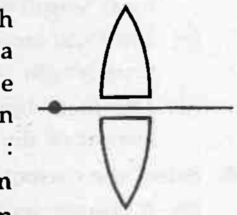
(a) f
(b) $\left(\frac{1}{2}\right)f$
(c) $2f$
(d) zero

81. A symmetric double convex lens is cut in two equal parts along its diameter. If the power of the original lens was 4 D, the power of a divided lens will be:
(a) 2 D (b) 3 D
(c) 4 D (d) 5 D

82. If an equiconvex lens of focal length 30 cm is cut into two equal parts by a horizontal plane, then:
(a) the light transmitting area of each part becomes half of the initial
(b) the intensity will reduce to half
(c) the aperture becomes $\frac{1}{\sqrt{2}}$ times of tis initial value
(d) all the above

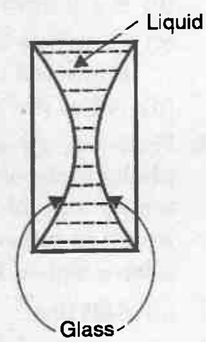
83. If an equiconvex lens of focal length 20 cm is cut into two equal parts by a vertical plane, the focal length of each part will become:
(a) 40 cm (b) 10 cm
(c) 20 cm (d) 5 cm

84. A convex lens of focal length 0.2 m, is cut into two halves each of which is displaced by 0.0005 m and a point object is placed at a distance of 0.3 m from the lens, as shown in figure. The position of the image is:



(a) 0.2 m (b) 0.3 m
(c) 0.6 m (d) 0.5 m

85. Two similar plano convex lenses are placed with their convex surfaces in contact and the space between them is filled with a liquid of refractive index 1.7, as shown in figure. The focal length of plano convex lens is 25 cm and radius of curvature of the curved surface is 12.5 cm and is made of glass of refractive index 1.5. The focal length of the combination is:



(a) – 31.25 cm (b) – 42.05 cm
(c) – 37.73 cm (d) – 52.65 cm

86. Mark correct option or options:
(a) The image formed by a convex lens may coincide with object
(b) The image formed by a plane mirror is always virtual
(c) If one surface of convex lens is silvered, then the image may coincide with the object
(d) Both (a) and (b) are correct

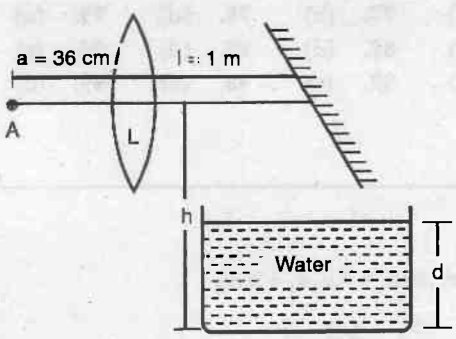
87. A convex lens forms real image at a point P. A plane mirror is placed at 45° to the line joining pole O of mirror and before point P at distance 10 cm, then:
(a) the final image is virtual
(b) the final image is on line the PO produced
(c) the final image is above the PO produced at distance 10 cm
(d) the final image is below the PO produced at distance 10 cm

88. The object distance u for a concave mirror :
(a) must be positive (b) must be negative
(c) must not be negative (d) may be negative

* 89. Two thin convex lenses of focal lengths f_1 and f_2 are separated by a horizontal distance d (where $d < f_1$, $d < f_2$) and their centres are displaced by a vertical separation Δ. Taking the origin of co-ordinates O at the centre of the first lens, the x and y co-ordinates of the focal point of this lens system for a parallel beam of rays coming from the left, are given by :
(a) $x = \dfrac{f_1 f_2}{f_1 + f_2}$, $y = \Delta$
(b) $x = \dfrac{f_1 (f_2 + d)}{f_1 + f_2 - d} - \dfrac{\Delta^2}{f_1 + f_2}$
(c) $x = \dfrac{f_1 f_2 + d (f_1 - d)}{f_1 + f_2 - d}$, $y = \dfrac{\Delta (f_1 - d)}{f_1 + f_2 - d}$
(d) $x = \dfrac{f_1 f_2 + d (f_1 - d)}{f_1 + f_2 - d}$, $y = 0$

90. A drop of water is placed on a glass plate. A double convex lens having radius of curvature of each surface 20 cm is placed on it. The focal length of water lens (μ for water 4/3) in metre is :
(a) -0.20 (b) 0.60
(c) -0.60 (d) 0.20

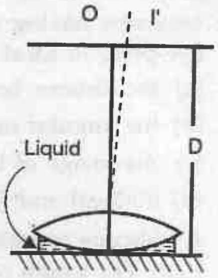
* 91. An arrangement of an object, a lens with a focal length of $f = 30$ cm, a flat mirror and a tray is shown in figure. A flat mirror is turned through 45° with respect to the optic axis of the lens. At what height 'h' from the optic axis should the bottom of a tray filled with water up to depth $d = 20$ cm be placed to obtain a sharp image of the object at the bottom ?



(a) $h = 0.62$ m (b) $h = 0.85$ m
(c) $h = 0.25$ m (d) $h = 1.25$ m

92. The focal length of plano-convex lens, the convex surface of which is silvered is 0.3 m. If μ of the lens is 7/4, the radius of curvature of the convex surface is :
(a) 0.45 m (b) 1.05 m
(c) 3 m (d) 0.9 m

* 93. On a horizontal plane mirror, a thin equi-convex lens of glass is placed and when the space between the lens and mirror is filled with a liquid, an object held at a distance D vertically above the lens is found to coincide with its own image as shown in figure. If equi-convex lens of glass has refractive index $\mu = 1.5$ and radius of curvature R, then find the refractive index of the liquid :



(a) $\mu = 2 + \dfrac{R}{D}$
(b) $\mu = 2 - \dfrac{R}{D}$
(c) $\mu = 2 + \dfrac{D}{R}$
(d) $\mu = 2 - \dfrac{D}{R}$

94. The focal length of the objective of a compound microscope is f_o and its distance from the eye piece is L. The object is placed at a distance u from the objective. For proper working of the instrument :
(a) $L > u$ (b) $L < u$
(c) $f_o < L < 2f_o$ (d) $L > 2f_o$

95. The magnification of a compound microscope is 30 and the focal length of its eye piece is 5 cm. The magnification produced by the objective, when the image is to be formed at least distance of distinct vision (25 cm), is :
(a) 5 (b) 6
(c) 8 (d) 10

96. A convergent doublet of separated lens, corrected for spherical aberration, are separated by 2 cm, and has an equivalent focal length of 10 cm. The focal length of its component lenses are :
(a) $f_1 = 18$ cm, $f_2 = 10$ cm
(b) $f_i = 20$ cm, $f_2 = 28$ cm
(c) $f_1 = 20$ cm, $f_2 = 18$ cm
(d) $f_1 = 24$ cm, $f_2 = 18$ cm

97. A compound microscope has an eye piece of focal length 10 cm and an objective of focal length 4 cm. The magnification, if an object is kept at a distance of 5 cm from the objective and final image is formed at the least distance of distinct vision (20 cm), is :
(a) 10 (b) 11
(c) 12 (d) 13

98. A simple microscope consists of a concave lens of power -10 D and a convex lens of power $+20$ D in contact. If the image formed at infinity, then the magnifying power (D = 25 cm) is :
(a) 2.5 (b) 3.5
(c) 2.0 (d) 3.0

99. An astronomical telescope has an angular magnification of magnitude 5 for distant object. The separation between the objective and the eye piece is 36 cm and final image is formed at infinity. The focal length of the objective and focal length of eye-piece respectively are :
(a) $f_o = 45$ cm and $f_e = -9$ cm
(b) $f_o = 50$ cm and $f_e = 10$ cm
(c) $f_o = 7.2$ cm and $f_e = 5$ cm
(d) $f_o = 30$ cm and $f_e = 6$ cm

100. A planet is observed by an astronomical refracting telescope having an objective of focal length 16 cm and eye-piece of focal length 20 cm. Then :
(a) the distance between objective and eye-piece is 16.02 m
(b) the angular magnification of the planet is 800
(c) the image of the planet is inverted
(d) both (a) and (b) are correct

101. A telescope consists of two lenses of focal length 10 cm and 1 cm. The length of the telescope, when an object is kept at a distance of 60 cm from the objective and the final image is formed at least distance of distinct vision, is :
(a) 15.05 cm (b) 12.96 cm
(c) 13.63 cm (d) 14.44 cm

102. What is the power of the lens, if the far point of a short sighted eye is 200 cm ?
(a) – 0.5 D (b) 2 D
(c) 1 D (d) – 1.5 D

103. The limit of resolution of microscope, if the numerical aperture of microscope is 0.12, and the wavelength of light used is 600 nm, is :
(a) 0.3 μm (b) 1.2 μm
(c) 2.3 μm (d) 3 μm

104. The power and type of the lens by which a person can see clearly the distant objects, if a person cannot see objects beyond 40 cm, are :
(a) – 2.5 D and concave lens
(b) – 2.5 D and convex lens
(c) – 3.5 D and concave lens
(d) – 3.5 D and convex lens

Answers

Level-1

1. (b)	2. (a)	3. (c)	4. (d)	5. (a)	6. (c)	7. (d)	8. (c)	9. (b)	10. (b)
11. (c)	12. (a)	13. (d)	14. (a)	15. (c)	16. (b)	17. (b)	18. (b)	19. (a)	20. (b)
21. (c)	22. (b)	23. (d)	24. (c)	25. (c)	26. (d)				

Level-2

1. (a)	2. (c)	3. (d)	4. (b)	5. (a)	6. (b)	7. (a)	8. (c)	9. (a)	10. (b)
11. (a)	12. (c)	13. (a)	14. (c)	15. (c)	16. (a)	17. (b)	18. (c)	19. (b)	20. (b)
21. (a)	22. (b)	23. (b)	24. (b)	25. (c)	26. (a)	27. (d)	28. (c)	29. (c)	30. (b)
31. (a)	32. (a)	33. (b)	34. (d)	35. (a)	36. (a)	37. (b)	38. (a)	39. (a)	40. (a)
41. (d)	42. (d)	43. (b)	44. (b)	45. (d)	46. (b)	47. (c)	48. (b)	49. (b)	50. (a)
51. (c)	52. (a)	53. (a)	54. (c)	55. (b)	56. (d)	57. (d)	58. (c)	59. (c)	60. (a)
61. (c)	62. (a)	63. (d)	64. (c)	65. (a)	66. (d)	67. (b)	68. (d)	69. (c)	70. (a)
71. (c)	72. (c)	73. (b)	74. (c)	75. (d)	76. (d)	77. (b)	78. (d)	79. (a)	80. (c)
81. (c)	82. (d)	83. (a)	84. (c)	85. (a)	86. (c)	87. (d)	88. (d)	89. (c)	90. (c)
91. (b)	92. (b)	93. (b)	94. (b)	95. (a)	96. (c)	97. (c)	98. (a)	99. (d)	100. (d)
101. (b)	102. (a)	103. (d)	104. (a)						

Solutions

Level-1

11. $f = \dfrac{10 \times (-10)}{10 - 10} = \infty$

19. Optical path $= \mu t$

1st optical path $= \mu_1 d_1$

2nd optical path $= \mu_2 d_2$

Total path, $x = \mu_1 d_1 + \mu_2 d_2$

20. ${}_w\mu_g = \dfrac{{}_a\mu_g}{{}_a\mu_w} = \dfrac{3/2}{4/3} = \dfrac{9}{8}$

Level-2

4. Refractive index $= \dfrac{c}{v} = \left(\dfrac{\varepsilon\mu}{\varepsilon_0 \mu_0}\right)^{1/2}$

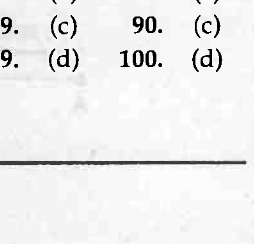
where, $c =$ velocity of light in vacuum $= \dfrac{1}{\sqrt{\mu_0 \varepsilon_0}}$

$v =$ velocity of light in the medium $= \dfrac{1}{\sqrt{\mu\varepsilon}}$

6. When the ray passes into the rarer medium, the deviation is $\delta = \phi - \theta$.

If $\theta = C$ and $\phi = \dfrac{\pi}{2}$ 'δ' is maximum

$= \left(\dfrac{\pi}{2} - C\right)$



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Wave Optics

Syllabus: *Wave nature of light, Interference : Young's double slit experiment, Diffraction : diffraction due to a single slit, elementary idea of polarisation.*

Review of Concepts

1. Interference :

(a) If $y_1 = a_1 \sin \omega t$ and $y_2 = a_2 \sin (\omega t + \phi)$, then

Resultant amplitude is $A = \sqrt{a_1^2 + a_2^2 + 2a_1 a_2 \cos \phi}$

(b) The intensity of wave is proportional to square of amplitude *i.e.*, $I \propto A^2$

$\therefore$ Resultant intensity is

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos \phi$$

(c) $I_{\max} = (\sqrt{I_1} + \sqrt{I_2})^2$ and $I_{\min} = (\sqrt{I_1} - \sqrt{I_2})^2$

(d) For constructive interference or formation of bright fringe or formation of maxima, path difference $\Delta x = m\lambda$, where $m = 0, 1, 2, \ldots$

and phase difference is $\Delta\phi = 2m\pi$

(e) For destructive interference, path difference is

$$\Delta x = (2m - 1)\frac{\lambda}{2} \qquad \text{where } m = 1, 2, 3, \ldots$$

(f) The relation between path difference and phase difference is

$$\Delta\phi = \frac{2\pi}{\lambda}\Delta x$$

(g) **Concept of path difference :** Following types of path difference occur during solving the problem:

(i) Initial path difference (Δx_1)

(ii) Geometrical path difference (Δx_2)

(iii) Path difference due to introduction of transparent sheet (Δx_3)

(iv) Path difference due to reflection (Δx_4)

Total path difference is $\Delta x = \Delta x_1 + \Delta x_2 + \Delta x_3 + \Delta x_4$.

(i) Initial path difference : The difference of paths of light waves from real source S while reaching slits S_1 and S_2.

In Fig. (*A*), initial path difference is

$$\Delta x_1 = SS_2 - SS_1 = 0$$

(ii) Geometrical path difference : This is the difference of paths travelled by light waves from S_1 and S_2 to point P in vacuum.

In Fig. (*A*), the geometrical path difference is

$$\Delta x_2 = S_2P - S_1P = \frac{-yD}{d}$$

In Fig. (*B*),

$$\Delta x_2 = S'P - SP = \frac{yd}{D}$$

Here, $d = SS' = h$

(iii) Path difference due to introduction of transparent sheets : In Fig. (*A*)

$$\Delta x_3 = (\mu_2 - 1)\, t_2 - (\mu_1 - 1)\, t_1$$

In Fig. (*B*), no transparent sheet is introduced. Hence, $\Delta x_3 = 0$

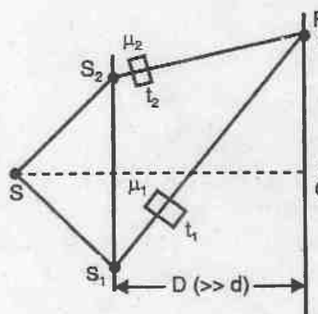
(iv) Path difference due to reflection : When light ray suffers reflection while travelling from rarer medium to denser medium, then reflected ray has an additional path $\lambda/2$ with respect to incident ray.

In Fig. (*A*), $\Delta x_4 = 0$

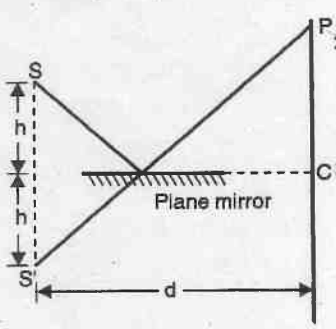
In Fig. (*B*), $\Delta x_4 = \lambda/2$

(h) **Young's double slit experiment :**

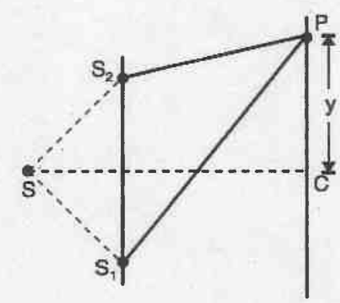
(i) Path difference $= \Delta x = \frac{yd}{D}$



(A)



(B)



(ii) Position of maxima from centre of screen is

$$y = \frac{m\lambda D}{d}, \qquad m = 0, 1, 2, 3, \ldots$$

(iii) For central maxima, $m = 0$

(iv) Position of minima,

$$y = \frac{(2m-1)\lambda D}{2d} \qquad \text{Here, } m = 1, 2, \ldots$$

(v) Fringe width, $\beta = \frac{D}{d}\lambda$

(vi) Angular fringe width, $\psi = \frac{\beta}{D} = \frac{\lambda}{d}$

(vii) For coherent source, phase difference is constant.

(viii) For incoherent sources, the resultant intensity

$$I = I_1 + I_2 + \ldots$$

(i) Due to interference of light, we see different colours in the films. In this case, for constructive interference, $2\mu t \cos r = (2n+1)\lambda/2$ and for destructive interference $2\mu t \cos r = (n+1)\lambda$ for reflected system.

(j) For the transmitted light $2\mu t \cos r = n\lambda$, the constructive interference takes place.

2. Diffraction of light:

(a) **Fraunhofer diffraction due to a single slit:** When monochromatic light of wavelength λ is used to illuminate a single slit of width e, the minima are given by

$$e \sin\theta = n\lambda, \quad n = \pm 1, \pm 2, \pm 3$$

(b) **Diffraction at a plane grating:** When polychromatic or monochromatic light of wavelength λ is incident normally on a plane transmission grating, the principal maxima are

$$(e+d)\sin\theta = n\lambda$$

where n = order of maximum,

θ = angle of diffraction,

$e + d$ = grating element

(c) Angular radius of central maximum in a fraunhofer diffraction is

$$\sin\theta = \frac{1.22\lambda}{d}$$

or $$\sin\theta \approx \theta = \frac{1.22\lambda}{d} \qquad \text{(for } \theta \text{ small)}$$

(d) Diffraction phenomenon is easily observed in sound as compared to light because $\lambda_{sound} > \lambda_{light}$.

Objective Questions

Level-1

1. The ratio of amplitudes of the waves coming from two slits having widths in the ratio 4 : 1, is

(a) 1 : 2 (b) 2 : 1

(c) 1 : 4 (d) 4 : 1

2. The resultant intensity after interference of two coherent waves respresented by $y_1 = a_1 \cos \omega t$ and $y_2 = a_2 \cos\left(\frac{\pi}{2} - \omega t\right)$, will be

(a) $a_1 - a_2$

(b) $a_1 + a_2$

(c) $a_1^2 - a_2^2$

(d) $a_1^2 + a_2^2$

3. A ray of light is coming from the source S. If a thin flim of thickness t and refractive index μ is placed in its path, the increase in length of optical path is:

(a) μt (b) $\frac{\mu}{t}$

(c) $(\mu - 1)t$ (d) none of these

4. The ratio of intensities in consecutive maxima in a diffraction pattern due to a single slit is:

(a) 1 : 2 : 3 (b) 1 : 4 : 9

(c) $1 : \frac{2}{\pi^2} : \frac{3}{\pi^2}$ (d) $1 : \frac{4}{9\pi^2} : \frac{4}{25\pi^2}$

5. In Young's double slit experiment, if wavelength of light changes from λ_1 to λ_2 and distance of seventh maxima changes from d_1 to d_2 then:

(a) $\frac{d_1}{d_2} = \frac{\lambda_1}{\lambda_2}$ (b) $\frac{d_1}{d_2} = \frac{\lambda_2}{\lambda_1}$

(c) $\frac{d_1}{d_2} = \left(\frac{\lambda_1}{\lambda_2^2}\right)^2$ (d) $\frac{d_1}{d_2} = \left(\frac{\lambda_2}{\lambda_1}\right)^2$

6. Light of wavelength λ is incident on a slit of width d and distance between screen and slit is D. Then width of maxima and width of slit will be equal, if D is:

(a) $\frac{d^2}{\lambda}$ (b) $\frac{2d}{\lambda}$ (c) $\frac{2d^2}{\lambda}$ (d) $\frac{d^2}{2\lambda}$

7. What is the amplitude of resultant wave, when two waves $y_1 = A_1 \sin(\omega t - B_1)$ and $y_2 = A_2 \sin(\omega t - B_2)$ superimpose?

(a) $A_1 + A_2$ (b) $|A_1 - A_2|$

(c) $\sqrt{A_1^2 + A_2^2 + 2A_1A_2 \cos(B_1 - B_2)}$

(d) $\sqrt{A_1^2 + A_2^2 + 2A_1A_2 \cos B_1 B_2}$

8. The slit width, when a light of wavelength 6500 Å is incident on a slit, if first minima for red light is at 30°, is

(a) 1×10^{-6} m (b) 5.2×10^{-6} m

(c) 1.3×10^{-6} m (d) 2.6×10^{-6} m

9. Two wave-fronts are emitted from coherent sources of path difference between them is 2.1 micron. Phase difference between the wave-fronts at that point is $7.692\,\pi$. Wavelength of light emitted by sources will be:

(a) 5386 Å (b) 5400 Å

(c) 5460 Å (d) 5892 Å

Level-2

1. Light propagates 2 cm distance in glass of refractive index 1.5 in time t_0. In the same time t_0, light propagates a distance of 2.25 cm in a medium. The refractive index of the medium is:
(a) 4/3
(b) 3/2
(c) 8/3
(d) none of these

2. A wave equation which gives the displacement along y-direction is given by $y = 10^{-4} \sin(60t + 2x)$, where x and y are in metre and t is in sec. This represents a wave:
(a) travelling with velocity of 30 m/s in the negative x-direction
(b) of wavelength (π) m
(c) of frequency $\left(\frac{30}{\pi}\right)$ Hz
(d) all of the above

3. The wave front due to a source situated at infinity is:
(a) spherical
(b) cylindrical
(c) planar
(d) none of these

4. A wave front is represented by the plane $y = 3 - x$. The propagation wave takes place at:
(a) 45° with the +ve x-direction
(b) 135° with the +ve x-direction
(c) 60° with the +ve-direction
(d) no sufficient data

5. In Young's double slit experiment with monochromatic light of wavelength 600 nm, the distance between slits is 10^{-3} m. For changing fringe width by 3×10^{-5} m:
(a) the screen is moved away from the slits by 5 cm
(b) the screen is moved by 5 cm towards the slits
(c) the screen is moved by 3 cm towards the slits
(d) both (a) and (b) are correct

6. In Young's double slit experiment, the distance between slits is 0.0344 mm. The wavelength of light used is 600 nm. What is the angular width of a fringe formed on a distant screen ?
(a) 1°
(b) 2°
(c) 3°
(d) 4°

7. Which of the following is not an essential condition for interference ?
(a) The two interfering waves must be propagated in almost the same direction or the two interfering waves must intersect at very small angle
(b) The wave must have the same period and wavelength
(c) The amplitude of the two waves must be equal
(d) The two interfering beams of light must originate from the same source

8. If Young's double slit experiment, is performed in water:
(a) the fringe width will decrease
(b) the fringe width will increase
(c) the fringe width will remain unchanged
(d) there will be no fringe

9. In Young's double slit experiment, the spacing between the slits is 'd' and wavelength of light used is 6000 Å. If the angular width of a fringe formed on a distant screen is 1°, then value of 'd' is:
(a) 1 mm
(b) 0.05 mm
(c) 0.03 mm
(d) 0.01 mm

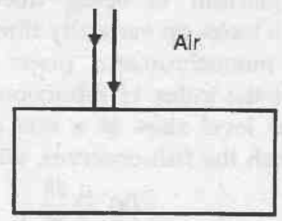
10. In Young's double slit experiment, when violet light of wavelength 4358 Å is used, then 84 fringes are seen in the field of view, but when sodium light of certain wave- length is used, then 62 fringes are seen in the field of view, the wavelength of sodium light is:
(a) 6893 Å
(b) 5904 Å
(c) 5523 Å
(d) 6429 Å

11. In a double slit experiment, 5th dark fringe is formed opposite to one of the slits. The wavelength of light is:
(a) $\frac{d^2}{6D}$
(b) $\frac{d^2}{5D}$
(c) $\frac{d^2}{15D}$
(d) $\frac{d^2}{9D}$

12. Two non-coherent sources emit light beam of intensities I and $4I$. The maximum and minimum intensities in the resulting beam are:
(a) $9I$ and I
(b) $9I$ and $3I$
(c) $5I$ and I
(d) $5I$ and $3I$

13. When two coherent monochromatic light beams of intensities I and $4I$ are superimposed, what are the maximum and minimum possible intensities in the resulting beams:
(a) $5I$ and I
(b) $5I$ and $3I$
(c) $9I$ and I
(d) $9I$ and $3I$

14. A parallel beam of light of intensity I_0 is incident on a glass plate, 25% of light is reflected by upper surface and 50% of light is reflected from lower surface. The ratio of maximum to minimum intensity in interference region of reflected rays is:

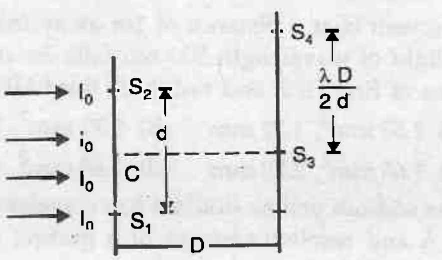


(a) $\left(\dfrac{\frac{1}{2}+\sqrt{\frac{3}{8}}}{\frac{1}{2}-\sqrt{\frac{3}{8}}}\right)^2$ (b) $\left(\dfrac{\frac{1}{4}+\sqrt{\frac{3}{8}}}{\frac{1}{2}-\sqrt{\frac{3}{8}}}\right)^2$

(c) $\frac{5}{8}$ (d) $\frac{8}{5}$

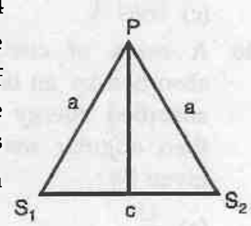
15. In an interference pattern the position of zeroth order maxima is 4.8 mm from a certain point P on the screen. The fringe width is 0.2 mm. The position of second maxima from point P is :
(a) 5.1 mm
(b) 5 mm
(c) 40 mm
(d) 5.2 mm

16. In the given figure, C is middle point of line S_1S_2. A monochromatic light of wavelength λ is incident on slits. The ratio of intensity of S_3 and S_4 is :



(a) 0 (b) ∞
(c) 4 : 1 (d) 1 : 4

17. In the given figure, S_1 and S_2 are coherent sources. The intensity of both sources are same. If the intensity at the point P is 4 watt/m^2, the intensity of each source is :



(a) 1 W/m^2 (b) 2 W/m^2
(c) 3 W/m^2 (d) 4 W/m^2

18. n incoherent sources of intensity I_0 are superimposed at a point, the intensity of the point is :
(a) $n\,I_0$ (b) $\frac{I_0}{n}$
(c) $n^2\,I_0$ (d) none of these

19. The maximum intensity in the case of n identical incoherent waves, each of intensity 2 W/m^2 is 32 W/m^2. The value of n is :
(a) 4 (b) 16
(c) 32 (d) 64

20. Newton's rings are observed by keeping a spherical surface of 100 cm radius on a plane glass plate. The wavelength of light used is 5880 Å. If the diameter of the 15th bright ring is 0.590 cm, then diameter of the 5th ring is :
(a) 0.226 cm (b) 0.446 cm
(c) 0.336 cm (d) 0.556 cm

21. Lenses are generally coated with thin films of transparent substance like, MgF_2 ($\mu = 1.38$) in order to reduce the reflection from the glass surface. How thick a coating is needed to produce a minimum reflection at the centre of visible spectrum of wavelength 5500 Å ?
(a) 1000 Å (b) 5500 Å
(c) 2000 Å (d) 500 Å

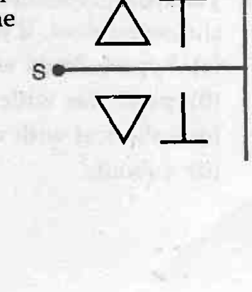
22. Interference fringes are obtained in Young's double slit experiment on a screen. Which of the following statements will not be correct about the effect of a thin transparent plate when placed in the path of one of the two interfering beams ?
(a) The separation between fringes remains unaffected
(b) The entire fringe system shifts towards the side on which the plate is placed
(c) The condition for maxima and minima are reversed *i.e.*, maxima for odd multiple of $\lambda/2$ and minima for even multiple of $\lambda/2$
(d) The shape of the fringe also remains unaffected

23. A transparent sheet of thickness 1178 μcm and refractive index 1.60 is placed in the path of the interfering beams in Young's double slit experiment using sodium light of wavelength 5890 Å. The central fringe shifts to a position originally occupied by :
(a) 11th fringe (b) 12th fringe
(c) 13th fringe (d) 9th fringe

24. One slit of a double slit experiment is covered by a thin glass plate of refractive index 1.4, and the other by a thin glass plate of the refractive index 1.7. The point on the screen where the central maximum fall before the glass plate was inserted, is now occupied by what had been the fifth bright fringe was seen before. Assume the plate have the same thickness t and wavelength of light 480 nm Then the value of t is :
(a) 2.4 mm (b) 4.8 mm
(c) 8 μm (d) 16 mm

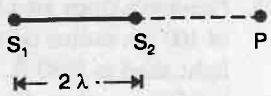
25. In a Young's experiment, one of the slit is covered with a transparent sheet of thickness 3.6×10^{-3} cm due to which position of central fringe shifts to a position originally occupied by 30th bright fringe. The refractive index of the sheet, if $\lambda = 6000$ Å, is :
(a) 1.5 (b) 1.2
(c) 1.3 (d) 1.7

26. In the given figure, if the gap between lenses decreases, the fringe width :



(a) decreases
(b) increases
(c) remains constant
(d) no sufficient information

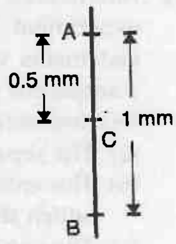
27. In the given arrangement, S_1 and S_2 are coherent sources (shown in figure) The point P is a point of :



(a) bright fringe (b) dark fringe
(c) either dark or bright (d) none of these

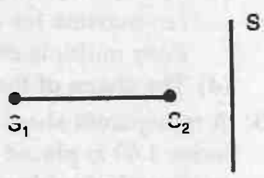
28. In Fresnel's biprism experiment, the distance between biprism and screen is 4m. The angle of prism is 2×10^{-3} radian, the refractive index of glass of biprism is 1.5. The fringe width observed on the screen is 15×10^{-4}m. The number of fringes on the screen is :
(a) 3 (b) 2
(c) 6 (d) 8

29. In Young's double slits experiment, the length of band is 1 mm. The fringe width is 0.021 mm. The number of fringes is :



(a) 45
(b) 46
(c) 47
(d) 48

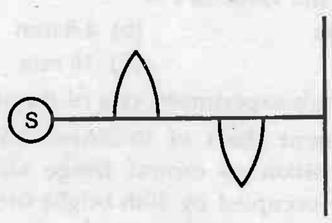
30. Two coherent sources S_1 and S_2 are situated on the x–axis, screen S is in y-z plane (as shown). The shape of the fringe on the screen is :



(a) straight line (b) elliptical
(c) circular (d) rectangular

31. If the width of slit is gradually increased, it will be observed experimentally that :
(a) bright fringes become reduced in intensity
(b) brignt fringes become increased in intensity
(c) the intensity of minima is strictly zero
(d) the fringes become more distinct

32. In the given figure, the convex lens is cut into two pieces and displace along the axes for small distance. The shape of fringe formed on the screen is :



(a) elliptical (b) hyperbolic
(c) circular (d) none of these

33. The true shapes of interference fringes in Young's double slit experiment, if the sources are pinholes, are :
(a) hyperboloids with sources at foci
(b) parabolas with sources at foci
(c) spherical with centre at screen
(d) cuboids

34. While an aquarium is being filled with water, a motionless fish looks up vertically through the surface of water at a monochromatic plane wave source of frequency f. If the index of refraction of the water is μ and the water level rises at a rate dh/dt, the shift in frequency which the fish observes, will then be :
(a) $\frac{(\mu - 1)}{c}\frac{dh}{dt}$ (b) $\frac{\mu}{c}\frac{dh}{dt}$
(c) $\frac{f}{c}\frac{dh}{dt}$ (d) none of these

35. Which of the following quantities is not carried by light ?
(a) Angular momentum (b) Linear momentum
(c) Energy (d) None of the above

36. In Fraunhofer diffraction pattern due to a single slit, the slit of width 0.1 mm is illuminated by monochromatic light of wavelength 600 nm. What is the ratio of separation between the central maximum and first secondary minimum to the distance between screen and the slit ?
(a) 6×10^{-3} m (b) 0.1 m
(c) 6 m (d) 100 m

37. The first diffraction minimum due to single slit diffraction is θ, for a light of wavelength 5000 Å. If the width of the slit is 1×10^{-4} cm, then the value of 'θ' is :
(a) 30° (b) 45°
(c) 60° (d) 15°

38. A screen is at a distance of 1m away from the aperture. If light of wavelength 500 nm falls on an aperture, then area of first HPZ and radius of third HPZ are :
(a) 1.57 mm^2, 1.22 mm (b) 1.22 mm^2, 1.57 mm
(c) 1.65 mm^2, 2.79 mm (d) 2.63 mm^2, 0.22 mm

39. The sodium yellow doublet has wavelengths 5890 Å and 'λ'Å and resolving power of a grating to resolve these lines is 982, then value of λ is :
(a) 5896 Å (b) 5880 Å
(c) 5869 Å (d) 5876 Å

40. A beam of circularly polarised light is completely absorbed by an object on which it falls. If U represents absorbed energy and ω represents angular frequency, then angular momentum transferred to the object is given by :
(a) $\frac{U}{\omega^2}$ (b) $\frac{U}{2\omega}$
(c) $\frac{U}{\omega}$ (d) $\frac{2U}{\omega}$

41. Which of the following phenomena can be used to analyse a beam of light into its component wavelength ?
(a) Reflection (b) Refraction
(c) Polarisation (d) Interference

42. Which of these waves can be polarised ?
(a) Sound waves
(b) Longitudinal waves on a string
(c) Transverse waves on a string
(d) Light waves

43. Polarisation of light proves that :
(a) corpuscular nature of light
(b) quantum nature of light
(c) transverse wave nature of light
(d) longitudinal wave nature of light

44. If white light is used in Young's double slit experiment, then the central fringe is :
(a) red
(b) coloured
(c) white
(d) blue

45. If n coherent sources of intensity I_0 are super imposed at a point, the intensity of the point is :
(a) nI_0
(b) n^2I_0
(c) n^3I_0
(d) $\frac{I_0}{n}$

Answers

Level-1

1. (b)	2. (d)	3. (c)	4. (d)	5. (a)	6. (d)	7. (c)	8. (c)	9. (c)

Level-2

1. (a)	2. (d)	3. (c)	4. (a)	5. (d)	6. (a)	7. (c)	8. (a)	9. (c)	10. (b)
11. (d)	12. (d)	13. (c)	14. (a)	15. (a)	16. (b)	17. (a)	18. (a)	19. (b)	20. (c)
21. (a)	22. (c)	23. (b)	24. (c)	25. (a)	26. (b)	27. (a)	28. (c)	29. (c)	30. (c)
31. (a)	32. (c)	33. (a)	34. (a)	35. (d)	36. (a)	37. (a)	38. (a)	39. (a)	40. (c)
41. (b)	42. (d)	43. (c)	44. (c)	45. (b)					

Solutions

Level-1

2. The two waves differ in phase by $\frac{\pi}{2}$

$\therefore$ $$I = (a_1^2 + a_2^2)$$

4. $$1 : \left(\frac{2}{3\pi}\right)^2 : \left(\frac{2}{5\pi}\right)^2$$

or $$1 : \frac{4}{9\pi^2} : \frac{4}{25\pi^2}$$

5. $$d_1 = 7\,\lambda_1 \frac{D}{d}$$

$$d_2 = 7\,\lambda_2 \frac{D}{d}$$

$$\frac{d_1}{d} = \frac{\lambda_1}{\lambda_2}$$

6. For linear width of central maxima

$$2x = \frac{2\lambda D}{d} = d$$

$$D = \frac{d^2}{2\lambda}$$

8. $$d \sin\theta = n\lambda$$

$$d = \frac{n\lambda}{\sin\theta}$$

$$d = \frac{1 \times 6500 \times 10^{-10}}{\left(\frac{1}{2}\right)}$$

$$= 1.3 \times 10^{-6}\text{ m}$$

9. $$\phi = \frac{2\pi x}{\lambda}$$

$$\lambda = \frac{2\pi \times 2.1 \times 10^{-6}}{7.692\,\pi}$$

$$= 5460 \times 10^{-10}\text{ m}$$

Level-2

1. For a given time, optical path remains constant

$\therefore$ $$\mu_1 x_1 = \mu_2 x_2$$

or $$1.5 \times 2 = \mu_2 \times 2.25$$

$\therefore$ $$\mu_2 = \frac{1.5 \times 2}{2.25} = \frac{2}{1.5} = \frac{20}{15} = \frac{4}{3}$$

4. The propagation of ray takes place in perpendicular direction of wave front.

Here $m_1 m_2 = -1$

Here, m_1 = slope of wave front $= -1$

m_2 = slope of ray

$\therefore$ $$m_1 m_2 = -1$$

22

Photometry and Doppler's Effect of Light

Syllabus : Source of light, luminous intensity, luminous flux, illuminance and photometry (elementary idea), Doppler's effect of light.

Review of Concepts

1. Radiant flux (R) : The rate of radiated energy by a source is known as radiant flux. Its unit is watt.

2. Luminous flux (ϕ) : The rate of light energy (400 nm to 700 nm) radiated by a source is known as luminous flux. Its unit is lumen. Luminous flux is given by as $F = 4\pi I$, since, total solid angle for all directions is 4π.

3. Luminous efficiency :

$$\eta = \frac{\text{output}}{\text{input}} = \frac{\text{luminous flux emitted}}{\text{power consumed in watt}}$$

4. Luminous intensity :

(a) The luminous intensity I of a light source in any direction is defined as the luminous flux emitted by source in unit solid angle in that direction *i.e.,*

$$I = \frac{\Delta F}{\Delta \omega}$$

where ΔF = luminous flux

(b) As $\Delta F = I\,\Delta\omega$ hence, total flux F for an isotropic point source is given by

$$F = \Sigma\,\Delta F = \Sigma\, I\,\Delta\omega$$

$$= 4\pi I \qquad (\text{as } \Sigma\,\Delta\omega = 4\pi)$$

5. Illuminance or intensity of illumination of a surface :

(a) Illuminance E is defined as the luminous flux falling per unit area of the surface.

$$E = \frac{\Delta F}{\Delta A}$$

(b) We know that

$$I = \frac{\Delta F}{\Delta \omega}$$

$$\therefore \quad \frac{E}{I} = \frac{\Delta F/\Delta A}{\Delta F/\Delta \omega}$$

$$= \frac{\Delta\omega}{\Delta A} = \frac{(\Delta A \cos\theta)/r^2}{\Delta A} \quad \left(\because \Delta\omega = \frac{\Delta A\cos\theta}{r^2}\right)$$

$$\therefore \quad \frac{E}{I} = \frac{\cos\theta}{r^2} \quad \text{or} \quad E = \frac{I\cos\theta}{r^2}$$

This is called as **Lambert's cosine law.**

6. Fogging of photographic plate : For equal fogging,

$$Et = \text{constant}$$

$$\frac{(I_1\cos\theta_1)\,t_1}{r_1^2} = \frac{(I_2\cos\theta_2)\,t_2}{r_2^2}$$

or $$\frac{I_1t_1}{r_1^2} = \frac{I_2t_2}{r_2^2} \qquad (\text{as usually } \theta_1 = \theta_2)$$

7. Doppler's effect in light :

Let f = actual frequency of light source

f' = apparent frequency

v = relative velocity of source and observer and

c = speed of light

(a) For approach: $f' > f$

$$f' = \left(\sqrt{\frac{1+\frac{v}{c}}{1-\frac{v}{c}}}\right)f$$

or $$\Delta f = f' - f = \frac{v}{c}f \qquad \text{if } v <<< c$$

Also, $$\Delta\lambda = \frac{v}{c}\lambda$$

(b) For receding: $f' < f$

$$f' = \left(\sqrt{\frac{1-\frac{v}{c}}{1+\frac{v}{c}}}\right)f$$

and $$\Delta f = f - f' = \frac{v}{c}f \qquad \text{if } v <<< c$$

Also, $$\Delta\lambda = \frac{v}{c}\lambda$$

Objective Questions

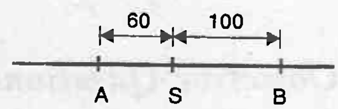
Level-1

1. Mark the correct option for inverse square law for illuminance :
(a) Isotropic point source
(b) Cylindrical source
(c) Search light
(d) All types of sources

2. If the distance between a point source of light and a screen is doubled, then the intensity will be:
   (a) four times the original value
   (b) two times the original value
   (c) half the original value
   (d) one quarter of the original value
3. Candela is a unit of:
   (a) acoustic intensity (b) electric intensity
   (c) luminous intensity (d) magnetic intensity
4. The unit of luminous efficiency of electric bulb is:
   (a) watt (b) lumen
   (c) $\frac{\text{lumen}}{\text{watt}}$ (d) lux
5. The lumen efficiency, if an electric bulb emit $68.5\ \frac{\text{lumen}}{\text{watt}}$ is:
   (a) 2.5% (b) 5%
   (c) 10% (d) 20%
6. The illumination on the screen, in case of a movie hall if the distance between the projector and the screen is increased by 1%, will be:
   (a) increased by 1% (b) decreased by 1%
   (c) increased by 2% (d) decreased by 2%
7. In a photometer two sources of light when placed at 30 cm and 50 cm respectively produce shadow of equal intensity. Their candle powers are in the ratio of:
   (a) $\frac{9}{25}$ (b) $\frac{16}{25}$
   (c) $\frac{3}{5}$ (d) $\frac{5}{3}$
8. The geometrical path of a ray of light in a medium of refractive index 2 is 8m. The optical path is:
   (a) 16 m (b) 8 m
   (c) 4 m (d) none of these
9. The luminous efficiency of the bulb in lumen/watt, if luminous intensity of a 100 watt unidirectional bulb is 100 candela, is:
   (a) 12 (b) 12.56
   (c) 13 (d) 15
10. A light source approaches the observer with velocity 0.5 c. Doppler shift for light of wavelength 5500 Å is:
   (a) 616 Å (b) 1833 Å
   (c) 5500 Å (d) 6160 Å

Level-2

1. The brightness of a source based upon sensation of eye is determined by:
   (a) radiant flux entering the eye
   (b) luminous flux entering the eye
   (c) wavelength of light
   (d) none of the above
2. The power of three sources *A*, *B* and *C* are same. The wavelengths emitted by sources are 4300 Å, 5550 Å and 7000 Å respectively. The brightness of sources on the basis of sensation of eye are L_1, L_2 and L_3 respectively. Then:
   (a) $L_1 > L_2 > L_3$ (b) $L_1 > L_3 > L_2$
   (c) $L_2 > L_1$ and $L_2 > L_3$ (d) $L_2 < L_1$ and $L_2 < L_3$
3. An isotropic point source emits light. A screen is situated at a given distance. If the distance between source and screen is decreased by 2%, illuminance will increase by:
   (a) 1% (b) 2% (c) 3% (d) 4%
4. The intensity produced by a point light source at a small distance *r* from the source is proportional to:
   (a) $\frac{1}{r}$ (b) r^2 (c) $\frac{1}{r^2}$ (d) $\frac{1}{r^3}$
5. A point source generates 10 J of light energy in 2 s. The luminous flux of source is:
   (a) 5 lumen (b) 10 lumen
   (c) 50 lumen (d) none of these
6. At what rate should light energy is allowed to fall on a perfectly reflecting mirror with $1\ \text{cm}^2$ of area for one hour such that the force that acts on the mirror is 6.7×10^{-8} N?
   (a) $1\ \text{W/cm}^2$ (b) $8\ \text{W/cm}^2$
   (c) $10\ \text{W/cm}^2$ (d) None of these
7. A surface is receiving light normally from a source, which is at a distance of 8 m from it. If the source is moved closer towards the surface, so that the distance between them becomes 4 m, then the angle through which the surface may be turned so that illuminance remain as it, was:
   (a) $\theta = \cos^{-1}(1/3)$ (b) $\theta = \cos^{-1}(1/4)$
   (c) $\theta = \cos^{-1}(1/8)$ (d) $\theta = \cos^{-1}(1/6)$
8. A 60 watt bulb has luminous intensity 200 candela. The luminous flux is:
   (a) 1000π (b) 600π (c) 800π (d) 200π
9. The luminous efficiency of the lamp, if luminous flux of 200 watt lamp is 400 lumen is:
   (a) 2 lumen/watt (b) 4 lumen/watt
   (c) 3 lumen/watt (d) 8 lumen/watt
10. On both side of a photometer '*S*' as shown in the figure, two lamps *A* and *B* are placed, in such a way that $AS = 60$ cm and $SB = 100$ cm. To make the illumination unequal on the photometer from both sides, a large perfectly reflecting mirror is placed 20 cm to the left of *A*, with its reflecting surface normal to the axis of the bench so that the light from *A* is reflected on the photometer. Now, through what distance must the lamp *B* be moved in order to restore equality of illumination of the photometer?



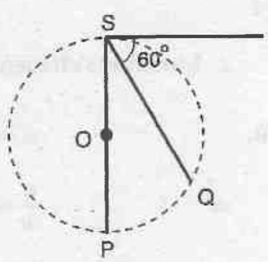
   (a) 16.25 cm (b) 15.25 cm
   (c) 14.25 cm (d) 13.25 cm

11. If at the focus of a convex lens of focal length 6 metre, a point source of 36 candela is placed, then the illuminance on a screen placed normally to the emergent beam of light is :
(a) 1 lux (b) 6 lux
(c) 1 phot (d) 6 phot

12. If in a cinema hall, the distance between the projector and the screen is increased by 2%, keeping everything else unchanged, then the intensity of illumination on the screen is :
(a) decreased by 4% (b) decreased by 2%
(c) increased by 2% (d) increased by 4%

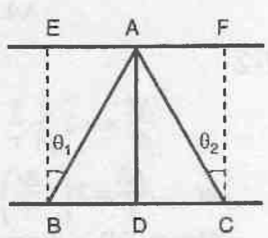
13. A small mirror of area A and mass m is suspended by means of a weightless thread, in vertical plane. On the mirror a beam of light of intensity I, is made to incident perpendicular to mirror, due to which mirror is displaced and thread makes a small angle α with the vertical. Assume mirror to be totally reflecting, calculate α :
(a) $\alpha = \frac{2IA}{cmg}$ (b) $\alpha = \frac{IA}{cmg}$
(c) $\alpha = \frac{3IA}{cmg}$ (d) $\alpha = \frac{IA}{2cmg}$

14. The figure shows the circular cross-section of a tunnel of diameter 2 m. A bulb of 100 watt is fixed at highest point of the tunnel. Compare the illuminance at lowest point P and point Q :



(a) $\frac{\sqrt{3}}{3}$
(b) $\frac{\sqrt{3}}{2}$
(c) $\frac{\sqrt{3}}{4}$
(d) $\frac{\sqrt{3}}{5}$

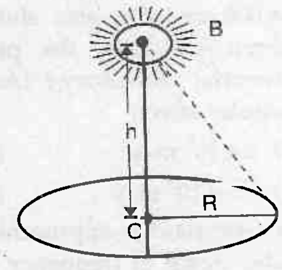
15. A screen is placed at the vertex A of equilateral triangle ABC, in such a way that the screen is parallel to the base BC as shown in figure. Three lamps placed at B, C, D give equal illumination at A on the screen and $BD = DC$. The ratio of their powers is :



(a) $8:8:3\sqrt{3}$ (b) $16:12:\sqrt{3}$
(c) $4:2:3$ (d) $\sqrt{3}:3\sqrt{3}:6$

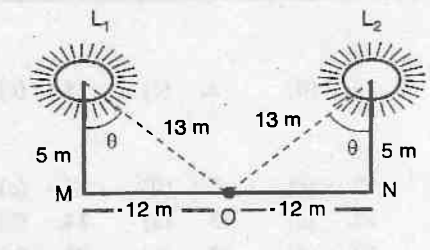
16. To obtain a good photographic print, an exposure of 2 s at a distance of 1 m from a 75 cd bulb is done. To obtain an equally satisfactory result, what should be the distance, if time of exposure is 12 s from a 50 cd bulb ?
(a) 1 m (b) 2 m
(c) 3 m (d) 4 m

17. An electric bulb is at a vertical distance of 'h' over the centre of a circular table of radius R as shown in figure. By what factor the intensity of illumination at the centre 'O' is greater than that at the edge of the table ?



(a) $\left(1-\frac{R^2}{h^2}\right)^{3/2}$
(b) $\left(1+\frac{R^2}{h^2}\right)^{3/2}$
(c) $\left(1+\frac{R^2}{h^2}\right)$
(d) $\left(1-\frac{R^2}{h^2}\right)$

18. Two electric lamps 24 metre apart and each having luminous intensity 450 candela are suspended 5 m above the ground. The illuminance at a point 'O' shown in the figure is :



(a) 3.05 lumen/m^2 (b) 2.04 lumen/m^2
(c) 1.05 lumen/m^2 (d) 8.05 lumen/m^2

19. If a man is standing on a vertical tower of height 20 m, then the distance upto which he will be able to see on the surface of the earth is : (Radius of earth = 6400 km, Neglect the height of the man)
(a) 20 km (b) 16 km
(c) 25 km (d) 10 km

20. An electric bulb is suspended at a vertical height 2 m from the centre of a square table of side 2 m. If the luminous intensity of bulb is 60 cd (candela), then the illumination at one corner of the table is :
(a) 8.16 cd/m^2 (b) 6.24 cd/m^2
(c) 9.25 cd/m^2 (d) 8.72 cd/m^2

21. At any time 3×10^4 photons of wavelength 'λ' metre enter the pupil of eye of area 10^{-4} m^2 per sec for vision, if the minimum light intensity that can be perceived by the eye is about 10^{-10} W/m^2, then λ is :
(a) 6.4×10^{-7} m (b) 5.9×10^{-7} m
(c) 2.85×10^{-7} m (d) 4.62×10^{-7} m

22. What must be the velocity of galaxy, if the wavelength of light coming from a distinct galaxy is 0.5% more than that coming from a source of earth ?
(a) 0.8×10^6 m/s (b) 1.2×10^6 m/s
(c) 2.5×10^6 m/s (d) 1.5×10^6 m/s

23. If wavelength $\lambda_R = 6200$ Å and $\lambda_G = 5400$ Å, then how fast one must move to see red light signal as a green one ?
(a) 4.1×10^7 m/s (b) 5.1×10^7 m/s
(c) 6.1×10^7 m/s (d) 8.1×10^7 m/s

24. What must be the velocity of star, if the spectral line $\lambda = 600$ nm of a star shifts by 0.1 Å towards longer wavelength from the position of the same line in terrestrial laboratory ? (Assume the shift to be due to Doppler effect)
(a) 6×10^3 m/s (b) 5×10^3 m/s
(c) 0.5×10^3 m/s (d) 6.25×10^3 m/s

25. An astronaut is approaching the moon. He sends out a radio signal of frequency 5000 MHz and the frequency of echo is different from that of the original frequency by 100 kHz. His velocity of approach with respect to the moon is :
(a) 2 km/s (b) 3 km/s
(c) 4 km/s (d) 5 km/s

26. What will be the Doppler's wavelength shift expected for light with wavelength 'λ' emitted from the edge of the sun's disc, if the period of rotation of the sun at its equator is T, and its radius is R? (Assume speed of light c)
(a) $\pm \frac{R\lambda}{cT}$ (b) $\pm \frac{T\lambda}{2\pi Rc}$
(c) $\pm \frac{2\pi Rc}{\lambda T}$ (d) $\pm \frac{2\pi R\lambda}{cT}$

Answers

Level-1

1. (a)	2. (d)	3. (c)	4. (c)	5. (c)	6. (d)	7. (a)	8. (a)	9. (b)	10. (b)

Level-2

1. (b)	2. (c)	3. (d)	4. (c)	5. (a)	6. (c)	7. (b)	8. (c)	9. (a)	10. (c)
11. (a)	12. (a)	13. (a)	14. (b)	15. (a)	16. (b)	17. (b)	18. (b)	19. (b)	20. (a)
21. (b)	22. (d)	23. (a)	24. (b)	25. (b)	26. (d)				

Solutions

Level-1

6. $$E \propto \frac{1}{r^2}$$
$$\frac{dE}{E} = 2\left(\frac{\Delta r}{r}\right) = 2 \times 1\% = 2\%$$
As the distance increases, the illumination will decrease.

8. Optical path = geometrical path × refractive index
$= 8 \text{ m} \times 2 = 16 \text{ m}$

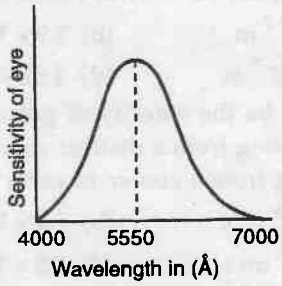
9. $$F = 4\pi I$$
$$F = (4 \times 3.14) \times 100 = 1256 \text{ lumen}$$
$$\therefore \text{ Luminous efficiency} = \frac{\text{luminous flux}}{\text{electric power}} = \frac{1256}{100} = 12.56$$

10. $$v' = \frac{c+v}{c} \cdot v$$
$$\Rightarrow \quad \frac{v'}{v} = \frac{c+v}{c} = \frac{\lambda}{\lambda'}$$
$$\Rightarrow \quad \lambda' = \frac{\lambda c}{c+v} = \frac{5500 \times c}{c + 0.5c} = 3667 \text{ Å}$$
$$\Delta\lambda = (5500 - 3667) \text{ Å} = 1833 \text{ Å}$$

Level-2

1. Only light of visible range excites the retina of eye. Hence, (b) is correct.

2. From the given graph, eye is most sensitive to 5550 Å. Hence, (c) is correct.



3. $$E \propto \frac{1}{r^2}$$
For small change, $\frac{\Delta E}{\Delta r} = \frac{-2k}{r^3}$
$$\frac{\Delta E}{\Delta r} = -2\frac{k}{r^2} \cdot \frac{1}{r} \quad \text{or} \quad \frac{\Delta E}{\Delta r} = -2\frac{E}{r}$$
$$\text{or} \quad \frac{\Delta E}{I} = 2\left(-\frac{\Delta r}{r}\right) \quad \therefore \quad \% \Delta E = 2 \times 2\% = 4\%$$
Hence, (d) is correct.

5. $$\text{Luminous flux} = \frac{\text{light energy}}{\text{time}} = \frac{10}{2} = 5 \text{ lumen}$$

6. Let E = energy falling on the surface per sec Momentum of photons, $p = \frac{h}{\lambda}$
and $\lambda = \frac{c}{\nu}$ or $p = \frac{E}{c}$
In case of reflection, change in momentum per sec
$$= 2p = \frac{2E}{c}$$
Also change in momemtum per sec = force
$$F = \frac{2E}{c} \Rightarrow E = \frac{Fc}{2}$$

23

Electric Charge

Syllabus: Charges and their conservation, Coulomb's law, S.I unit of charge, dielectric constant, electric field.

Review of Concepts

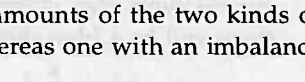
1. Definition of electric charge : The strength of particle's electric interaction with objects around it depends on its electric charge, which can be either positive or negative. An object with equal amounts of the two kinds of charge is electrically neutral, whereas one with an imbalance is electrically charged.

In the table given below, if a body in the first column is rubbed against a body in the second column, the body in first column will acquire positive charge, while that in the second column will acquire negative charge.

	First Column	Second Column
(i)	Glass rod	Silk rod
(ii)	Flannes or Cat skin	Ebonite rod
(iii)	Woollen cloth	Amber
(iv)	Woollen cloth	Rubber shoes
(v)	Woollen cloth	Plastic objects

2. Elementary charge : Electric charge is **quantized;** any charge can be written as ne, where n is a positive or negative integer and e is a constant of nature called the **elementary charge** (approximately 1.60×10^{-19} C). Electric charge is **conserved** : the (algebraic) net charge of any isolated system cannot be changed.

3. Coulomb's law:



Here, (i) $\vec{F}_{12} = -F_{21}$

(ii) $F_{12} = F_{21} = F$

(iii) $F = \dfrac{q_1 q_2}{4\pi\varepsilon_0 r^2}$

Some conceptual points :

(i) Coulomb's law is only applicable for point charges.

(ii) Like charged bodies may attract each other.

(iii) Attraction also takes place between charged and neutral body.

(iv) Electrostatic force of interaction is conservative in nature.

If $\vec{F}$ = electrostatic force and U = electrical potential energy, then

$$\vec{F} = -\frac{\partial U}{\partial x}\hat{i} - \frac{\partial U}{\partial y}\hat{j} - \frac{\partial U}{\partial z}\hat{k}$$

(v) The work done by electrostatic force does not depend upon path. It only depends upon initial and final positions.

(vi) In a closed path work done by electrostatic force is zero. *i.e.,*

$$\int_c \vec{F} \cdot d\vec{l} = 0$$

(vii) Coulomb's law holds good for all distances greater than 10^{-15} m.

(viii) No relativistic variation is found in electric charge.

(ix) The transfer of charge without mass is not possible.

(x) The transfer of mass without charge is possible.

(xi) Massless particle (*e.g.*, photon) never be charged.

(xii) Charging by induction takes place without any loss of charge from the charging body.

(xiii) The magnitude of induced charge is always less or equal to charging body.

(xiv) Electrostatic induction does not take place between point charges.

(xv) Electrostatic induction only takes place between bodies of definite shape (either conducting or non-conducting.)

(xvi) Electrostatic force between two short dipoles of moments p_1 and p_2 at separation r is

$F = \dfrac{1}{4\pi\varepsilon_0}\dfrac{6p_1 p_2}{r^4}$ (when coaxial) and

$F = \dfrac{1}{4\pi\varepsilon_0}\dfrac{3p_1 p_2}{r^4}$ (when mutually perpendicular)

(xvii) **Electric field due to non-conducting uniformly spherical charge :**

(a) $E_{outside} = \dfrac{1}{4\pi\varepsilon_0}\left(\dfrac{q}{r^2}\right)$, $(r > R)$

(b) $E_{surface} = \dfrac{1}{4\pi\varepsilon_0}\dfrac{q}{R^2}$, $(r = R)$

(c) $E_{inside} = \dfrac{\rho r}{3\varepsilon_0}$, $(r < R)$

where ρ = cubical charge density $= \dfrac{3q}{4\pi R^3}$

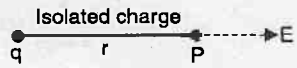
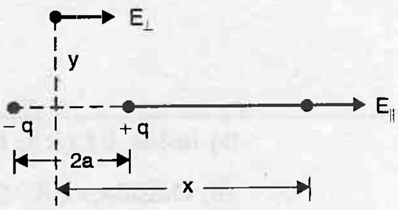
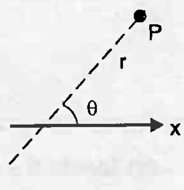
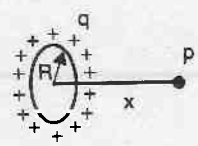
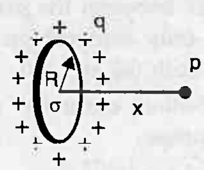
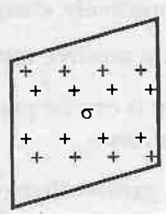
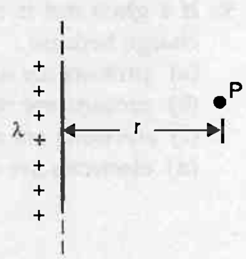
Potential :

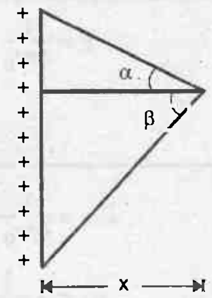
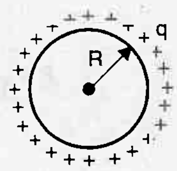
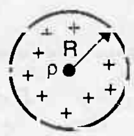
(a) $V_{outside} = \dfrac{1}{4\pi\varepsilon_0} \cdot \dfrac{q}{r}$, $(r > R)$

(b) $V_{surface} = \dfrac{1}{4\pi\varepsilon_0} \cdot \dfrac{q}{R}$, $(r = R)$

(c) $V_{inside} = \dfrac{1}{4\pi\varepsilon_0}\dfrac{q(3R^2 - r^2)}{2R^3}$, $(r < R)$

4. Electric field intensity in some particular cases :

S. No.	System	Electric Field Intensity
1.	Isolated charge 	$E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r^2}$
2.	Dipole  $x, y >> a$ 	$E_{\parallel} = \frac{1}{4\pi\varepsilon_0} \frac{2\vec{p}}{x^3}$ $E_{\perp} = -\frac{1}{4\pi\varepsilon_0} \frac{\vec{p}}{y^3}$ $E = \frac{1}{4\pi\varepsilon_0} \frac{p\sqrt{3\cos^2\theta + 1}}{r^3}$
3.	A ring of charge 	$E = \frac{1}{4\pi\varepsilon_0} \frac{qx}{(R^2 + x^2)^{3/2}}$
4.	A disc of charge 	$E = \frac{\sigma}{2\varepsilon_0}\left[1 - \frac{x}{\sqrt{x^2 + R^2}}\right]$
5.	Infinite sheet of charge 	$E = \frac{\sigma}{2\varepsilon_0}$
6.	Infinitely long line of charge 	$E = \frac{\lambda}{2\pi\varepsilon_0 r}$

S. No.	System	Electric Field Intensity
7.	Finite line of charge 	$E_{\perp} = \frac{\lambda}{4\pi\varepsilon_0 x}(\sin\alpha + \sin\beta)$ $E_{\mid\mid} = \frac{\lambda}{4\pi\varepsilon_0 x}(\cos\alpha - \cos\beta)$
8.	Charged spherical shell 	(a) Inside, $0 < r < R$, $E = 0$ (b) Outside, $r \geq R$, $E = \frac{q}{4\pi\varepsilon_0 r^2}$
9.	Solid sphere of charge 	(a) Inside $0 < r < R$, $E = \frac{\rho r}{3\varepsilon_0}$ (b) Outside $r > R$, $E = \frac{\rho R}{3\varepsilon_0}\left(\frac{R}{r}\right)^2$

Objective Questions

Level-1

1. No current flows between two charged bodies when connected if they have same :
   (a) capacity (b) potential
   (c) charge (d) none of these
2. An isolated conducting sphere is given positive charge. Its mass :
   (a) remains unchanged (b) decreases
   (c) increases (d) may increase or decrease
3. A charge conductor has charge on its :
   (a) outer surface (b) inner surface
   (c) middle point (d) surrounding
4. In comparison with the electrostatic force between two electrons, the electrostatic force between two protons is :
   (a) greater (b) same
   (c) smaller (d) zero
5. When a bird sits on a very high voltage cable :
   (a) its feathers tend to spead
   (b) its feathers tend to compress
   (c) it receives an electric shock
   (d) neither its feathers have any effect nor electric shock is received by it
6. Force between the protons and neutrons in a nucleus is :
   (a) only coulombian (b) only nuclear
   (c) both (a) and (b) (d) none of these
7. A billion electrons are added to a body, its charge becomes :
   (a) 1.6×10^{-19} C (b) 1.6×10^{-28} C
   (c) -1.6×10^{-10} C (d) -1.6×10^{-28} C
8. A positively charged ball hangs from a silk thread. We put a positive test charge q_0 at a point and measure $\frac{F}{q_0}$ then it can be predicted that the electric field strength E becomes :
   (a) greater than $\frac{F}{q_0}$ (b) equal to $\frac{F}{q_0}$
   (c) less than $\frac{F}{q_0}$ (d) cannot be estimated
9. If a glass rod is rubbed with silk, it acquires a positive charge because :
   (a) protons are added to it
   (b) protons are removed from it
   (c) electrons are added to it
   (d) electrons are removed from it

10. The electric charge in a uniform motion produces :
(a) an electric field only
(b) a magnetic field only
(c) both (a) and (b)
(d) neither electric nor magnetic field

11. An isolated solid metallic sphere is given $+Q$ charge. The charge will be distributed on the sphere :
(a) uniformly but only on surface
(b) only on surface but non uniformly
(c) uniformly inside the volume
(d) non uniformly inside the volume

12. When 10^{14} electrons are removed from a neutral metal sphere, the charge on the sphere becomes :
(a) 16 μC (b) – 16 μC
(c) 32 μC (d) – 32 μC

13. Two plates are 2 cm apart. A potential difference of 10 volt is applied between them, the electric field between the plates is :
(a) 20 N/C (b) 500 N/C
(c) 5 N/C (d) 250 N/C

14. Conduction electrons are almost uniformly distributed within a conducting plate. When placed in an electrostatic field E, the electric field within the plate :
(a) is zero
(b) depends upon $|\vec{E}|$
(c) depends upon $\vec{E}$
(d) depends upon the atomic number of the conducting element

15. A soap bubble is given a negative charge then its radius :
(a) decreases
(b) increases
(c) remains unchanged
(d) nothing can be predicted as information is insufficient

16. An electron and a proton are in a uniform electric field, the ratio of their accelerations will be :
(a) zero
(b) unity
(c) the ratio of the masses of proton and electron in order
(d) the ratio of the masses of electron and proton in order

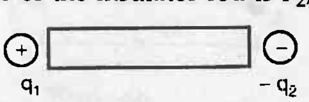
17. There are two charges + 1μC and + 5 μC. The ratio of the forces acting on them will be :
(a) 1 : 5 (b) 1 : 1 (c) 5 : 1 (d) 1 : 25

18. A body can be negatively charged by :
(a) giving excess of electrons to it
(b) removing some electrons from it
(c) giving some protons to it
(d) removing some neutrons from it

19. An electron of mass m and charge e is accelerating from rest through a potential difference V in vacuum its final speed will be :
(a) $\sqrt{\frac{2eV}{m}}$ (b) $\sqrt{\frac{eV}{m}}$ (c) $\frac{eV}{2m}$ (d) $\frac{eV}{m}$

Level-2

1. A thin insulator rod is placed between two unlike point charges $+q_1$ and $-q_2$ (shown in figure). The magnitude of electrostatic force on q_1 in the absence of the insulator rod is F_1. But the magnitude of electrostatic force on q_1 in the presence of the insulator rod is F_2, then :



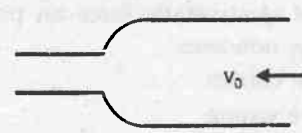
(a) $F_1 = F_2$ (b) $F_1 > F_2$
(c) $F_1 < F_2$ (d) none of these

2. One brass plate is inserted between two charges. The force between two charges will :
(a) remain the same
(b) increase
(c) decrease
(d) fluctuate

3. Two uncharged thin and small metal rods x and y are placed near a non-conducting sheet s of uniform charge density σ, then :
(a) s attracts both x and y
(b) x attracts both s and y
(c) y attracts both s and x
(d) all of the above

4. Five balls, numbered 1 to 5 are suspended using separate threads. Pairs (1, 2), (2, 4), (4, 1) show electrostatic attraction; while pairs (2, 3) and (4, 5) show repulsion therefore, ball 1 must be :
(a) positively charged
(b) negatively charged
(c) neutral
(d) made of metal

5. An electron moves along a metal tube with variable cross-section. The velocity of the electron when it approaches the neck of tube, is :



(a) greater than v_0
(b) equal to v_0
(c) less than v_0
(d) not defined

6. A sure test of electrification is :
(a) attraction
(b) repulsion
(c) friction
(d) induction

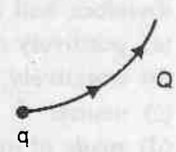
7. Two metallic spheres carry equal charges. The distance between the spheres cannot be considered large in comparison with the diameters of the spheres. In which case, will the force of interaction between the spheres be greater ?
   (a) Like charges
   (b) Unlike charges
   (c) One is neutral and other is charged
   (d) None of the above

8. Mark correct option or options :
   (a) The electric charge without mass is possible
   (b) The charge without mass is not possible
   (c) The electric charge may be transferred without transferring mass
   (d) Mass without electric charge is not possible

9. In relativistic mechanics $m = \frac{m_0}{\sqrt{\left(1-\frac{v^2}{c^2}\right)}}$ the equivalent relation in electricity for electric charge is :
   (a) $q = q_0$ (b) $q = \frac{q_0}{\sqrt{\left(1-\frac{v^2}{c^2}\right)}}$
   (c) $q_0 = \frac{q}{\sqrt{\left(1-\frac{v^2}{c^2}\right)}}$ (d) $q = \frac{q_0 v}{c}$

10. Mark correct option or options :
   (a) Like charged bodies always repel each other
   (b) Like charged bodies always attract each other
   (c) Like charged bodies may attract each other
   (d) None of the above

11. A particle with positive charge Q is held fixed at the origin. A second particle with positive charge q is fired at the first particle and follows a trajectory as shown (assume region to be gravity free) :



   (a) Angular momentum of the point charge q about O remains constant during motion
   (b) The torque of electrostatic force on point charge q about origin is non-zero
   (c) (a) and (b) are correct
   (d) (a) and (b) are wrong

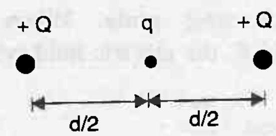
12. The charge conservation principle is :
   (a) only applicable when charges are in rest
   (b) only applicable when charges are in motion
   (c) not applicable in nuclear reaction
   (d) applicable in nuclear reaction

13. Coulomb's law is applicable to :
   (a) point charges (b) spherical charges
   (c) like charges (d) all of these

14. Two identically charged spheres when suspended by strings of equal lengths make an angle of 30° with each other. When they are immersed in a liquid of density less than the density of the material of the spheres :
   (a) the electric force between them increases
   (b) the electric force between them decreases
   (c) the net downward force will increase
   (d) the net downward force will remain unchanged

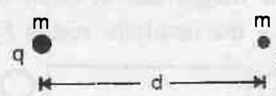
15. In the midway between two equal and similar charges, a third equal and similar charge is placed. Then third charge :
   (a) experiences a force on the equatorial line
   (b) experiences a net force on the axial line
   (c) is in unstable equilibrium
   (d) is in stable equilibrium

16. Two positively charged particles each having charge Q are d distance apart. A third charge is introduced in midway on the line joining the two. Find nature and magnitude of third charge, so that the system is in equilibrium :



   (a) $q = \frac{-Q}{4}$ (b) $q = \frac{Q}{4}$
   (c) $q = \frac{3Q}{4}$ (d) $q = -\frac{3Q}{4}$

17. As shown in the adjoining figure two charge particles each having charge q and mass m are d distance apart from each other. If two particles are in equilibrium under the gravitational and electric force then the ratio q/m is :



   (a) 10^{-8} (b) 10^{-10}
   (c) 10^{10} (d) none of these

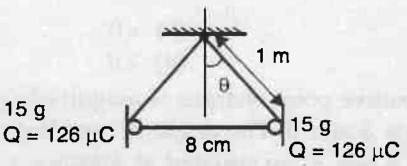
18. Two negative charges of unit magnitude and a positive charge q are placed along a straight line. The charge q is placed between negative charges as such the system of charges is in equilibrium. This system is in :
   (a) stable equilibrium for the displacement of charge q in the normal direction of line joining the negative charges
   (b) unstable equilibrium for the displacement of charge q in the normal direction of line joining the negative charges
   (c) stable equilibrium for the displacement of charge q in the direction of line joining the negative charges
   (d) neutral equilibrium for the displacement of charge q along the line joining the negative charges

19. Mark correct option :
Electrostatic experiment is :
(a) affected on the humid day
(b) not affected on humid day
(c) independent of medium
(d) none of the above

20. A positively charged ball hangs from long silk thread. We put a positive charge 'q_0' at a point and measure F/q_0, then it can be predicted that field E :
(a) $> \frac{F}{q_0}$ (b) $= \frac{F}{q_0}$
(c) $< \frac{F}{q_0}$ (d) none of these

21. Two identical pendulums A and B are suspended from the same point. The bobs are given positive charges, with A having more charge than B. They diverge and reach at equilibrium, with A and B making angles θ_1 and θ_2 with the vertical respectively :
(a) $\theta_1 > \theta_2$
(b) $\theta_1 < \theta_2$
(c) $\theta_1 = \theta_2$
(d) the tension in A is greater than that in B

22. Two balls of same radius and mass are suspended on threads of length 1 m as shown. The mass of each ball and charge is 15 g and 126 μC respectively. When the balls are in equilibrium, the separation between them is



8 cm. The new saparation between them when one of the balls is discharged to half of original charge, is :
(a) 5 cm (b) 6 cm
(c) 4 cm (d) 2 cm

23. Mark correct option or options :
(a) A point charge can not exert force on itself
(b) Coulomb's force is stronger than the gravitational force
(c) Electric field can exist only in material medium
(d) None of the above

24. A negatively charged metallic ball is supported on a rigid insulating stand. We wish to measure the electric field E at a point P in the same horizontal level as that of the metallic ball. To do so, we put a positive charge q_0 and measure F/q_0. The electric field at the point P is :
(a) $= \frac{F}{q_0}$ (b) $< \frac{F}{q_0}$
(c) $> \frac{F}{q_0}$ (d) none of these

25. Two bodies A and B of definite shape are placed near one another. Electrostatic attraction is found between the bodies, then :
(a) both bodies must be positively charged
(b) both bodies must be negatively charged
(c) both bodies must be oppositely charged
(d) body A may be neutral

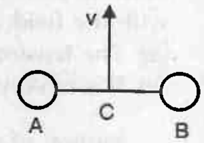
26. If σ = surface charge density, ε = electric permittivity, the dimensions of $\frac{\sigma}{\varepsilon}$ are same as :
(a) electric force
(b) electric field intensity
(c) pressure
(d) electric charge

27. Two equal negative charges $-q$ are fixed at points $(0, a)$ and $(0, -a)$ on the y-axis. A positive charge Q is released from rest at the point $(2a, 0)$ on the x-axis. The motion of charge Q will be :
(a) simple harmonic motion
(b) oscillatory
(c) circular motion
(d) none of the above

28. Two negatively charged particles of unit magnitude and charge q are placed along a straight line. If charge q is placed at the mid point between charges, then :
(a) q is in stable equilibrium
(b) q is in unstable equilibrium
(c) q is in neutral equilibrium
(d) none of the above

29. Four equal positive charges each of magnitude q are placed at the respective vertices of a square of side length l. A point charge Q is placed at the centre of the square. Then :
(a) Q must not be in equilibrium
(b) Q must be in stable equilibrium
(c) Q must be in neutral equilibrium
(d) Q must be in unstable equilibrium

30. Two small particles A and B of equal masses carrying equal positive charges are attached to the ends of a non-conducting light thread of length $2l$. A particle C of mass twice of A is attached at mid-point of thread. The whole system is placed on a smooth horizontal floor and the particle C is given a velocity v as shown in the figure. Which of following statements is correct ?



(a) The velocity of centre of mass of the system will remain constant during motion
(b) At the instant of minimum separation between A and B, there is no approach velocity between them or velocities of three particles are identical
(c) The velocity of centre of mass of the system will be $v/2$
(d) All of the above

31. Two small identical balls A and B lying on a horizontal smooth plane are connected by a massless spring. Ball A is fixed but ball B is free to move. When both balls are charged identically, then :

(a) at the time of maximum separation between balls, magnitude of acceleration will be maximum
(b) at the equilibrium position of B, velocity of ball B will be maximum
(c) the ball B executes simple harmonic motion
(d) all of the above

32. For the metallic conductor:
(a) dielectric constant must be zero
(b) dielectric constant must not be infinity
(c) dielectric constant must be infinity
(d) dielectric constant may be infinity

33. A dimensionless body having a physical quantity varies as $1/r^2$, where r is distance from the body. This physical quantity may be:
(a) gravitational potential
(b) electric field
(c) gravitational field
(d) none of the above

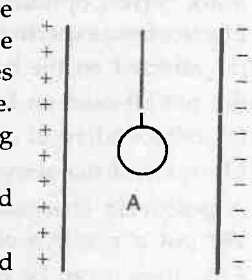
34. A charged particle moves in an electric field from A to B and then B to A:
(a) If $W_{AB} > W_{BA}$, then the field is conser- vative
(b) If $W_{AB} + W_{BA} = 0$, then the field is conservative
(c) If $W_{AB} + W_{BA} > 0$, then the field is conservative
(d) If $W_{AB} = W_{BA}$, then the field is conservative

35. If two charged particles of same mass and charge are projected in a uniform electric field with the same speed, then:
(a) both have same momentum at any instant
(b) both have same kinetic energy at any instant
(c) both have same magnitude of momentum at any instant
(d) they may move on a straight line

36. A point particle of mass m is attached to one end of a massless rigid non-conducting rod of length l. Another point particle of same mass is attached to the other end of the rod. The two particles carry equal charges $+q$ and $-q$ respectively. This arrangement is held in a region of uniform electric field E such that the rod makes an angle with the field direction:
(a) The tension in rod remains constant
(b) If q is very small, the rod executes simple harmonic motion of period $2\pi\sqrt{\dfrac{ml}{2qE}}$
(c) At every instant, net force on the system is zero
(d) Both (b) and (c) are correct

37. A particle having charge q and mass m is projected in uniform electric field E with speed u making angle $\theta = 30^\circ$ with electric field:
(a) If the gravitational field is present, the path may be straight line
(b) If the gravitational field is absent, the path may be circle
(c) If the gravitational field is absent, the path may not be parabola
(d) If the gravitational field is absent, the path may not be straight line

38. The uncharged metallic sphere A suspended as shown in figure is given a push so that it moves towards the positive plate. Which one of the following statements is correct?

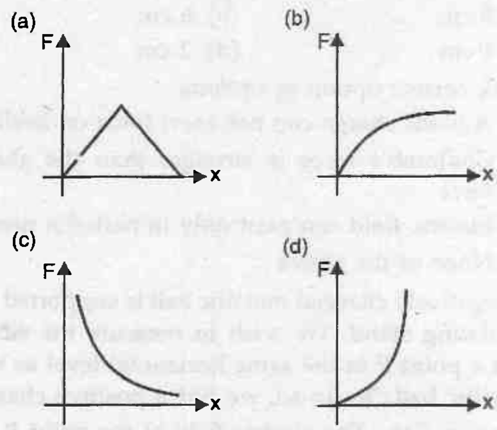


(a) A touches positive plate and remains in contact with it
(b) A touches positive plate and then moves towards negative plate and remain in contact with it
(c) A moves to and fro between the two plates with a constant time period
(d) A moves to and fro between two plates with an increasing time period

39. A spring block system undergoes vertical oscillation above a large horizontal metal sheet with uniform positive charge. The time period of the oscillation is T. If the block is given a charge Q, its time period of oscillation will be:
(a) equal to T
(b) less than T
(c) greater than T
(d) greater than T if Q is positive and less than T if Q is negative

40. A positive charge q is located at a point. What is the work done if an electron is carried once completely around this charge along a circle of radius r about this point charge q?
(a) >0 (b) $=0$
(c) <0 (d) >0

41. Two positive point charges of magnitude q each are fixed at points A and B. The origin of coordinate system at the points A and B are situated at distance x on x-axis from the origin. Which of the following is best represented for force of interaction F versus x-graph?



42. Two points charges $+q_1$ and $+q_2$ are placed at a certain distance apart, then:
(a) they produce the same electric field on each other
(b) they exert same forces on each other
(c) for minimum force between them, the magnitude of each charge must be equal to 1.6×10^{-19} C
(d) all of the above

43. An electrostatic field E of magnitude 10 N/C is directed along positive x-axis. A point charge of 10^{-6} C is shifted from A (1 m, 0) to B (2 m, 0, 1 m), then from point B to C (0, 0, 0), the work done by electrostatic force is :
(a) -10^{-5} J (b) 10^{-5} J
(c) -10^{-4} J (d) none of these

44. The electric field inside a conductor :
(a) must be zero
(b) may be non-zero
(c) must be non-zero
(d) (a) and (c) are correct

45. If a conductor encloses a charge, then in equilibrium :
(a) its inner surface will have an opposite charge equal in magnitude to the charge enclosed
(b) its inner surface has no charge
(c) its inner surface will have same nature charge equal in the magnitude to the charge enclosed
(d) its inner surface will have opposite nature but not equal in the magnitude of the charge enclosed

46. The electric intensity at a point A at distance x from uniformly charged non-conducting plane is E. Then :
(a) the electric charge per unit area on the plane is $2\varepsilon E$
(b) magnitude $E/2$ of field is due to the charges at points within distance $2x$ from the point 'A'
(c) magnitude E of field is due to the charges at points within distance $2x$ from point A
(d) both (a) and (c) are correct

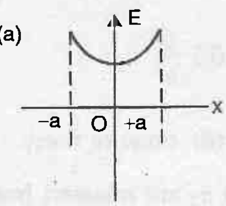
47. In a region, electric field varies as $E = 2x^2 - 4$ where x is distance in S.I. from origin along x-axis. A positive charge of 1 μC is released with minimum velocity from infinity for crossing the origin, then :
(a) the kinetic energy at the origin must be zero
(b) the kinetic energy at the origin may be zero
(c) the kinetic energy at $x = \sqrt{2}$ m must be zero
(d) the kinetic energy at $x = 2$ m may be zero

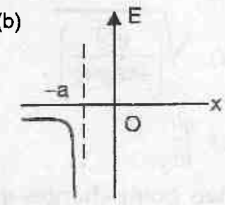
48. The electric field versus distance graph is shown, where distance is measured from the centre of the body, then :

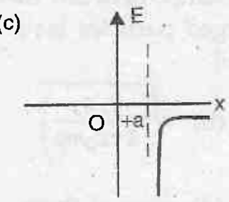
(a) the body must be spherical
(b) the body may be spherical
(c) the body may be spherical having volume charge density
(d) the body may be hollow sphere

49. Three charged particles are collinear and are in equilibrium. Then :
(a) all the charged particles have the same polarity
(b) the equilibrium is unstable
(c) all the charged particles cannot have the same polarity
(d) both (b) and (c) are correct

50. A point charge q and a charge $(-q)$ are placed at $x = -a$ and $x = +a$ respectively. Which of the following represents a part of E-x graph ?

(a)


(b)


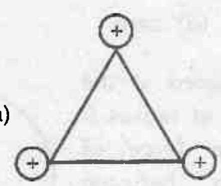
(c)


(d) All of these

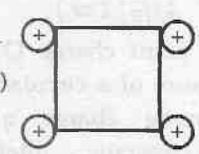
51. A non-conducting solid sphere of radius R is uniformly charged. The magnitude of electric field due to the sphere at a distance r from its centre :
(a) increases as r increases for $r < R$
(b) decreases as r increases for $0 < r < \infty$
(c) decreases as r increases for $R < r < \infty$
(d) is discontinuous at $r = R$
(e) both (a) and (c) are correct

52. A conducting solid sphere of radius R is uniformly charged. The magnitude of the electric field due to the sphere at a distance r from its centre
(a) increases as r increases
(b) decreases as r increases
(c) decreases as r increases, for $R < r < \infty$
(d) is discontinuous at $r = R$
(e) both (c) and (d) are correct.

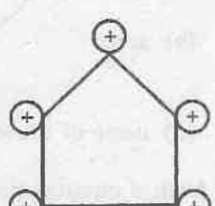
53. In the following diagrams, all the charges have equal magnitude. Electric field is zero at the centre of ·

(a)


Equilateral triangle

(b)


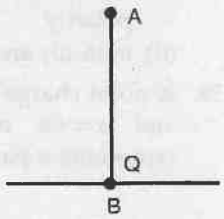
Square

(c)


Regular pentagon

(d) All of these

54. A point charge Q is situated at point B on the ground. A point charge q of mass m is vertically dropped along line AB from a multi-storey building of height h. The position of the point charge q when it is in equilibrium is :



(a) $\sqrt{\left(\frac{qQ}{4\pi\varepsilon_0 mg}\right)}$ (b) $\frac{Q}{h^2}$

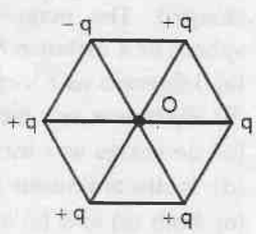
(c) $\frac{qh}{m}$ (d) none of these

55. Two point charges q_1 and q_2 are released from rest in a gravity free hall when distance between them is a. The maximum speeds of charged particles is : [The mass of each charged particle is m]

(a) $\frac{q_1 q_2}{4\pi\epsilon_0 a}$ (b) $\sqrt{\left(\frac{q_1 q_2}{4\pi\varepsilon_0 ma}\right)}$

(c) $\sqrt{\left(\frac{2q_1 q_2}{4\pi\varepsilon_0 ma}\right)}$ (d) none of these

56. Six point charges are arranged at the vertices of a regular hexagon of side length a (shown in figure). The magnitude of electric field at the centre of regular hexagon is :



(a) $\frac{q}{4\pi\varepsilon_0 a^2}$ (b) zero

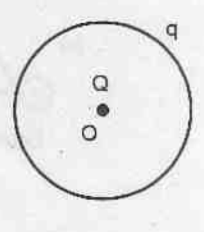
(c) $\frac{q}{2\pi\varepsilon_0 a^2}$ (d) none of the above

57. Calculate the work done in carrying a charge q once round over a closed circular path of radius 'r' and a charge Q is at the centre :

(a) $\frac{qQ}{4\pi\varepsilon_0 r}$ (b) $\frac{qQ}{4\pi\varepsilon_0 \pi r}$

(c) $\frac{qQ}{4\pi\varepsilon_0}\left(\frac{1}{2\pi r}\right)$ (d) zero

58. A point charge Q is placed at the centre of a circular wire of radius R having charge q. The force of electrostatic interaction between point charge and the wire is :



(a) $\frac{qQ}{4\pi\varepsilon_0 R^2}$ (b) zero

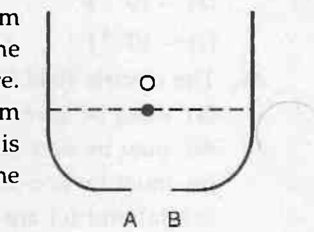
(c) $\frac{q^2}{4\pi\varepsilon_0 R}$ (d) none of these

59. A small element l is cut from a circular ring of radius a and λ charge per unit length. The net electric field at the centre of ring is :

(a) zero (b) $\frac{\lambda l}{4\pi\varepsilon_0 a^2}$

(c) ∞ (d) $\frac{\lambda}{4\pi\varepsilon l}$

60. A long thread carrying a uniform charge λ per unit length has the configuration shown in the figure. An element of charge q is cut from the thread. The cutting portion is shown as small gap (AB). The electric field at the point O is :



(a) zero (b) $\frac{q}{4\pi\varepsilon_0 R^2}$

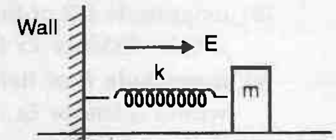
(c) $\frac{\lambda}{2\pi\varepsilon_0 R}$ (d) none of these

61. A point charge $q = 1$ C and mass 1 kg is projected with speed $v_0 = 10$ m/s in the perpendicular direction of uniform electric field $E = 100$ V/m. The value of latus-rectum of the path followed by charge particle is :

(a) 2 m (b) 100 m

(c) 400 m (d) none of these

62. A point mass m and charge q is connected with massless spring of natural length L. Initially spring is in its natural length.



If a horizontal uniform electric field E is switched on (shown in figure), the maximum separation between the point mass and the wall is : (Assume all surfaces are frictionless).

(a) $L + \frac{2qE}{k}$ (b) $L + \frac{qE}{k}$

(c) L (d) none of these

63. In the previous problem, the separation of the point mass and wall at the equilibrium position of the mass is :

(a) $L + \frac{qE}{k}$ (b) $L - \frac{qE}{k}$

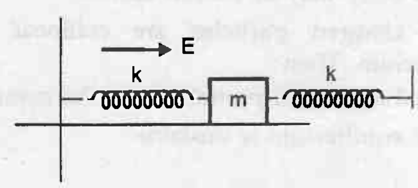
(c) $\frac{qE}{k} - L$ (d) none of these

64. In the previous problem, energy stored in spring at the equilibrium position of the point mass is :

(a) $\frac{q^2E^2}{2k}$ (b) $\frac{1}{2}kE^2$

(c) $\frac{q^2E^2}{k}$ (d) none of these

65. A particle of mass m and having a charge q is placed on a smooth horizontal table and is connected to walls



through unstressed springs of constant k (shown in figure). A horizontal electric field E parallel to spring is switched on. The maximum speed of the particle is :

(a) $\frac{qE}{\sqrt{2mk}}$ (b) $\frac{qE}{mk}$

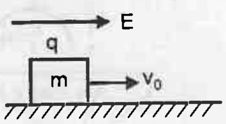
(c) $\frac{qE}{m}$ (d) none of these

66. A point charge is projected along the axis of circular ring of charge Q and radius $10\sqrt{2}$ cm. The distance of the point charge from centre of ring, where acceleration of charged particle is maximum, will be :

(a) 10 cm (b) 20 cm

(c) at infinity (d) none of these

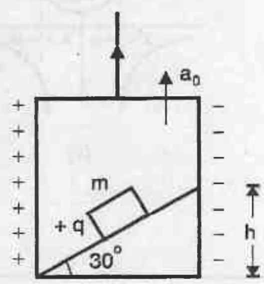
67. If a charged particle is projected on a rough horizontal surface with speed v_0, the value of dynamic coefficient of friction if the kinetic energy of system is constant, is :



(a) $\frac{qE}{mg}$ (b) $\frac{qE}{m}$

(c) $\frac{q}{g}$ (d) none of these

* 68. A small block of mass 'm' is kept on a smooth inclined plane of angle 30°, placed in an elevator going upward, with acceleration a_0. Electric field E exists between the vertical sides of the wall of the elevator. The charge on the block is $+q$.. The time taken by the block to come to the lowest point of inclined plane is : (take the surface to be smooth)



(a) $\sqrt{\left(\frac{2h}{g}\right)}$ (b) $\sqrt{\left(\frac{2h}{(g-a_0)+\frac{qE}{m}}\right)}$

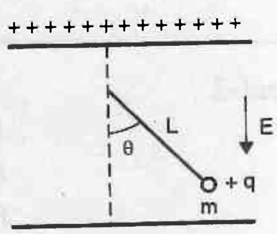
(c) $2\sqrt{\left(\frac{2h}{(g+a_0)-\frac{qE}{m}\sqrt{3}}\right)}$ (d) $\sqrt{\left(\frac{2h}{(g+a_0)^2-\left(\frac{qE}{m}\right)h^2}\right)}$

69. Two charges of values 2 μC and − 50 μC are placed at a distance 80 cm apart. The distance of the point from the smaller charge where the intensity will be zero, is :

(a) 20 cm (b) 35 cm

(c) 30 cm (d) 25 cm

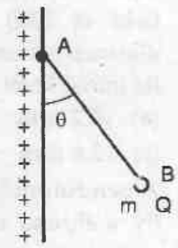
* 70. Between two large parallel plates, a uniform vertical field $\vec{E}$ is set up as shown in figure. Find the period of oscillation of the pendulum, if the pendulum of length L having a small conducting sphere of mass m and charge $+q$ is oscillating between the plates :



(a) $T = 2\pi\sqrt{\frac{L}{g+\frac{qE}{m}}}$ (b) $T = 2\pi\sqrt{\frac{L}{g-\frac{qE}{m}}}$

(c) $T = \pi\sqrt{\frac{L}{g+\frac{qE}{m}}}$ (d) $T = \pi\sqrt{\frac{L}{g-\frac{qE}{m}}}$

* 71. An infinite plane consists of a positive charge and has σ C/m² surface charge density. Calculate the angle θ, if a metallic ball B of mass m and charge $+Q$ is attached to a thread and tied to a point A on the sheet PQ, as shown in figure : (ε_a = permittivity of air)



(a) $\theta = \tan^{-1}\left(\frac{2Q\sigma}{\varepsilon_0\varepsilon_a mg}\right)$

(b) $\theta = \tan^{-1}\left(\frac{Q\sigma}{2\varepsilon_0\varepsilon_a mg}\right)$

(c) $\theta = \tan^{-1}\left(\frac{Q\sigma}{3\varepsilon_0\varepsilon_a mg}\right)$

(d) none of the above

72. In the diagram shown electric field intensity will be zero at a point :

(a) between − q and + $2q$ charge

(b) on the RHS of + $2q$ charge

(c) on the LHS of − q charge

(d) no where on the line

73. Two charged particles of charge + $2q$ and + q have masses m and $2m$ respectively. They are kept in uniform electric field and allowed to move for the same time. The ratio of their kinetic energies is :

(a) 1 : 8 (b) 16 : 1

(c) 2 : 1 (d) 3 : 1

74. A copper ball of density ρ_c and diameter d is immersed in oil of density ρ_o. What charge should be present on the ball, so that it could be suspended in the oil, if a homogeneous electric field E is applied vertically upward ?

(a) $Q = \frac{\pi d^2(\rho_c - \rho_o)g}{6E}$ (b) $Q = \frac{\pi d^3(\rho_c - \rho_o)g}{6E}$

(c) $Q = \frac{\pi d^3(\rho_c - \rho_o)g}{E}$ (d) None of these

75. An oil drop of charge of 2 electrons fall freely with a terminal speed. The mass of oil drop so, it can move upward with same terminal speed, if electric field of 2×10^3 V/m is applied, is :

(a) 3.0×10^{-17} kg (b) 3.2×10^{-17} kg

(c) 2.5×10^{-17} kg (d) 3.3×10^{-17} kg

* 76. An electron of mass m and charge e leaves the lower plate of a parallel plate capacitor of length L, with an initial velocity v_0 making an angle α with the plate and come

out of the capacitor making an angle β to the plate. The electric field intensity between the plates :

(a) $E = \dfrac{mv_0^2 \cos^2\alpha}{eL}(\tan\alpha + \tan\beta)$

(b) $E = \dfrac{mv_0^2 \cos^2\alpha}{eL}(\tan\alpha - \tan\beta)$

(c) $E = \dfrac{mv_0^2 \cos^2\alpha}{eL}(\tan\beta - \tan\alpha)$

(d) none of the above

77. An electron is projected with velocity 10^7 m/s at an angle $\theta\ (=30°)$ with horizontal in a region of uniform electric field of 5000 N/C vertically upwards. The maximum distance covered by an electron in vertical direction above its initial level is :

(a) 14.2 mm (b) 15 mm
(c) 12.6 mm (d) 14.2 cm

78. A pendulum bob of mass '*m*' and charge '*q*' is suspended by a thread of length *l*. The pendulum is placed in a region of a uniform electric field *E* directed vertically upward. If the electrostatic force acting on the sphere is less than that of gravitational force, the period with which the pendulum oscillates is : (Assume small oscillation)

(a) $T = 2\pi\sqrt{\dfrac{l}{g + \dfrac{qE}{m}}}$ (b) $T = 2\pi\sqrt{\dfrac{l}{g - \dfrac{qE}{m}}}$

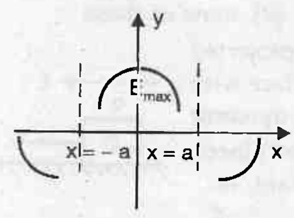
(c) $T = \pi\sqrt{\dfrac{l}{g - \dfrac{qE}{m}}}$ (d) $T = \pi\sqrt{\dfrac{l}{g + \dfrac{qE}{m}}}$

79. Identical charges of magnitude Q are placed at $(n-1)$ corners of a regular polygon of n sides each corner of the polygon is at a distance r from the centre. The field at the centre is :

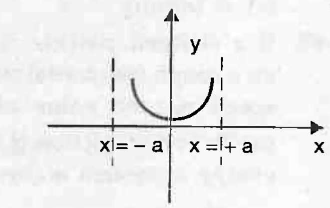
(a) $\dfrac{kQ}{r^2}$ (b) $(n-1)\dfrac{kQ}{r^2}$

(c) $\dfrac{n}{(n-1)}\cdot\dfrac{kQ}{r^2}$ (d) $\dfrac{(n-1)}{n}\cdot\dfrac{kQ}{r^2}$

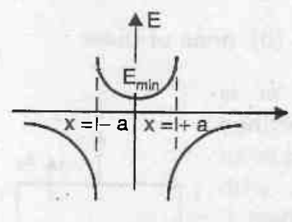
80. As shown in the figure a positive charge $+q$ is placed at $x = -a$ and negative charge $-q$ is placed at $x = +a$. Then choose the curve which shows variation of E along the x-axis :



(a)



(b)



(c)

(d) none of these

Answers

Level-1

1.	(b)	2.	(b)	3.	(a)	4.	(b)	5.	(a)	6.	(c)	7.	(b)	8.	(a)	9.	(d)	10.	(c)
11.	(a)	12.	(a)	13.	(b)	14.	(a)	15.	(b)	16.	(c)	17.	(b)	18.	(a)	19.	(a)		

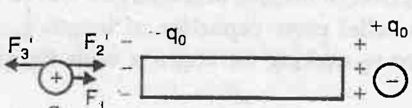
Level-2

1.	(c)	2.	(b)	3.	(d)	4.	(c)	5.	(a)	6.	(b)	7.	(b)	8.	(b)	9.	(a)	10.	(c)
11.	(a)	12.	(d)	13.	(a)	14.	(b)	15.	(c)	16.	(a)	17.	(b)	18.	(a)	19.	(a)	20.	(a)
21.	(c)	22.	(a)	23.	(a)	24.	(b)	25.	(d)	26.	(b)	27.	(b)	28.	(b)	29.	(d)	30.	(d)
31.	(d)	32.	(d)	33.	(b)	34.	(b)	35.	(d)	36.	(d)	37.	(a)	38.	(d)	39.	(a)	40.	(b)
41.	(c)	42.	(c)	43.	(a)	44.	(b)	45.	(a)	46.	(d)	47.	(c)	48.	(c)	49.	(d)	50.	(d)
51.	(e)	52.	(e)	53.	(d)	54.	(a)	55.	(b)	56.	(c)	57.	(d)	58.	(b)	59.	(b)	60.	(b)
61.	(a)	62.	(a)	63.	(a)	64.	(a)	65.	(a)	66.	(a)	67.	(a)	68.	(c)	69.	(a)	70.	(a)
71.	(b)	72.	(c)	73.	(b)	74.	(b)	75.	(b)	76.	(b)	77.	(a)	78.	(b)	79.	(a)	80.	(c)

Solutions

Level-2

1. In the figure,



F_1 = force due to q_2

F_2' = force due to $(-q_0)$

F_3' = force due to $(+q_0)$

$(-q_0)$ charge is nearer to q_1 than $+q_0$.

$\therefore \quad F_2' > F_3'$

24

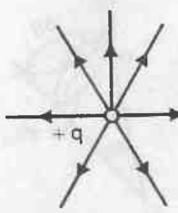
Gauss's Law and Electric Potential

Syllabus: Lines of forces, field due to dipole and its behaviour in a uniform electric field, electric flux, Gauss's law in simple geometries, electric potential, potential due to point charge, conductors and insulators, distribution of charge on conductor.

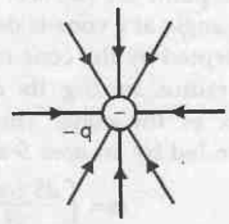
Review of Concepts

1. **Electric lines of force:** Faraday gave a new approach for representation of electric field in the form of electric lines of force. Electric lines of force are graphical representation of electric field. This model of electric field has the following characteristics:

(a) Electric lines of force are originated from positive charge and terminated into negative charge.

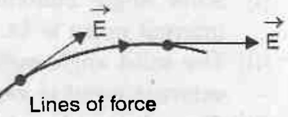


Isolated positive charge



Isolated negative charge

(b) It is imaginary line, the tangent at a point on electric lines of force gives the direction of electric field at the point.

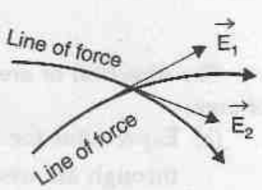


(c) The number of electric lines of force originates from a point charge q is q/ε_0. Electric lines of force may be fraction.

(d) The number of lines per unit area that pass through a surface perpendicular to the electric field lines is proportional to the strength of field in that region.

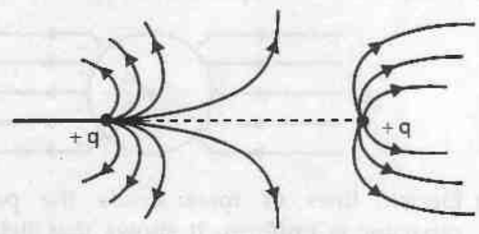
(e) Closer electric lines of force mean stronger field.

(f) No electric lines of forces cross each other. If two electric lines of force cross each other, it means electric field has two directions at the point of cross. This is not physically possible.

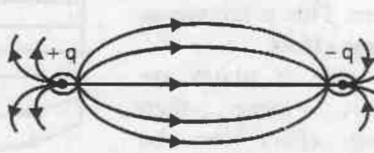


(g) Electrostatic lines of force never form a closed curve. But electric lines of force in the case of induced electric field are in closed curve.

(h) Electric lines of force for two equal positive point charges are said to have rotational symmetry about the axis joining the charges.

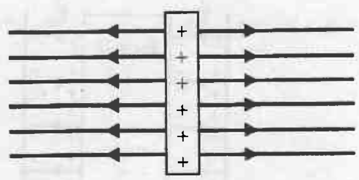


(i) Electric lines of force for a point positive and a nearby negative point charge that are equal in magnitude are said to have rotational symmetry about an axis passing through both charges in the plane of the page.



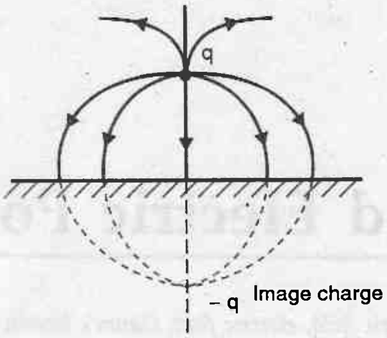
Electric dipole

(j) Electric lines of force due to infinitely large sheet of positive charge is normal to the sheet.

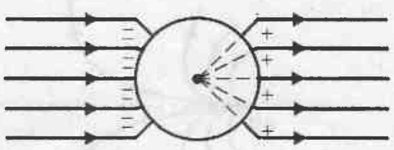


(k) If no electric lines of force are present in a region, the electric field in that region is zero and potential is constant.

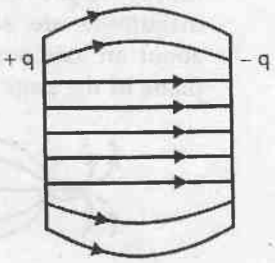
(l) If a point charge is placed near a conducting plane, for solving problem, the formation of image charge takes place.



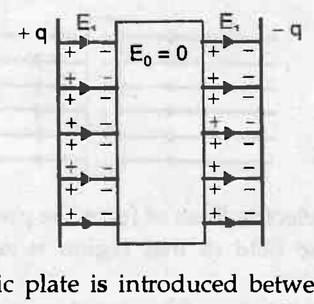
(m) No electrostatic lines of force are present inside a conductor. Also electric lines of force are perpendicular to the surface of conductor. As for example if a conducting sphere is placed in a region where uniform electric field is present. Then induced charges are developed on the sphere.



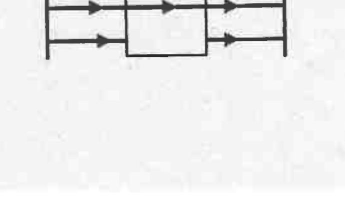
(n) Electric lines of force inside the parallel plate capacitor is uniform. It shows that field inside the parallel plate capacitor is uniform. But at the edge of plates, electric lines of force are curved. It shows electric lines of force at the edge of plates is non-uniform. This is known as **fringing effect.**
If the size of plates are infinitely large then fringing effect can be neglected.



(o) If a metallic plate is introduced between plates of a charged capacitor, then electric lines of force can be discontinuous.



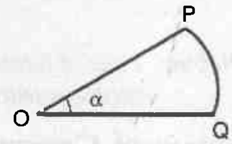
(p) If a dielectric plate is introduced between plates of a charged capacitor then, number of lines of forces in dielectric is lesser than that in case of vacuum space.



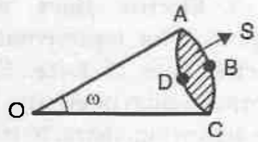
(q) If a charged particle is released from rest in region where only uniform electric field is present, then charged particle moves along an electric lines of force. But if charged particle has initial velocity, then the charged particle may or may not follow the electric lines of force.

(r) Electric potential decreases in the direction of electric lines of force.

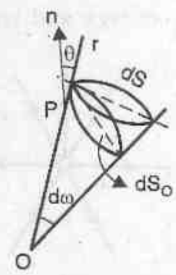
2. Solid angle : A plane consists of a number of lines. We consider a curve *PQO* (shown in figure). This curve makes an angle α at point *O*.



A solid consists of a number of planes. We consider a plane *ABCD*. If all points *A, B, C, D* and the periphery of the plane are joined with a point *O*. It is called solid angle.



Then this plane makes solid angle 'ω' at point *O*. Its unit is steradian. Solid angle at a cone is defined as area intercepted by the cone on a sphere of unit radius having its centre at the vertex of the cone. The solid angle subtended by an area *S* at *O* is



$$\omega = \int_S \frac{dS \cos\theta}{r^2}$$

Some conceptual points :

(i) Solid angle subtended by a closed surface at an internal point is 4π.

(ii) The solid angle subtended by a closed surface at an external point is zero.

(iii) The solid angle subtended by a right circular cone at its vertex is $2\pi(1 - \cos\alpha)$ where α is semivertex angle.

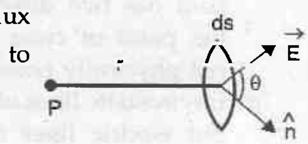
3. Electric flux : The word flux comes from Latin word meaning to flow. Electric flux is a measure of the flow of electric field through a surface. It is given by the scalar product of electric field and area vector. It is denoted by ϕ

$$\phi = \int \vec{\mathbf{E}} \cdot \vec{\mathbf{dS}}$$

$$\phi = \int EdS \cos\theta$$

The direction of area vector is taken normal to the plane of area.

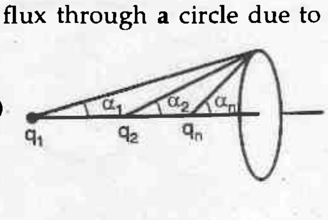
(a) Expression for electric flux through an area $\vec{dS}$ due to a point charge q.



$$\phi = \frac{1}{4\pi\varepsilon_0} \sum_{i=1}^{n} q_i \omega_i$$

(b) Expression for electric flux through a circle due to a point charge.

$$\phi = \frac{1}{2\varepsilon_0} \sum_{i=1}^{n} q_i (1 - \cos\alpha_i)$$



4. Gauss's law: Gauss's and Coulomb's law are not two separate laws. But they are supplementary to each other. Gauss's law is used to solve for a problem having high symmetry.

Statement: The total electric flux through a closed surface is equal to $1/\varepsilon_0$ times the total charge enclosed by the surface. Completely enclosed a volume is known as closed surface.

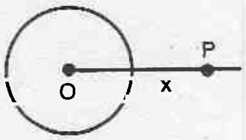
$$\therefore \quad \int_C \vec{\mathbf{E}} \cdot \vec{\mathbf{dS}} = \frac{q}{\varepsilon_0}$$

Application of Gauss's law: Gauss's law is applicable for any distribution of charges and any type of closed surface. But it is easy to solve the problem of high symmetry by using Gauss's law.

(a) Electric field due to uniformly charged conducting sphere (solid or hollow).

Case I: When $x > R$

$$E = \frac{q}{4\pi\varepsilon_0 x^2}$$



Case II: When $x < R$

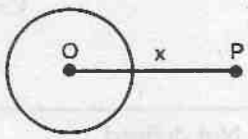
$$E = 0$$

It means electrostatic field inside the conductor is zero.

(b) Electric field due to uniform charged non-conducting sphere.

Case I: When $x > R$

$$E = \frac{q}{4\pi\varepsilon_0 x^2}$$



Case II: When $x < R$

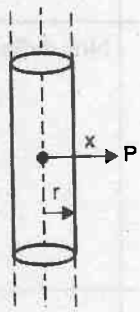
$$E = \frac{\rho x}{3\varepsilon_0}$$

where ρ = cubical charge density $= \frac{3q}{4\pi R^3}$

(c) Electric field due to charged cylindrical conductor of infinite length.

Case I: If point P is outside the cylinder and is radial and perpendicular to the surface $(x > r)$

$$E = \frac{\lambda}{2\pi\varepsilon_0 x}$$



Case II: When $x = r$

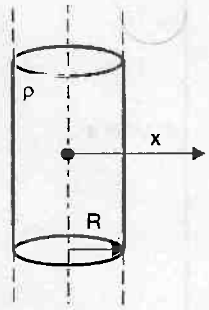
$$E = \frac{\lambda}{2\pi\varepsilon_0 r}$$

Case III: When $(x < r)$, since, electric charge only resides on the surface of conductor, hence, inside the conductor, electric field is zero.

(d) Electric field due to a charged non-conducting solid cylinder of infinite length.

Case I: When $(x < R)$

$$E = \frac{\rho x}{2\varepsilon_0}$$



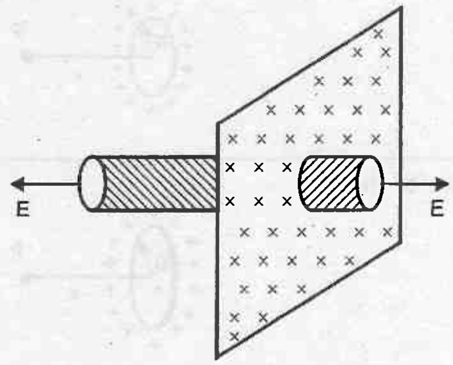
Case II: When $(x = R)$

$$E = \frac{\rho R}{2\varepsilon_0}$$

Case III: When $(x > R)$

$$E = \frac{\rho R^2}{2\varepsilon_0 x}$$

(e) Electric field due to infinite plane sheet of charge.



$$E = \frac{\sigma}{2\varepsilon_0}$$

(f) Electric field due to charged conducting plate, charges resides on both the sides.

$$E = \frac{\sigma}{\varepsilon_0}$$

(g) Relation between electric field and electric potential :

(i) $dV = -\vec{\mathbf{E}} \cdot \vec{\mathbf{dr}}$

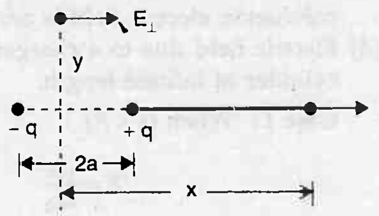
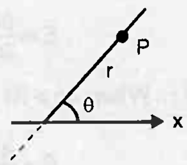
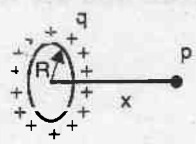
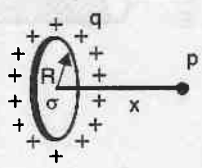
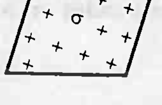
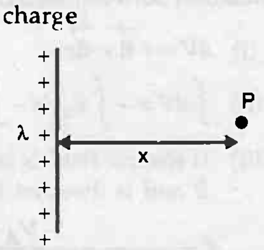
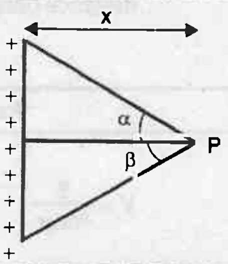
(ii) $\int dV = -\int E_x dx - \int E_y dy - \int E_z dz$

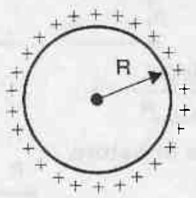
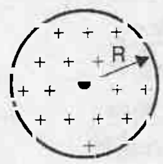
(iii) If electric field is constant between points A and B and is directed from A to B, then

$$E = \frac{V_A - V_B}{\text{distance between points } A \text{ and } B}$$

5. System Potential :

S.No.	System	Potential
1.	Isolated charge 	$V = \frac{q}{4\pi\varepsilon_0 r}$

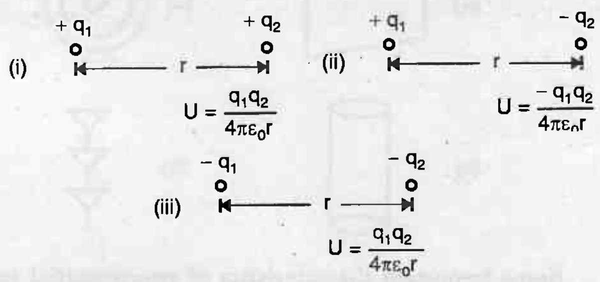
	System	Potential
2.	Dipole  $x, y >> a$ 	$V_{\parallel}=\frac{p}{4\pi\varepsilon_0 x^2}$ $V_\perp = 0$ $V=\frac{p\cos\theta}{4\pi\varepsilon_0 r^2}$
3.	A ring of charge 	$V=\frac{1}{4\pi\varepsilon_0}\frac{q}{\sqrt{R^2+x^2}}$
4.	A disc of charge 	$V=\frac{\sigma}{2\varepsilon_0}[\sqrt{R^2+x^2}-x]$
5.	Infinite sheet of charge 	Not defined
6.	Infinitely long line of charge 	Not defined
7.	Finite line of charge 	$V=\frac{\lambda}{4\pi\varepsilon_0}\ln\left\vert\frac{\sec\beta+\tan\beta}{\sec\alpha-\tan\alpha}\right\vert$

	System	Potential
8.	Charged spherical shell 	(a) Inside $0 < r < R$ $V = \dfrac{q}{4\pi\varepsilon_0 R}$ (b) Outside $r > R$ $V = \dfrac{q}{4\pi\varepsilon_0 r}$
9.	Solid sphere of charge 	(a) Inside $0 \le r \le R$ $V = \dfrac{\rho R^2}{6\varepsilon_0}\left[3 - \dfrac{r^2}{R^2}\right]$ (b) Outside $r > R$ $V = \dfrac{\rho R^3}{3\varepsilon_0}\left[\dfrac{1}{r}\right]$

6. Electric potential energy: A field of force is a region of space at every point of which a particle experiences a force varying regularly from point to point, *e.g.*, electrostatic field. If the electrostatic field at each point of a region of space does not vary in the course of time, such an electrostatic field is known as stationary electrostatic field. In a case of electrostatic stationary field of forces the work performed by these forces between any two points does not depend upon the shape of path but depends only on initial and final position of the points which is referred to as electric potential, while the electrostatic forces themselves are called conservative in nature. From this point of view it is clear that the work done by electrostatic force does not depend upon path but only depends upon initial and final positions.

So, concept of electric potential energy comes into play.

(a) Electrostatic potential energy of a system of two point charges:



(i) $U = \dfrac{q_1 q_2}{4\pi\varepsilon_0 r}$ (ii) $U = \dfrac{-q_1 q_2}{4\pi\varepsilon_0 r}$ (iii) $U = \dfrac{q_1 q_2}{4\pi\varepsilon_0 r}$

(b) Electrostatic potential energy of a system of n point charges:

The number of pairs $= {}^nC_2$

$$U = \frac{1}{4\pi\varepsilon_0}\sum_{\substack{i,j=1\\ i<j}}^{n}\frac{q_i q_j}{r_{ij}}$$

(c) Self potential energy of a conducting sphere:

$$U = \frac{q^2}{8\pi\varepsilon_0 R}$$

(d) Self potential energy of a non-conducting solid sphere:

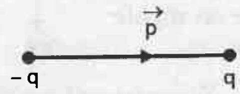
$$U = \frac{4\pi\rho^2 R^5}{15\varepsilon_0}$$

Here, ρ = constant volume charge density

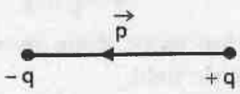
7. Electric dipole or bipole or doublet: The combination of two points charges q of opposite sign separated by a distance $2a$, constitutes an electric dipole. The strength of electric dipole is measured in the form of electric dipole moment $(\vec{p})$.

It is given by $p = q \times 2a$

In physics



In chemistry on the basis of electronegativity.

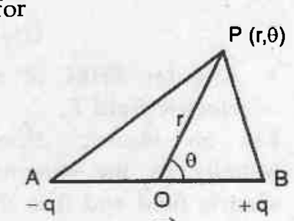


- **Expression for field and potential at a point due to an electric dipole.**

An expression for potential and field at point $P(r, \theta)$ due to a dipole of strength $(p = q \times 2a)$, provided only that the point is not too close to the dipole.

Case I: Expression for potential

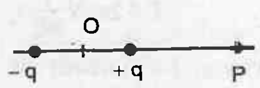
$$V = \frac{p\cos\theta}{4\pi\varepsilon_0 r^2}$$



Situation 1: If point P lies on end on position

$\therefore$ $\theta = 0°$

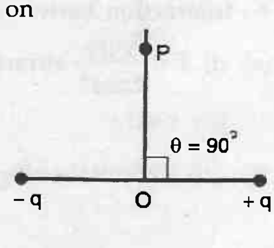
$\therefore$ $V = \dfrac{p}{4\pi\varepsilon_0 r^2}$



Situation 2: If point P lies on broad side on position

$\theta = 90°$

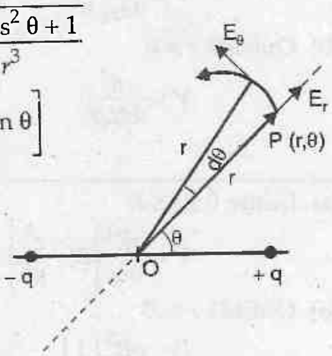
$\therefore$ $V = 0$



Case II : Expression for electric field intensity

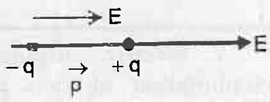
$$|\vec{E}| = \frac{p}{4\pi\varepsilon_0} \frac{\sqrt{3\cos^2\theta + 1}}{r^3}$$

and $\alpha = \tan^{-1}\left[\frac{1}{2}\tan\theta\right]$

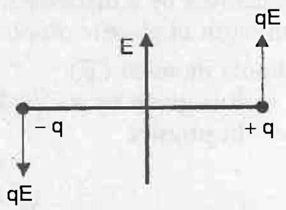


- **Electric dipole in uniform electric field.**

Case I : If electric dipole is placed parallel to electric field, therefore, net force on dipole is zero.



Case II : If electric dipole is placed perpendicular to electric field, in this case net force on dipole will zero but torque on dipole will not be zero.



$$\text{Toque } (\tau) = pE\sin\theta$$

or $$\vec{\tau} = \vec{p} \times \vec{E}$$

- Expression for work done in rotating a dipole in uniform electric field.

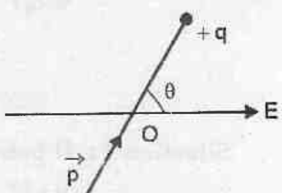
$$W = pE[\cos\theta_1 - \cos\theta_2]$$

- **Potential energy of dipole (U) :** Potential energy of dipole is defined as work done in rotating a dipole from a direction perpendicular to the field to a given direction

$$U = -\vec{p}\cdot\vec{E}$$

- **Angular SHM of an electric dipole in uniform electric field E.**

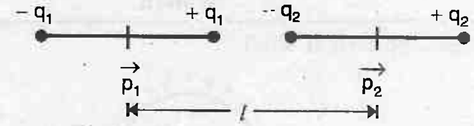
Let an electric dipole is initially in the direction of electric field and it is slightly displaced by an angle θ with this position.



$$\therefore \quad T = 2\pi\sqrt{\frac{I}{pE}}$$

where, I = moment of inertia of dipole about its centre of mass

- **Interaction between two electric dipoles**



(a) (i) $F = \frac{3p_1p_2}{2\pi\varepsilon_0 l^4}$ attractive in nature.

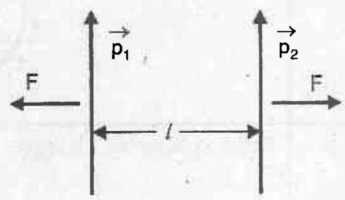
(ii) $\tau = 0$

(iii) Potential energy $(U) = \frac{-p_1p_2}{2\pi\varepsilon_0 l^3}$

(b) (i) $F = \frac{3p_1p_2}{4\pi\varepsilon_0 l^4}$, repulsive in nature.

(ii) $\tau = 0$

(iii) $U = \frac{p_1p_2}{2\pi\varepsilon_0 l^3}$

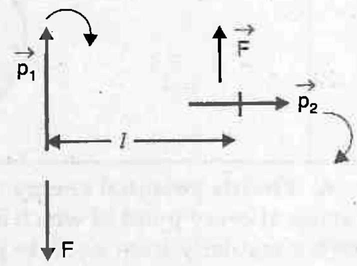


(c) (i) $F = \frac{3p_1p_2}{4\pi\varepsilon_0 l^4}$

(ii) $\tau_1 = \frac{p_1p_2}{2\pi\varepsilon_0 l^3}$, clockwise

$\tau_2 = \frac{p_1p_2}{4\pi\varepsilon_0 l^3}$ clockwise

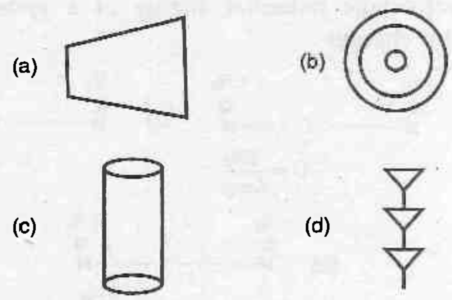
(iii) $U = 0$



8. Equipotential surface : The surface at every point of which has same electric potential, is called equipotential surface. If V is electric potential at any surface defined by $V(x, y, z)$ = constant, is called an equipotential surface.

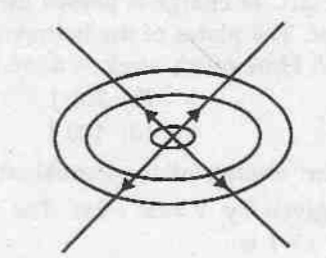
Some types of equipotentials are :

(a) All planes perpendicular to vector $\hat{i} + 2\hat{j} - \hat{k}$.
(b) All spheres with centre at origin.
(c) All right circular cylinders with the z-axis as axis of symmetry.
(d) A family of cones.

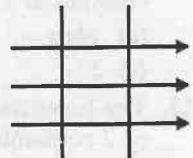


Some important characteristics of equipotential surface :

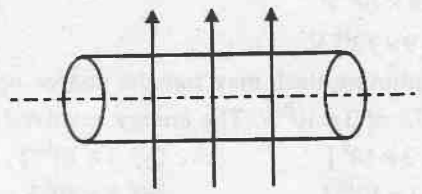
(a) Equipotential surface may be planar, solid etc. But equipotential surface never be a point.
(b) Equipotential surface is single valued. So, equipotential surface never cross each other.
(c) Electric field is always perpendicular to equipotential surface.
(d) Electric lines of force cross equipotential surface perpendicularly.
(e) Work done to move a point charge q between two points on equipotential surface is zero.
(f) The surface of a conductor in equilibrium is equipotential surface.
(g) Equipotential surface due to isolated point charge is spherical.



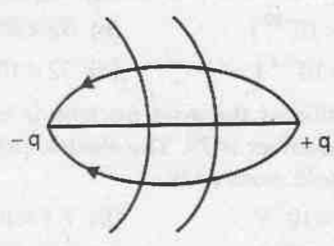
(h) Equipotential surfaces are planar in uniform electric field.



(i) Equipotential surface due to line charge is cylindrical.



(j) Equipotential surface due to an electric dipole is shown in the figure.



Some conceptual points :

(i) At the point where electric field is zero, the direction of electric lines of force become indeterminate. Such a point is known as neutral point or null point or equilibrium point.

(ii) There can be no charge at any point in the substance of the conductor in equilibrium state. It means the charge on a conductor in an electrostatic field resides entirely on the surface of conductor.

(iii) If the electric potential is constant throughout any region in equilibrium, then there can be no electric charge in the substance of the conductor in equilibrium.

(iv) If the normal component of gradient of the electric potential is continuous across any surface, then there can be no charge on the surface.

(v) The electric potential cannot have a maximum or a minimum value at any point in space which is not occupied by an electric charge.

(vi) A free charge cannot be in state of stable equilibrium at a point at which there is no charge.

(vii) If electric potential at any point is maximum, the point must be occupied by a positive charge. If the electric potential is minimum at any point, the point must be occupied by negative charge.

(viii) The electric potential throughout the region bounded by a closed surface containing no charge, is constant.

Objective Questions

Level-1

1. The intensity of electric field due to a proton at a distance of 0.2 nm is :

(a) 3.6×10^{8} NC^{-1}

(b) 3.6×10^{10} NC^{-1}

(c) 3.6×10^{12} NC^{-1}

(d) 3.6×10^{13} NC^{-1}

2. Force acting upon a charged particle, kept between the charged pair of plates is F. If one of the plates is removed, force acting on the same particle will become :

(a) $3F$ (b) $\frac{F}{2}$

(c) F (d) $2F$

3. Two point charges $+4e$ and e are kept at distance x apart. At what distance a charge q must be placed from charge $+e$ so that q is in equilibrium :

(a) $\frac{x}{2}$ (b) $\frac{2x}{3}$

(c) $\frac{x}{3}$ (d) $\frac{x}{6}$

4. Two concentric metallic spheres of radii r_1 and r_2 $(r_1 > r_2)$ contain charges Q_1 and Q_2 respectively, then the potential at a distance x between r_1 and r_2 will be :

$\left(K = \frac{1}{4\pi\epsilon_0}\right)$

(a) $K\left(\frac{Q_1 + Q_2}{x}\right)$ (b) $K\left(\frac{Q_1}{x} + \frac{Q_2}{r_2}\right)$

(c) $K\left(\frac{Q_2}{x} + \frac{Q_1}{r_1}\right)$ (d) $K\left(\frac{Q_1}{r_1} + \frac{Q_2}{r_2}\right)$

5. A charge $q = 8.75\ \mu$C in an electric field is acted upon by a force $F = 4.5$ N, the potential gradient at this point is :

(a) 3.70×10^{5} Vm^{-1}

(b) 5.14×10^{3} Vm^{-1}

(c) 5.14×10^{4} Vm^{-1}

(d) 5.14×10^{5} Vm^{-1}

6. A ring made of wire with a radius of 10 cm is charged negatively and carries a charge of -5×10^{-9} C. The distance from the centre to the point on the axis of the ring where the intensity of the electric field is maximum, will be :
(a) 0.71 m
(b) 7.1×10^{-2} m
(c) 7.1×10^{-3} m
(d) 1.7×10^{-2} m

7. A hollow sphere of charge does not produce electric field at any :
(a) interior point
(b) outer point
(c) beyond 2m
(d) beyond 10 cm

8. The radius of hollow metallic sphere is r. If the potential difference between its surface and a point at a distance $3r$ from its centre is V, then the electric field intensity at a distance of $3r$ from its centre is :
(a) $\frac{V}{2r}$ (b) $\frac{V}{3r}$
(c) $\frac{V}{4r}$ (d) $\frac{V}{6r}$

9. The work done in moving an alpha particle between two points of potential difference 25 V will be :
(a) 8×10^{-18} J (b) 8×10^{-19} J
(c) 8×10^{-20} J (d) 8×10^{-16} J

10. The work done to transport 20 C charge from points A to another point B over distance of 0.2 m is 2 joule, the potential difference across AB is :
(a) 2×10^{-2} V (b) 4×10^{-1} V
(c) 1×10^{-1} V (d) 8 V

11. A ball of mass 1 g and charge 10^{-8} C moves from point A whose potential is 600 V to the point B whose potential is zero volt. If velocity of the ball at B is 20 ms^{-1}, what is its velocity at A ?
(a) 0.17 ms^{-1}
(b) 0.27 ms^{-1}
(c) 0.37 ms^{-1}
(d) 0.07 ms^{-1}

12. Point charges of 3×10^{-9} C are situated at each of three corners of a square, whose side is 15 cm. The magnitude and direction of the electric field at the vacant corner of the square are :
(a) 2296 V/m along the diagonal
(b) 9622 V/m along the diagonal
(c) 22.0 V/m along the diagonal
(d) zero

13. In a circuit 20 C of charge is passed through a battery in a given time. The plates of the battery are maintained at P.D. of 20 V. How much work is done by the battery ?
(a) 400 J (b) 300 J
(c) 200 J (d) 100 J

14. Suppose the electrostatic potential at some points in space are given by $V=(x^2-2x)$. The electrostatic field strength at $x=1$ is :
(a) zero (b) -2
(c) 2 (d) 4

15. The potential of a sphere of radius 2 cm when a charge of 2 coulomb is given to it, will be :
(a) 9×10^{3} V
(b) 9×10^{11} V
(c) 9×10^{6} V
(d) 9×10^{16} V

16. A lightning flash may transfer charge upto 50 C through a P.D. of 2×10^{8} V. The energy involved is :
(a) 3×10^{9} J (b) 3×10^{12} J
(c) 1×10^{10} J (d) 2×10^{6} J

17. A proton is moved between two points whose potential difference is 20 V. The energy acquired by the proton is :
(a) 32×10^{-19} J (b) 32×10^{-16} J
(c) 32×10^{-14} J (d) 32×10^{-13} J

18. The radius of the gold nucleus is 6.6×10^{-15} m and the atomic number is 79. The electric potential at the surface of the gold nucleus is :
(a) 1.7×10^{-7} V (b) 7.1×10^{-7} V
(c) 1.7×10^{7} V (d) 7.1×10^{7} V

19. The dielectric constant K of an insulator can be :
(a) ∞ (b) zero
(c) -2 (d) 6

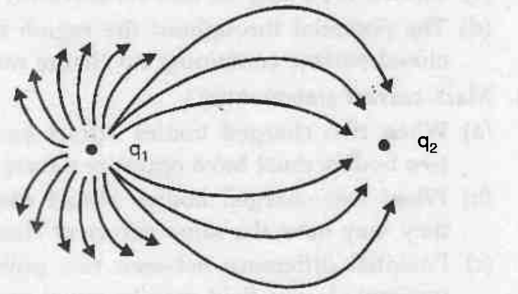
20. A solid metal sphere of radius 50 cm carries a charge 25×10^{-10} C. The electrostatic potential at a distance of 20 cm from the centre will be :
(a) 25 V (b) 15 V
(c) 35 V (d) 45 V

21. Two charges of $-10\,\mu$C and $30\,\mu$C are separated by 30 cm. The ratio of the forces acting on them will be :
(a) 1 : 1 (b) 1 : 2
(c) 2 : 1 (d) 1 : 4

22. An alpha particle is made to move in a circular path of radius 20 cm around another alpha particle, the work done is :
(a) 8×10^{-18} J (b) 8×10^{-19} J
(c) 8×10^{-20} J (d) zero

Level-2

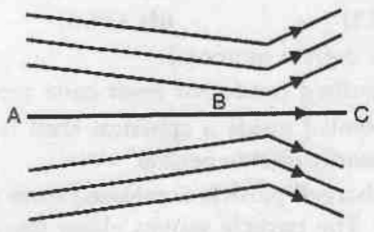
1. Determine the ratio q_1/q_2. As lines of forces of two point charges are shown in figure :



(a) $\frac{q_1}{q_2}=4$ (b) $\frac{q_1}{q_2}=3$

(c) $\frac{q_1}{q_2}=2$ (d) $\frac{q_1}{q_2}=1$

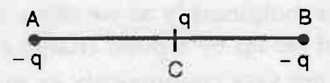
2. In the given figure, electric lines of force diagram is shown. Then :

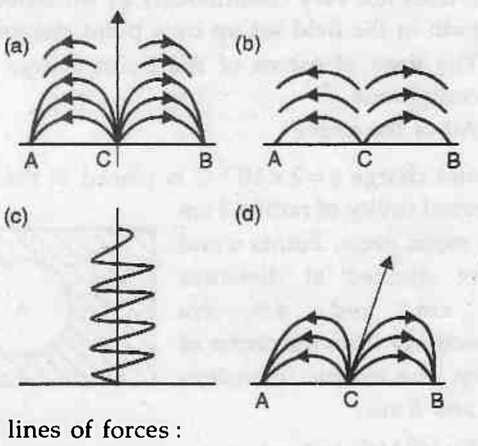


(a) $E_A=E_B=E_C$ (b) $E_A>E_B>E_C$

(c) $E_C>E_B$ (d) $E_A<E_B$

3. In the given arrangement of charges :





4. Electric lines of forces :
(a) may form closed path
(b) must form closed path
(c) may be discontinuous
(d) both (a) and (c) are correct

5. If a point charge $+q$ of mass m is released from rest in a region where only electric field is present then :
(a) it follows a line of force
(b) it must follow a line of force, if electric field is uniform
(c) it may follow a line of force, if field is uniform
(d) none of the above

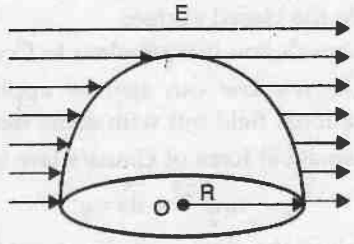
6. If $E=0$, at all points of a closed surface :
(a) the electric flux through the surface is zero
(b) the total charge enclosed by the surface is zero
(c) no charge resides on the surface
(d) all of the above

7. Flux coming out from a positive unit charge placed in air, is :

(a) ε_0 (b) ε_0^{-1}

(c) $(4\pi\varepsilon_0)^{-1}$ (d) $4\pi\varepsilon_0$

8. In a region of uniform electric field E, a hemispherical body is placed in such a way that field is parallel to its base (as shown in figure). The flux linked with the curved surface is :



(a) zero (b) $-\pi R^2E$

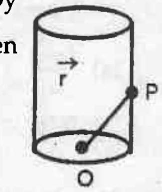
(c) πR^2E (d) $\frac{\pi R^2}{2}E$

9. A surface $S=10\hat{j}$ is kept in an electric field. $E=2\hat{i}+4\hat{j}+7\hat{k}$. How much electric flux will come out through the surface ?

(a) 40 unit (b) 50 unit

(c) 30 unit (d) 20 unit

10. Electric field at point P is given by $\vec{E}=\vec{r}E_0$. The total flux through the given cylinder of radius R and height h is :



(a) $E_0\pi R^2h$ (b) $2E_0\pi R^2h$

(c) $3E_0\pi R^2h$ (d) $4E_0\pi R^2h$

11. A point charge Q is placed at the centre of a hemisphere. The electric flux passing through flat surface of hemisphere is :

(a) $\frac{Q}{\varepsilon_0}$

(b) zero

(c) $\frac{Q}{2\varepsilon_0}$

(d) none of these

12. A point charge Q is placed at the centre of a hemisphere. The ratio of electric flux passing through curved surface and plane surface of the hemisphere is :
(a) $1:1$ (b) $1:2$
(c) $2\pi:1$ (d) $4\pi:1$

13. What should be the flux linked with one face of a cube, if a point charge q is placed at one corner of a cube ?
(a) $\frac{q}{\varepsilon_0}$ (b) $\frac{q}{2\varepsilon_0}$
(c) $\frac{q}{3\varepsilon_0}$ (d) $\frac{q}{8\varepsilon_0}$

14. In electrostatics, the Gauss's law is true, when the charges enclosed in the Gaussian surface are :
(a) moving only (b) stationary only
(c) moving or stationary (d) none of these

15. Select the wrong statement :
(a) The electric field calculated by Gauss's law is the field due to the charges inside the Gaussian surface
(b) The electric field calculated by Gauss's law is the resultant field due to all the charges inside and outside the closed surface
(c) The Gauss's law is equivalent to Coulomb's law
(d) The Gauss's law can also be applied to calculate gravitational field but with some modifications

16. The mathematical form of Gauss's law is

$$\varepsilon_0 \oint \vec{E} \cdot \vec{ds} = q$$

Then which of the statements is correct ?
(a) E depends on the charge q which is enclosed within the Gaussian surface only
(b) E depends on the charge which is inside and outside the Gaussian surface
(c) E does not depend on the magnitude of charge q
(d) All of the above

17. The electric field in a region is given by $E = \alpha x \hat{i}$, where α = constant of proper dimensions. What should be the charge contained inside a cube bounded by the surface, $x = l, x = 2l, y = 0, y = l, z = 0, z = l$?
(a) $\frac{\varepsilon_0 l^3}{\alpha}$ (b) $\alpha \varepsilon_0 l^3$
(c) $\frac{\alpha \varepsilon_0}{l^3}$ (d) $2\alpha \varepsilon_0 l^3$

18. The electric flux passing through the sphere, if an electric dipole is placed at the centre of a sphere, is :
(a) $\frac{1}{\varepsilon_0}$ (b) $\frac{2}{\varepsilon_0}$
(c) zero (d) none of these

19. If a space has no electric charge, then :
(a) at any point in the space, potential is maximum
(b) at any point in the space, potential is minimum
(c) at only one point in the space, potential is maximum
(d) at any point in the space, potential is neither maximum nor minimum

20. Mark the correct option(s) :
(a) Electric field must be conservative
(b) Electric field must be non-conservative
(c) Electric field may be non-conservative
(d) The potential throughout the region bounded by a closed surface containing no charge may be variable

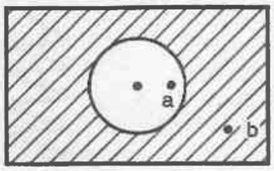
21. Mark correct statement(s) :
(a) When two charged bodies attract each other, then two bodies must have opposite nature of charges
(b) When two charged bodies attract each other, then they may have the same nature of charge
(c) Potential difference between two points lying in a uniform electric field may be equal to zero
(d) Both (b) and (c) are correct

22. A Na^+ ion is moving through an evacuated vessel in the positive x-direction with speed of 10^7 m/s. At $x = 0, y = 0$ it enters an electric field of 500 V/cm in the positive x-direction. Its position (x, y) after 10^{-6} s is :
(a) (10, 5) (b) (1, 0.4)
(c) (10, 0.1) (d) (10, 8)

23. Mark the correct option(s) :
(a) An earthed conductor must have zero charge
(b) If potential inside a spherical shell is zero, then it is necessarily electric neutral
(c) If a charged particle is released from rest in a electric field. The particle moves along the electric lines of force
(d) None of the above

24. Mark the correct option(s) :
(a) E varies continuously as we move along any path in the field set-up by a point charge q
(b) E does not vary continuously as we move along any path in the field set up by a point charge q
(c) The lines of forces of the point charge q must be continuous
(d) All of the above

25. A point charge $q = 2 \times 10^{-7}$ C is placed at the centre of a spherical cavity of radius 3 cm in a metal piece. Points a and b are situated at distances 1.5 cm and 4.5 cm respectively from the centre of cavity. The electric intensities at a and b are :



(a) 8×10^6 N/C and zero
(b) zero and zero
(c) zero and 8.9×10^5 N/C
(d) none of the above

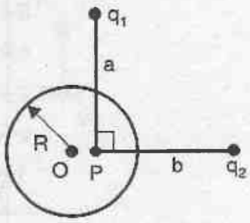
26. In the given figure, two point charges q_1 and q_2 are placed at distance a and b from centre of a metallic sphere having charge Q. The electric field due to the metallic sphere at the point P is :

(a) $\frac{1}{4\pi\varepsilon_0}\sqrt{\left(\frac{q_1}{a^2}\right)^2+\left(\frac{q_2}{b^2}\right)^2}$

(b) $\frac{1}{4\pi\varepsilon_0}\frac{Q}{R^2}$

(c) $\frac{1}{4\pi\varepsilon_0}\sqrt{\left(\frac{Q}{R^2}\right)^2+\left(\frac{q_1}{a^2}+\frac{q_2}{b^2}\right)^2}$

(d) none of the above



27. The minimum surface density of charge on the plate, so that a body of mass 2 kg/m^2 may just be lifted, is :

(a) 2.84×10^{-5} C/m^2 (b) 2.25×10^{-5} C/m^2
(c) 1.86×10^{-5} C/m^2 (d) none of these

28. The surface density of electric charge at a place on the earth's surface where the rate of fall of potential is 250 V, is :

(a) 2.0×10^{-9} C/m^2 (b) 2.21×10^{-9} C/m^2
(c) 3.36×10^{-9} C/m^2 (d) 3.5×10^{-9} C/m^2

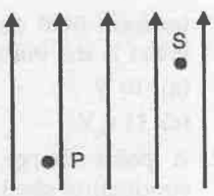
29. Which is independent of the medium ?

(a) Electric intensity (b) Electric potential
(c) Electric displacement (d) None of the above

30. If r and T are radius and surface tension of a spherical bubble respectively, the charge needed to double the radius of bubble is :

(a) $4\pi r\,[\varepsilon_0 r\,(7Pr+12T)]^{1/2}$
(b) $8\pi r\,[\varepsilon_0 r\,(7Pr+12T)]^{1/2}$
(c) $2\pi r\,[\varepsilon_0 r\,(7Pr+12T)]^{1/2}$
(d) $\pi r\,[\varepsilon_0 r\,(7Pr-12T)]^{1/2}$

31. P and S are two points in a uniform electric field E shown in the figure. If the potential at P and S are denoted by V_P and V_S then :



(a) $V_P > V_S$
(b) $V_P < V_S$
(c) $V_P = V_S$
(d) $V_P > V_S > 0$

32. An external agent pulls a unit positive charge from infinity to a point, then the potential of that point is :

(a) positive
(b) negative
(c) may be positive or may be negative
(d) zero

33. In the direction of electric field, electric potential :

(a) decreases (b) increases
(c) remains constant (d) none of these

34. If potential difference is applied between the ends of the conductor, then :

(a) electric lines of force are not present inside the conductor
(b) electric lines of force must be present inside the conductor
(c) the electric field inside the conductor may be non-conservative in the nature
(d) the electric field inside the conductor must be non-conservative in the nature

35. If potential at a point is maximum, then :

(a) the point must be occupied by a negative charge
(b) the point may be occupied by a negative charge
(c) the point must be occupied by a positive charge
(d) the point may be occupied by a positive charge

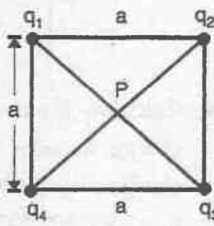
36. A free charge is placed at a point at which there is no charge, then :

(a) the charge must be in stable equilibrium
(b) the charge may be in stable equilibrium
(c) the charge must not be in stable equilibrium
(d) the potential energy of the charge is minimum

37. If the potential at each point on a conductor is same to each other, then :

(a) electric lines of force may begin or end on the same conductor
(b) no electric lines of force can begin or end on the same conductor
(c) the electric field inside the conductor may be non-zero
(d) none of the above

38. Four point charges q_1, q_2, q_3 and q_4 are placed at the corners of the square of side a, as shown in figure. The potential at the centre of the square is : (Given: $q_1 = 1 \times 10^{-8}$ C, $q_2 = -2 \times 10^{-8}$ C, $q_3 = 3 \times 10^{-8}$ C, $q_4 = 2 \times 10^{-8}$ C, $a = 1$ m)

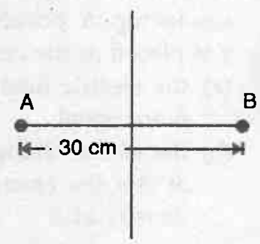


(a) 507 V (b) 607 V
(c) 550 V (d) 650 V

39. Over a thin ring of radius R a charge q is distributed non-uniformly. The work done of the force field in displacing a point charge q' from centre of the ring to infinity is :

(a) $\frac{qq'}{4\pi\varepsilon_0 R}$ (b) $\frac{qq'}{2\pi\varepsilon_0 R}$
(c) $\frac{qq'}{\pi\varepsilon_0 R}$ (d) none of these

40. As shown in the figure two point charges of equal magnitude Q but of opposite nature are placed at A and B (30 cm apart). A point charge placed on right bisector of line AB will be in :

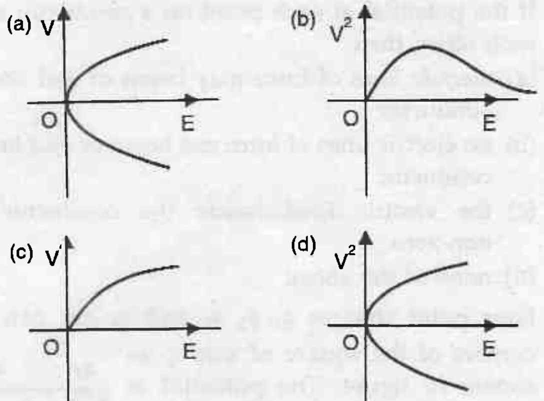


(a) dynamic equilibrium
(b) neutral equilibrium
(c) unstable equilibrium
(d) none of the above

41. Mark for right option :
(a) A given conducting sphere can be charged to any extent
(b) A given conducting sphere cannot be charged to a potential greater than a certain value
(c) A given conducting sphere cannot be charged to a potential less than a certain minimum value
(d) none of the above

42. Two drops of water each with a charge of 3×10^{-7} C having surface potential 500 V form a single drop. What is the surface potential of the new drop ?
(a) 794 V (b) 1000 V
(c) 250 V (d) 750 V

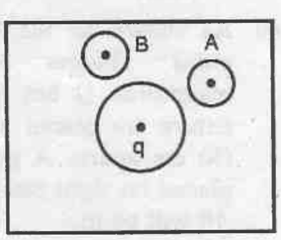
43. If at distance r from a positively charged particle, electric field strength and potential are E and V respectively, which of the following graphs is/are correct ?



44. Calculate the earth's potential. Assume earth has a surface charge density of 1 electron/m^2: (Given: the electronic charge $= -1.6 \times 10^{-19}$ C, Earth's radius $= 6.4 \times 10^6$ m, $\varepsilon_0 = 8.9 \times 10^{-12}$ C^2/Nm^2)
(a) -0.115 V (b) 0.215 V
(c) -0.225 V (d) 0.185 V

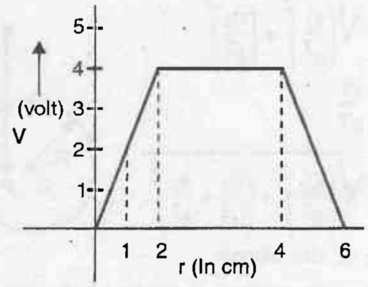
45. Four charges, all of the same magnitude are placed at the four corners of a square. At the centre of the square, the potential is V and the field is E. By suitable choices of the signs of the four charges, which of the following can be obtained ?
(a) $V = 0, E = 0$ (b) $V = 0, E \neq 0$
(c) $V \neq 0, E = 0$ (d) None of these

46. A circular cavity is made in a conductor. A positive charge q is placed at the centre



(a) the electric field at A and B are equal
(b) the electric charge density at A = the electric charge density at B
(c) potential at A and B are equal
(d) all of the above

47. The variation of potential with distance R from fixed point is shown in figure. The electric field at $R = 5$ cm is :



(a) 2.5 V/cm (b) 2 V/cm
(c) -2.5 V/cm (d) 2/5 V/cm

48. If two electric charges q and $-2q$ are placed at a distance $6a$ apart, then the locus of point in the plane of charge, where the field potential is zero, is :
(a) $x^2 + 2y^2 - 4ax - 12a^2 = 0$
(b) $2x^2 + y^2 + 4ax - 12a^2 = 0$
(c) $x^2 + y^2 + 4ax - 12a^2 = 0$
(d) $x^2 + y^2 + 8ax + 12a^2 = 0$

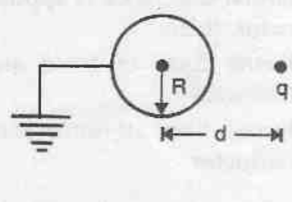
49. Two fixed charges $-2q$ and q are located at the points equidistant on the x-axis from the origin on either sides. The locus of points of equipotential lying in x-y plane is :
(a) straight line (b) circle
(c) hyperbola (d) parabola

50. Four identical charges are placed at the points (1, 0, 0), (0, 1, 0), (– 1, 0, 0) and (0, – 1, 0) :
(a) The potential at the origin is zero
(b) The field at the origin is zero
(c) The potential at all points on the z-axis, other than the origin, is zero
(d) none of the above

51. An electron is released from rest at one point in a uniform field and moves a distance of 10 cm in 10^{-7} s. What is the voltage between the points ?
(a) 10 V (b) 7 V
(c) 11.4 V (d) 8 V

52. A point charge q is placed at the centre of neutral conducting shell. Then :
(a) the electric potential of the point charge q outside the shell is zero
(b) the electric potential of the point charge outside the shell will be inversely proportional to the distance
(c) the electric field of the point charge outside the shell will be inversely proportional to the square of distance
(d) the electric field outside the shell will be depend on the position of the q inside the shell

53. In the shown figure, the charge appears on the sphere is :
(a) q
(b) $\frac{qd}{r}$
(c) $-\frac{qr}{d}$
(d) 0



54. In a region, an electric field $\vec{E} = E_0 \hat{i}$ is present. The potential of points $A(a, 0, 0)$, $B(0, b, 0)$, $C(0, 0, c)$ and $D(-a, 0, 0)$ are V_A, V_B, V_C and V_D respectively, then :
(a) $V_A = V_B = V_C = V_D$ (b) $V_B = V_C$
(c) $V_D < V_B < V_A$ (d) none of these

55. At the eight corners of a cube of side 10 cm, equal charges each of value 10 C are placed. The potential at the centre of the cube is :
(a) 83.14×10^{11} V (b) 16.62×10^{11} V
(c) 1.66×10^{11} V (d) 1662.7×10^{11} V

56. The work required to bring a unit positive charge from infinity to a mid-point between two charges 20 μC and 10 μC separated by a distance of 50 m, is :
(a) 10.8×10^4 J (b) 10.8×10^3 J
(c) 1.08×10^6 J (d) 0.54×10^5 J

57. If V_0 is the potential at the origin in an electric field $\vec{E} = E_x \hat{i} + E_y \hat{j}$, the potential at the point (x, y) is :
(a) $V_0 - xE_x - yE_y$
(b) $V_0 + xE_x + yE_y$
(c) $xE_x + yE_y - V_0$
(d) $(\sqrt{x^2 + y^2})(\sqrt{E_x^2 + E_y^2}) - V_0$

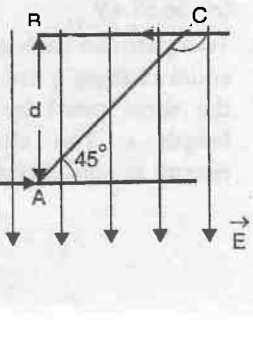
58. The potential difference V_{AB} between $A(0, 0, 0)$ and $B(1, 1, 0)$ in an electric field $\vec{E} = x\hat{i} + z\hat{k}$, is :
(a) 1 V (b) $\frac{3}{2}$ V
(c) $\frac{1}{2}$ V (d) 2 V

59. In a region the electric potential is given by
$$V = 2x + 2y - 3z$$
obtain the expression for electric field :
(a) $-2\hat{i} - 2\hat{j} + 3\hat{k}$ (b) $3\hat{i} + 4\hat{j} - 2\hat{k}$
(c) $2\hat{i} - 2\hat{j} - 3\hat{k}$ (d) none of these

60. Electric field in a plane varies like $(2x\hat{i} + 2y\hat{j})$ N/C. If potential at infinity is taken as zero, potential at $x = 2$ m, $y = 2$ m is :
(a) 8 V (b) -8 V
(c) zero (d) infinity

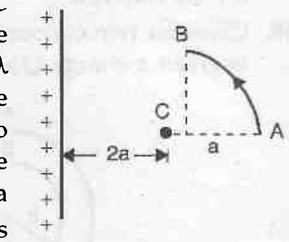
61. Two charges $+q$ and $-3q$ are placed at a distance of 1 m apart. The points on the line joining two charges, where electric potential is zero, is :
(a) 0.25 m, 0.5 m (b) 1 cm, 0.50 m
(c) 0.35 cm, 24 cm (d) none of these

62. Assume if a test charge q_0 is moved without acceleration from A to B over the path shown in figure, then the potential difference between points A and B is :
(a) $2Ed$
(b) Ed
(c) $Ed/2$
(d) $3Ed$



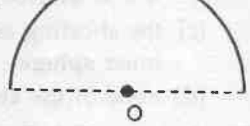
63. Two points are at distance r_1 and r_2 $(r_1 < r_2)$ from a long string having charge per unit length σ. The potential difference between the points is proportional to :
(a) σ (b) $\log\left(\frac{r_2}{r_1}\right)$
(c) $1/\sigma$ (d) r_2/r_1

64. The arc AB with the centre C and the infinitely long wire having linear charge density λ are lying in the same plane. The minimum amount of work to be done to move a point charge q_0 from point A to B through a circular path AB of radius a is equal to :



(a) $\frac{q_0^2}{2\pi\varepsilon_0} \ln\left(\frac{2}{3}\right)$ (b) $\frac{q_0 \lambda}{2\pi\varepsilon_0} \ln\left(\frac{3}{2}\right)$
(c) $\frac{q_0 \lambda}{2\pi\varepsilon_0} \ln\left(\frac{2}{3}\right)$ (d) $\frac{q_0 \lambda}{\sqrt{2}\pi\varepsilon_0}$

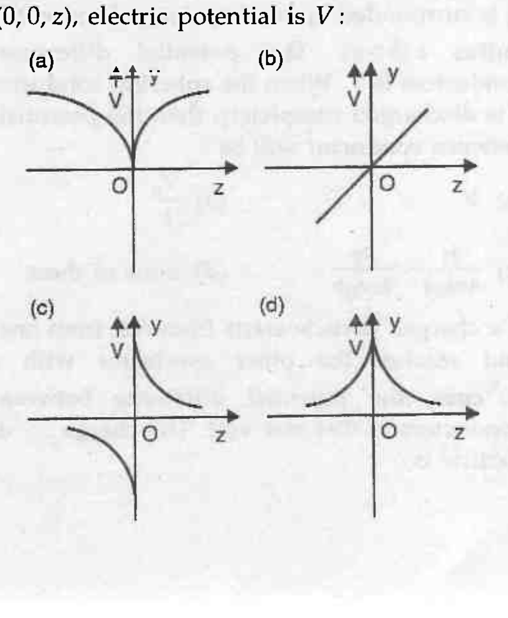
65. A semicircular wire of radius a having λ as charge per unit length is shown in the figure. The electric potential at the centre of the semicircular wire is :



(a) λ/ε_0 (b) $\lambda/4\pi\varepsilon_0 R$
(c) $\lambda/4\varepsilon_0$ (d) none of these

66. A charge $+Q$ is uniformly distributed over a thin ring of the radius R. The velocity of an electron at the moment when it passes through the centre O of the ring, if the electron was initially at rest at a point A which is very far always from the centre and on the axis of the ring is :
(a) $\sqrt{\left(\frac{2KQe}{mR}\right)}$ (b) $\sqrt{\left(\frac{KQe}{m}\right)}$
(c) $\sqrt{\left(\frac{Kme}{QR}\right)}$ (d) $\sqrt{\left(\frac{KQe}{mR}\right)}$

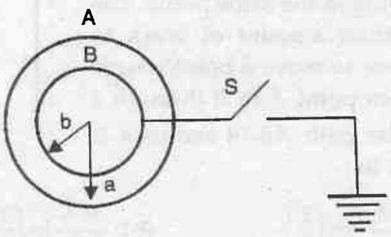
67. Select the appropriate graph for a circular ring placed in x-y plane with centre at origin of coordinate system. The ring carries a uniformly distributed positive charge at a point $(0, 0, z)$, electric potential is V :



68. If a charged particle starts from rest from one conductor and reaches the other conductor with a velocity of 10^9 cm/s, then the potential difference between the two conductors is: [The mass of the charged particle is 9×10^{-28} g and the charge is 4.8×10^{-10} esu]

(a) 0.94 stat volt (b) 1 stat volt
(c) 1.2 stat volt (d) 0.2 stat volt

69. Consider two concentric metal spheres. The outer sphere is given a charge $Q > 0$, then:



(a) the inner sphere will be polarized due to field of the charge Q
(b) the electrons will flow from inner sphere to the earth if S is shorted
(c) the shorting of S will produce a charge of $-Q$ on the inner sphere
(d) none of the above

70. A charge Q is uniformly distributed over the surface of two conducting concentric spheres of radii R and $r\ (R > r)$. Then potential at common centre of these spheres is:

(a) $\frac{kQ(R+r)}{Rr}$ (b) $\frac{kQ(R+r)}{(R^2+r^2)}$
(c) $\frac{kQ}{\sqrt{R^2+r^2}}$ (d) $kQ\left(\frac{1}{R}-\frac{1}{r}\right)$

71. Three concentric spherical metallic shells A, B and C of radii a, b and c $(a < b < c)$ have charge densities σ, $-\sigma$ and σ respectively. If the shells A and C are at same potential, then the relation between a, b and c is:

(a) $a+b+c=0$ (b) $a+c=b$
(c) $a+b=c$ (d) $a=b+c$

72. A charged spherical conductor of radius a and charge q_1 is surrounded by another charged concentric sphere of radius $b\ (b > a)$. The potential difference between conductors is V. When the spherical conductor of radius b is discharged completely, then the potential difference between conductor will be:

(a) V (b) $\frac{Va}{b}$
(c) $\frac{q_1}{4\pi\varepsilon_0 a} - \frac{q_2}{4\pi\varepsilon_0 b}$ (d) none of these

73. If a charged particle starts from rest from one conductor and reaches the other conductor with a velocity 10^9 cm/s, the potential difference between the two conductors is 0.94 stat volt. The charge of the charged particle is:
(Given: mass of charged particle $= 9 \times 10^{-28}$ g)

(a) 5.8×10^{-10} esu (b) 4.8×10^{-10} esu
(c) 3.8×10^{-10} esu (d) 2.75×10^{-10} esu

74. Two identical metal balls are charged, one with potential V_1 and other with potential V_2. The radius of each ball is r and are $a\ (a >> r)$ distance apart. The charges q_1 and q_2 on these balls in CGS are:

(a) $q_1 = \frac{rV_2 + aV_1}{r^2 + a^2}$, $q_2 = \frac{rV_1 + V_2 a}{r^2 + a^2}$
(b) $q_1 = \frac{(rV_2 - aV_1)\, ra}{r^2 - a^2}$, $q_2 = \frac{(rV_1 - aV_2)\, ra}{(r^2 - a^2)}$
(c) $q_1 = \frac{aV_2}{(r^2 - a^2)}$, $q_2 = \frac{rV_1}{(r^2 - a^2)}$
(d) $q_1 = \frac{rV_1}{(r^2 - a^2)}$, $q_2 = \frac{rV_2}{(r^2 - a^2)}$

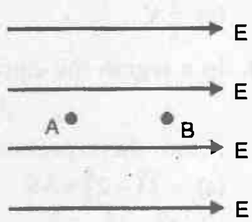
75. The potential of the big drop, if eight charged water drops each with a radius of 1 mm and a charge of 10^{-10} C merge into a single drop, is:

(a) 3200 V (b) 4000 V
(c) 3600 V (d) 4200 V

76. A charge $q = 2\ \mu$C is moved by some external force from infinity to a point where electric potential is 10^4 V. The work done by external force is:

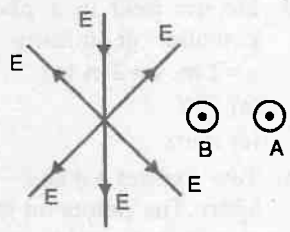
(a) 1×10^{-2} J (b) 2×10^{-2} J
(c) 0.2×10^{-2} J (d) 12×10^{-2} J

77. In the shown electric field, a positive charge is moved from point A to point B. Its potential energy:



(a) increases
(b) decreases
(c) remains constant
(d) none of these

78. In the shown electric field, a positive charge is moved from A to B. Its potential energy:

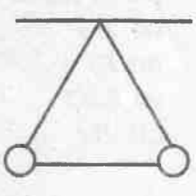


(a) decreases
(b) increases
(c) becomes equal to zero
(d) remain same

79. The electric potential energy of electron-proton system of hydrogen atom is: (Given: The radius of electron orbit $= 0.53$ Å, electronic charge $= 1.6 \times 10^{-19}$ C)

(a) -27.17 eV (b) -20.18 eV
(c) 36.55 eV (d) none of these

80. Two particles each of mass m having equal charges q are suspended from the same point by strings each of length a. The electrical potential energy at equilibrium position is:



(For calculation simplicity, assume that the equilibrium separation between charges $x << a$)

(a) $\dfrac{q^2\left(\dfrac{q^2 a}{2\pi\varepsilon_0 mg}\right)^{-1/3}}{4\pi\varepsilon_0}$ (b) $\dfrac{q^2}{4\pi\varepsilon_0 a}$

(c) $\dfrac{q^2}{4\pi\varepsilon_0 a^2}$ (d) none of these

81. Three charges Q, $2Q$, $8Q$ are to be placed on a line whose length is R metre. Locate the positions where these charges should be placed such that the potential energy of the system is minimum :

(a) $\dfrac{R}{3}$ (b) $\dfrac{3R}{3}$

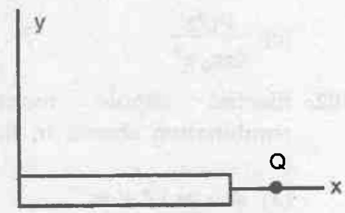
(c) $\dfrac{3R}{2}$ (d) $\dfrac{4R}{3}$

82. There is an infinite straight chain of alternating charges $+q$ and $-q$. The distance between neighbouring charges is a. The interaction energy of each charge with all the others will be :

(a) $-\dfrac{2\ln 2}{4\pi\varepsilon_0}\dfrac{q^2}{a}$ (b) $\dfrac{-2q^2}{4\pi\varepsilon_0 a}$

(c) $\dfrac{-2q\ln 2}{4\pi\varepsilon_0 a}$ (d) $\dfrac{-2q^2}{4\pi\varepsilon_0 a}$

***83.** A thin uniformly charged rod having charge $q = 2$ C and length $L = 2$ m is placed along the x-axis as such its one end is at the origin of co-ordinate system. A point charge $Q = 10^{-9}$ C is placed at the point (4, 0, 0). Find the electrostatic potential energy of this system :



(a) $9\ln 2$ joule (b) 10 joule

(c) $10\ln 2$ joule (d) none of these

84. The charge in electric potential energy of a positive test charge q_0 when it is displaced in a uniform electric field $\vec{E} = E_0\hat{j}$, from $y_i = a$ to $y_f = 2a$ along the y-axis, is :

(a) $-q_0E_0a$ (b) $-2q_0E_0a$

(c) $-3q_0E_0a$ (d) none of these

85. Two identical particles has mass m, charge q. Initially first particle is at rest and the second particle is projected towards first particle with a velocity of 'v' from infinite. Distance of minimum approach is :

(a) $\dfrac{4kq^2}{mv^2}$ (b) $\dfrac{2kq^2}{mv^2}$

(c) $\dfrac{kq^2}{mv^2}$ (d) zero

86. Two small balls of mass m bearing a charge q each one connected by a non-conducting thread of length $2l$. At a certain instant the middle of the thread starts moving at a constant velocity v perpendicular to the direction of the thread at the initial instant. The minimum distance between the balls will be :

(a) $\left(\dfrac{2lq}{q^2+4\pi\varepsilon_0 mv^2 l}\right)$ (b) $\left(\dfrac{2lq^2}{q^2+8\pi\varepsilon_0 mv^2 l}\right)$

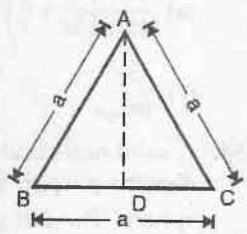
(c) $\left(\dfrac{2lq^2}{q^2+\pi\varepsilon_0 mv^2 l}\right)$ (d) $\left(\dfrac{2lq^2}{q^2+2\pi\varepsilon_0 mv^2 l}\right)$

87. A particle of mass 2 g and charge 1 μC is held at rest on a frictionless horizontal surface at a distance of 1 m from a fixed charge 1 mC. If the particle is released, it will be repelled. The speed of the particle when it is at a distance of 10 m from the fixed charge is :

(a) 100 m/s (b) 90 m/s

(c) 60 m/s (d) 45 m/s

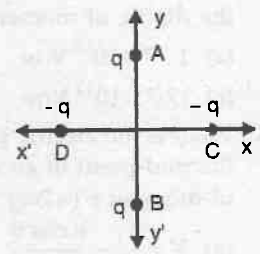
88. At the corners of an equilateral triangle of side a (= 1 metre), three point charges are placed (each of 0.1 C). If this system is supplied energy at the rate of 1 kW, then the time required to move one of charges to the mid-point of the line joining the other two is :



(a) 50 hour (b) 60 hour

(c) 48 hour (d) 54 hour

89. Four point charges are arranged as shown in figure. The point A, B, C and D are lying on a circle of radius a having centre at the origin. What is the energy needed to compose such an arrangement of charges from infinity ?



(a) $\dfrac{q^2}{4\pi\varepsilon_0 a}(1-2\sqrt{2})$

(b) $\dfrac{\sqrt{2}q^2}{4\pi\varepsilon_0 a}$

(c) $\dfrac{q^2}{4\pi\varepsilon_0 a}(2\sqrt{2}-1)$

(d) None of the above

90. If Q charge is given to a spherical sheet of radius R, the energy of the system is :

(a) $\dfrac{Q^2}{8\pi\varepsilon_0 R}$ (b) $\dfrac{Q^2}{4\pi\varepsilon_0 R}$

(c) $\dfrac{Q^2}{15\pi\varepsilon_0 R}$ (d) none of these

91. A particle is free to move along the x-axis has potential energy given by $U(x) = K(1 - e^{-x^2})$ for $-\infty < x < \infty$ where K is a positive constant of appropriate dimension, then :

(a) at a point away from the origin the particle is in unstable equilibrium

(b) for any finite non-zero value of x, there is a force directed away from the origin

(c) if its total mechanical energy is $K/2$, it has its minimum KE at the origin

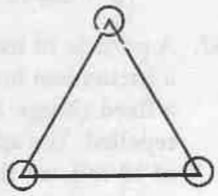
(d) for small displacement along x-axis, the motion is SHM

92. Two balls with charges 5 μC and 10 μC are at a distance of 1 m from each other. In order to reduce the distance between them to 0.5 m, the amount of work to be performed is :

(a) 45 J (b) 0.45×10^{-6} J

(c) 1.2×10^{-4} J (d) 0.45 J

93. Three small conducting spheres each of radius a and charge q is placed at the corners of an equilateral triangle of side length l. The side length l is considerably larger than dimensions of the spheres. The electrical potential energy of system is :



(a) $\frac{3q^2}{4\pi\varepsilon_0}\left(\frac{1}{2a}+\frac{1}{l}\right)$ (b) $\frac{3q^2}{4\pi\varepsilon_0 l}$

(c) $\frac{3q^2}{8\pi\varepsilon_0 a}$ (d) none of these

94. A solid non-conducting sphere of radius R having charge density $\rho = \rho_0 x$, where x is distance from the centre of sphere. The self potential energy of the sphere is :

(a) $\frac{\pi\rho_0^2 R^4}{6\varepsilon_0}$ (b) $\frac{\pi\rho_0^2 R^6}{4\varepsilon_0}$

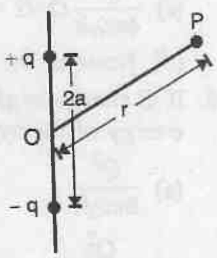
(c) $\frac{\pi\rho_0^2 R^6}{6\varepsilon_0}$ (d) none of these

95. What is the electric field intensity at a point at a distance 20 cm on a line making an angle of 45° with the axis of the dipole of moment 10 C-m ?

(a) 1.77×10^{13} V/m (b) 0.177×10^{13} V/m

(c) 17.7×10^{13} V/m (d) 177×10^{13} V/m

96. What is the electric potential at a point P, distance r from the mid-point of an electric dipole of moment $p\ (= 2aq)$:



(a) $V = \frac{1}{4\pi\varepsilon_0}\frac{p\cos\theta}{r^2}$

(b) $V = \frac{1}{4\pi\varepsilon_0}\frac{2p\cos\theta}{r^3}$

(c) $V = \frac{1}{4\pi\varepsilon_0}\frac{2p\cos\theta}{r^2}$

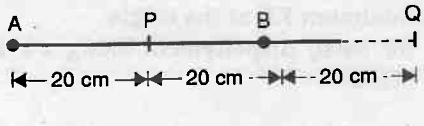
(d) None of the above

97. What is the electric potential at a point distant 100 cm from the centre of an electric dipole of moment 2×10^{-4} C-m on a line making an angle of 60° ?

(a) 7×10^{5} V (b) 8×10^{5} V

(c) 9×10^5 V (d) 10×10^5 V

98. Two point charges $q_1 = -10 \times 10^{-6}$ C and $q_2 = 15 \times 10^{-6}$ C are 40 cm apart as shown in figure. The potential difference between the points P and Q is :



(a) -945×10^3 V (b) -1000×10^3 V

(c) -880×10^3 V (d) none of these

99. An electric dipole, made up of positive and negative charges, each of 1 μC and placed at a distance 2 cm apart. If the dipole is placed in an electric field of 10^5 N/C then the maximum torque which the field can exert on the dipole, if it is turned from a position $\theta = 0°$ to $\theta = 180°$ is, is :

(a) 2×10^{-3} N-m (b) 3×10^{-3} N-m

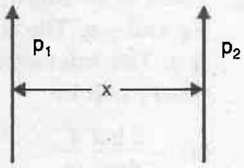
(c) 4×10^{-3} N-m (d) 2.8×10^{-3} N-m

100. What work must be done to rotate an electric dipole through an angle θ with the electric field, if an electric dipole of moment p is placed in an uniform electric field E with p parallel to E ?

(a) $W = pE\,(1 - \cos\theta)$ (b) $W = pE\,(1 + \cos\theta)$

(c) $W = 2pE\,(1 - \cos\theta)$ (d) none of these

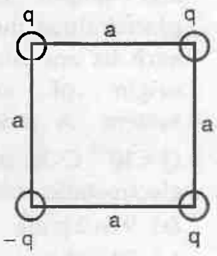
101. The force of intraction of two dipoles, if the two dipole moments are parallel to each other and placed at a distance x apart :



(a) $\frac{3p_1p_2}{4\pi\varepsilon_0 x^4}$ (b) $\frac{p_1p_2}{4\pi\varepsilon_0 x^4}$

(c) $\frac{p_1p_2}{4\pi\varepsilon_0 x^4}$ (d) $\frac{p_1p_2}{3\pi\varepsilon_0 x^4}$

102. Electric dipole moment of combination shown in the figure, is :



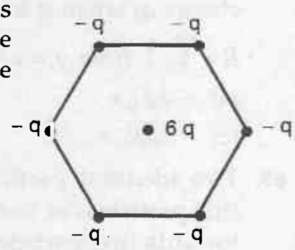
(a) $qa + qa\sqrt{2} + qa$

(b) $2\sqrt{2}qa$

(c) $\sqrt{2}qa$

(d) $(\sqrt{2} + 1)\,qa$

103. Six negative equal charges are placed at the vertices of a regular hexagon. $6q$ charge is placed at the centre of the hexagon. The electric dipole moment of the system is :



(a) zero

(b) $6qa$

(c) $3qa$

(d) none of the above

104. The angle between the electric lines of force and an equipotential surface is :

(a) 45° (b) 90°

(c) 0° (d) 180°

105. P is a point on an equipotential surface S. The field at P is E then :

(a) E must be perpendicular to S in all cases

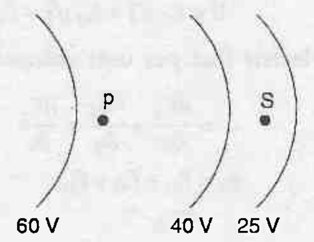
(b) E cannot have a component along a tangent to S

(c) E may have a non-zero component along a tangent to S, if S is a curved surface

(d) both (a) and (b) are correct

106. Mark the correct option(s) :
(a) For the point charge, equipotential surface is plane
(b) For the uniform electric field, the equipotential surface is spherical
(c) For the uniform electric field, the equipotential surface is plane
(d) For a line of charge, the equipotential surface is plane

107. Figure show the lines of equipotentials in the region. The potentials are shown with the equipoten- tials. If electric intensities are E_P and E_S, then :



(a) $E_P = E_S$
(b) $E_P > E_S$
(c) $E_S > E_P$
(d) $E_P - E_S = 0$

108. In a region electric field is parallel to x-axis. The equation of equipotential surface is :
(a) $y = C$
(b) $x = C$
(c) $z = C$
(d) none of these

109. Electric lines of force in a region are parallel making angle 45°, with the positive x-axis. The equation of equipotential surface is :
(a) $x^2 + y^2 = c$
(b) $x + y = c$
(c) $x = c$
(d) none of these

Answers

Level-1

1.	(b)	2.	(b)	3.	(c)	4.	(c)	5.	(d)	6.	(d)	7.	(b)	8.	(d)	9.	(a)	10.	(c)
11.	(a)	12.	(a)	13.	(a)	14.	(a)	15.	(b)	16.	(c)	17.	(a)	18.	(a)	19.	(d)	20.	(d)
21.	(a)	22.	(d)																

Level-2

1.	(b)	2.	(d)	3.	(a)	4.	(d)	5.	(b)	6.	(d)	7.	(b)	8.	(a)	9.	(a)	10.	(c)
11.	(c)	12.	(a)	13.	(d)	14.	(c)	15.	(a)	16.	(b)	17.	(b)	18.	(c)	19.	(d)	20.	(b)
21.	(d)	22.	(c)	23.	(d)	24.	(a)	25.	(a)	26.	(a)	27.	(c)	28.	(b)	29.	(c)	30.	(b)
31.	(a)	32.	(a)	33.	(a)	34.	(b)	35.	(c)	36.	(c)	37.	(b)	38.	(a)	39.	(a)	40.	(b)
41.	(b)	42.	(a)	43.	(d)	44.	(a)	45.	(c)	46.	(d)	47.	(b)	48.	(c)	49.	(b)	50.	(b)
51.	(c)	52.	(a)	53.	(c)	54.	(b)	55.	(a)	56.	(b)	57.	(a)	58.	(c)	59.	(a)	60.	(d)
61.	(a)	62.	(b)	63.	(b)	64.	(b)	65.	(c)	66.	(a)	67.	(d)	68.	(a)	69.	(c)	70.	(b)
71.	(c)	72.	(a)	73.	(b)	74.	(b)	75.	(c)	76.	(b)	77.	(b)	78.	(b)	79.	(a)	80.	(a)
81.	(a)	82.	(a)	83.	(a)	84.	(a)	85.	(a)	86.	(b)	87.	(b)	88.	(a)	89.	(a)	90.	(a)
91.	(d)	92.	(d)	93.	(a)	94.	(c)	95.	(a)	96.	(a)	97.	(c)	98.	(a)	99.	(a)	100.	(a)
101.	(a)	102.	(b)	103.	(a)	104.	(b)	105.	(d)	106.	(c)	107.	(c)	108.	(b)	109.	(d)		

Solutions

Level-1

8.
$$V = \frac{Q}{4\pi\varepsilon_0 r} - \frac{Q}{4\pi\varepsilon_0\, 3r}$$

$$\Rightarrow \quad V = \frac{1}{4\pi\varepsilon_0}\frac{2Q}{3r}$$

$$E = \frac{Q}{4\pi\varepsilon_0 (3r)^2} - \frac{4\pi\varepsilon_0 \dfrac{3rV}{2}}{4\pi\varepsilon_0 (3r)^2}$$

$$\therefore \quad E = \frac{V}{6r}$$

10. $\text{P.D.} = \dfrac{\text{work}}{\text{charge}} = \dfrac{2\ \text{J}}{20\ \text{C}} = 1 \times 10^{-1}$ volt

13. Work done = charge × P.D.
$= 20\ \text{C} \times 20\ \text{V} = 400\ \text{J}$

14.
$$V_x = x^2 - 2x$$

$$\frac{d(V_x)}{dx} = 2x - 2$$

$$E_{(x)} = -\frac{d(V_x)}{dx} = 2 - 2x$$

Electric field strength at $x = 1$ is $(E_{x=1}) = 0$

25

Electric Capacitor

Syllabus: Distribution of charge on conductors, capacitance, parallel plate capacitor, combination of capacitors, energy of capacitors, van-de Graff generator.

Review of Concepts

1. Electric Capacitance : The electric potential at the surface of sphere containing charge q, surrounded by a dielectric of relative permittivity ε_r, is

$$V = \frac{q}{4\pi\, \varepsilon_0\, \varepsilon_r\, R}$$

$$\therefore \quad \frac{q}{V} = 4\pi\, \varepsilon_0\, \varepsilon_r\, R$$

Here $\frac{q}{V}$ is a constant quantity only depends upon shape and size of conductor and the medium in which it is placed. This constant is known as capacitance of a conductor

$$C = \frac{q}{V}$$

Unit of capacitance is farad.

Some Conceptual Points :

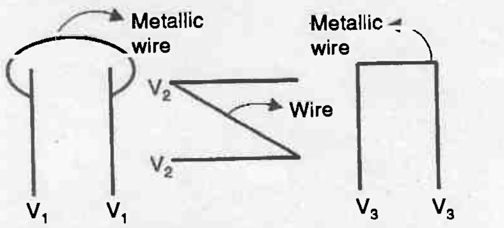
(i) A simple capacitor is the combination of two conductors placed close to each other. The electric charges on the capacitors must be equal in magnitude and opposite in directions.

(ii) The capacitance of the capacitor is defined as ratio of positive charge on conductor and potential difference between conductors.

$$\therefore \quad C = \frac{q}{V} = \frac{\text{charge on positive plates}}{\text{potential difference between plates}}$$

(iii) The capacitance of a capacitor depends on the geometry (shape and size), the gap between conductors and the material filled the capacitor.

2. Parallel Plates Capacitor in Different Situations :

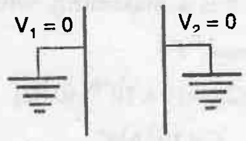


$V = V_1 - V_1 = 0 \qquad V = V_2 - V_2 = 0 \qquad V = V_3 - V_3 = 0$

(a) If both plates are connected by a metallic wire.

$$\therefore \quad C = \frac{q}{V} = \frac{q}{0} = \infty$$

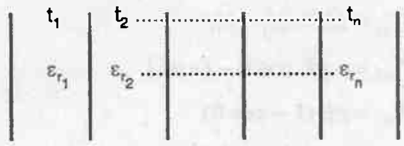
(b) If both plates are earthed:



$V = V_1 - V_2 = 0$

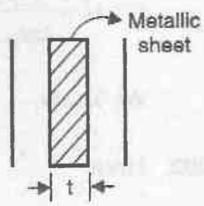
$$\therefore \quad C = \frac{q}{V} - \frac{q}{0} = \infty$$

(c) If n different sheets of dielectric constants $\varepsilon_{r_1}, \varepsilon_{r_2}, \varepsilon_{r_3}, \ldots, \varepsilon_{r_n}$ of thickness $t_1, t_2, \ldots, t_n$ are placed between plates of parallel plates capacitor, then capacitance is



$$C = \frac{\varepsilon_0 A}{\sum_{i=1}^{n} \frac{t_i}{\varepsilon_{r_i}}}$$

(d) If a metallic sheet of thickness t $(t < d)$ is introduced between the plates of capacitor.



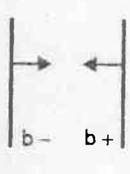
$$\therefore \quad C = \frac{\varepsilon_0 A}{(d - t)}$$

(e) Due to introduction of metallic sheet, capacitance of the capacitor increases.

(f) If space between plates of a parallel plate capacitor is filled with a dielectric medium which linearly varies as such its value near one plate is K_1 and that near other plate is K_2, then

$$C = \frac{\varepsilon_0 A (K_2 - K_1)}{\ln\left(\frac{K_2}{K_1}\right)}$$

3. (a) Force of electrostatic interaction between plates of capacitor

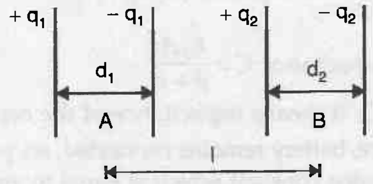


$$F = \frac{q^2}{2A\varepsilon_0}$$

where, q = charge on capacitor plate,
A = area of plate

(b) Force of interaction between the plates is attractive in nature.

(c) Force of interaction between two parallel plates capacitors A and B arranged perpendicular to the common axis. The separation l between the capacitors is much larger than the separation between their plates and their size. Capacitors A and B are charged to charges q_1 and q_2 respectively.



$$F = \frac{3q_1 d_1 q_2 d_2}{2\pi\, \varepsilon_0\, l^4}$$

(d) Electrostatic energy stored in capacitor

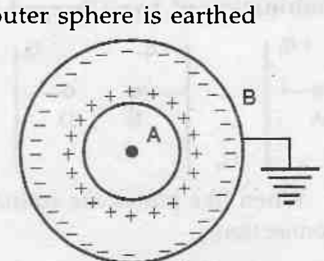
$$U = \frac{1}{2}CV^2 = \frac{1}{2}\frac{\varepsilon_0 A}{d}V^2 = \frac{1}{2}\varepsilon_0 E^2 Ad$$

(e) Electrostatic energy stored per unit volume in electric field (energy density)

$$U = \frac{1}{2}\varepsilon_0 E^2$$

4. Spherical Capacitor : A spherical capacitor consists of two concentric spherical conductors of radii a and b $(b > a)$.

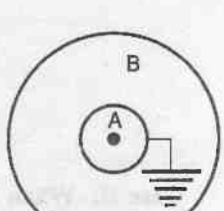
Case I: When outer sphere is earthed



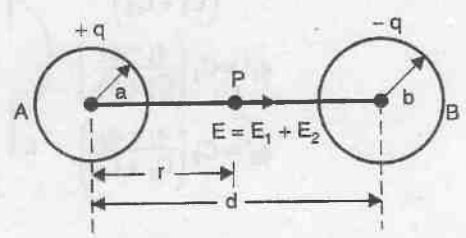
$$\text{Capacitance (C)} = \frac{4\pi\varepsilon_0\, ab}{(b-a)}$$

Case II: When inner sphere is earthed and outer sphere is charged with charge Q

$$C = \frac{4\pi\varepsilon_0\, b^2}{(b-a)}$$



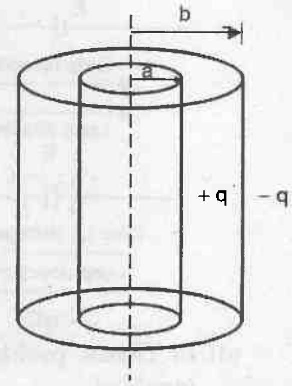
Case III: If both spheres are separated by a distance d



$$C = \frac{4\pi\varepsilon_0}{\left[\frac{1}{a} + \frac{1}{b} - \frac{2}{d}\right]}$$

5. Cylindrical Capacitor : It consists of two long co-axial cylindrical conductors A and B of radii a and b $(a < b)$, electric charge on inner cylinder is $+q$ but on outer cylinder is $(-q)$

$$C = \frac{2\pi\, \varepsilon_0\, l}{\ln\left(\frac{b}{a}\right)}$$



6. Electric Cell: Electric cell is a device which converts other forms of energy into electrical energy. This conversion of energy takes place by internal chemistry of the cell.

(a) The electric cell has two terminals:
  (i) Positive terminal (anode)
  (ii) Negative terminal (cathode)

(b) The strength of cell is measured in the form of electromotive force (EMF).

(c) EMF is defined as work done by driving force to shift unit positive charge from negative terminal of cell to positive terminal of cell.

(d) Unit is volt.

Some Conceptual Points :

(i) Cell provides a constant potential difference between the terminals.

(ii) In the case of ideal cell, internal resistance of cell is negligible. It means the potential difference between terminals of cell is equal to emf of the cell.

(iii) Electric cell always remains in neutral condition. It means if charge q leaves from positive terminal of cell, then charge q also enters into cell from negative terminal.

(iv) The charge q passes through cell from negative terminal to positive terminal of the cell. Then work done by battery $W = Eq$.

(v) Representation of cell.

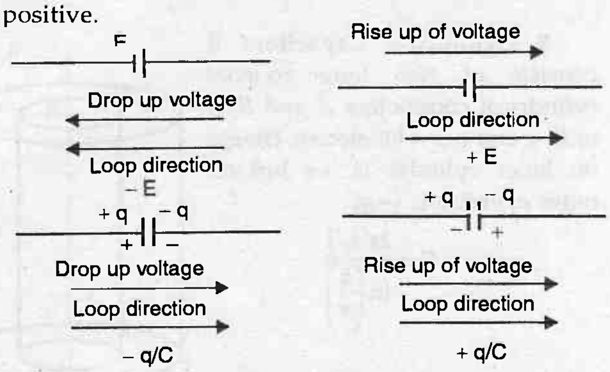
(vi) The combination of cells is known as battery.

7. For solving circuit between problem two directions come into play:

(a) **Loop direction:** The direction is not specified and direction of loop is chosen in comfortable manner.

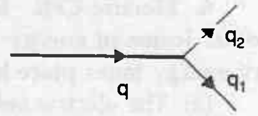
(b) **Drop up voltage:** When we go from a point of higher potential to a point of lower potential in loop direction, drop up of voltage takes place. In sign convention, drop up voltage is taken as negative.

(c) **Rise up of voltage :** If we go from lower potential point to high potential point, rise up of voltage takes place. In convention, rise up of voltage is taken as positive.



(d) **In circuit problems, two important concepts are involved.**

Concept 1 : Capacitor circuit obeys conservation principle of charge.



i.e., $q = q_1 + q_2$

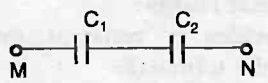
Concept 2 : In a closed circuit, the algebraic sum of rise up and drop up voltage is zero.

$$\Sigma V = 0$$

8. Combination of Capacitors :

(a) Capacitors connected in series :

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$$



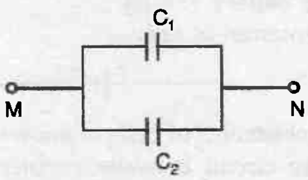
Similarly, for *n* capacitors connected in series

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots + \frac{1}{C_n}$$

$$\Rightarrow \quad \frac{1}{C} = \sum_{i=1}^{n} \frac{1}{C_i}$$

(b) Capacitors connected in parallel :

$$C = C_1 + C_2 + C_3 + \dots$$



Similarly, for *n* capacitors connected in parallel.

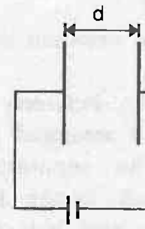
$$C = \sum_{i=1}^{n} C_i$$

If medium is continuous $C = \int dC$

9. Qualitative Discussion of Capacitor :

Case I: When the separation between the plates of parallel plate capacitor of area *A* and initial separation *d* is increased with battery attached.

Let separation is increased by distance *x*.



(a) Let initial capacitance $C_0 = \frac{\varepsilon_0 A}{d}$

Final capacitance $C = \frac{\varepsilon_0 A}{d + x}$

$\therefore$ $C < C_0$, it means capacitance of the capacitor decreases.

(b) Since, battery remains connected, so, potential difference remains constant which is equal to emf of cell.

(c) Energy stored in capacitor: $U < U_0$

$\therefore$ Energy stored in capacitor decreases.

(d) Charge decreases $q < q_0$

(e) Electric field decreases.

Case II: When separation between the plates of capacitor is increased after disconnecting the battery.

(a) Charge on capacitor remains unchanged $q = q_0$

(b) Capacitance decreases $C < C_0$

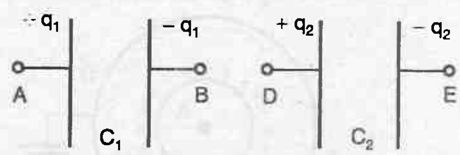
(c) Potential difference increases

$$V > V_0$$

(d) Electric field remains constant.

(e) Energy stored in capacitor increases $U > U_0$

10. Combination of two Charged Capacitors :

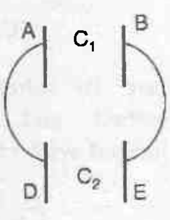


Case I: When like plates are connected together.
After connection,

Common potential $(V) = \left(\frac{q_1 + q_2}{C_1 + C_2}\right)$

$$q_1' = C_1\left(\frac{q_1 + q_2}{C_1 + C_2}\right)$$

$$q_2' = C_2\left(\frac{q_1 + q_2}{C_1 + C_2}\right)$$

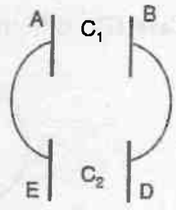


Case II: When unlike plates are connected together.
After connection

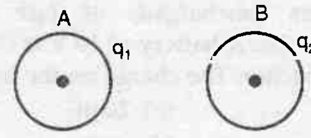
$$V = \left(\frac{q_1 - q_2}{C_1 + C_2}\right)$$

$$q_1' = C_1\left(\frac{q_1 - q_2}{C_1 + C_2}\right)$$

$$q_2' = C_2\left(\frac{q_1 - q_2}{C_1 + C_2}\right)$$



11. Sharing of Charge Between two Conductors: Let two spherical isolated conductors A and B are of radii r_1 and r_2 respectively and electric charges on sphere A and sphere B are q_1 and q_2 respectively.



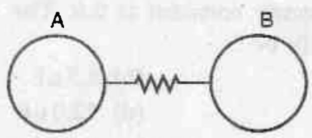
Capacitance of $A \Rightarrow C_1 = 4\pi\varepsilon_0 r_1$

Electric potential of $A \Rightarrow V_1 = \dfrac{q_1}{C_1}$

Capacitance of $B \Rightarrow C_2 = 4\pi\varepsilon_0 r_2$

Electric potential of $B \Rightarrow V_2 = \dfrac{q_2}{C_2}$

When they are connected.



Common potential $(V) = \dfrac{C_1V_1 + C_2V_2}{C_1 + C_2}$

Loss of energy $= \dfrac{C_1C_2\,(V_1 - V_2)^2}{2(C_1 + C_2)}$

12. Dielectric:
(a) Non-conducting materials are known as dielectrics.
(b) Dielectrics have no free electrons.
(c) Polarization: Polarization vector is defined as dipole moment per unit volume of a dielectric material in the presence of electric field.

(d) Dielectrics

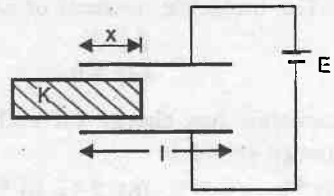
(i) Monoatomic material (ii) Polyatomic material

(1) Polar (2) Non-polar

(e) Expression for magnitude of induced charge density

$$\sigma_i = \sigma_0\left(1 - \frac{1}{K}\right)$$

(f) Introduction of dielectric slab between plates of a parallel plate capacitor.



Case I: If battery of emf E remains connected to the plates of capacitor.

$$C = \frac{\varepsilon_0 a}{d}\,[x + (l - x)\,K],$$

$$F = \frac{-\,\varepsilon_0 a E^2 (K - 1)}{2d}$$

Case II: When battery is disconnected.

$$C = \frac{\varepsilon_0 a}{d}\,[x + (l - x)\,K],$$

$$F = \frac{-\,q_0^2\, d\,(K - 1)}{2\varepsilon_0 a\,[Kl - (K - 1)x]^2}$$

Objective Questions

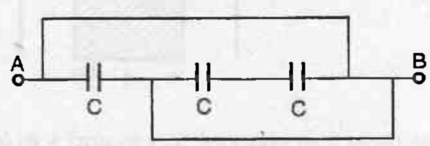
Level-1

1. In order to increase the capacity of parallel plate condenser one should introduce between the plates, a sheet of:
(a) mica (b) tin
(c) copper (d) stainless steel

2. Three capacitors 4, 6 and 12 μF are connected in series to a 10 V source. The charge on the middle capacitor is:
(a) 10 μC (b) 20 μC
(c) 60 μC (d) 5 μC

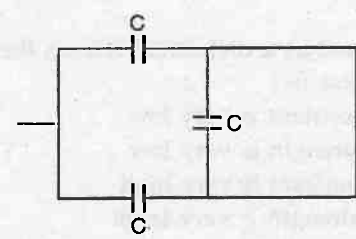
3. Two 30 μF capacitors are joined in parallel. This combination is then joined in series with series combination of two 30 μF capacitors. The effective capacitance will be:
(a) 12 μF (b) 45 μF
(c) 12 μF (d) 30 μF

4. The equivalent capacitance between A and B in the circuit shown in figure, is:



(a) C (b) 2C (c) 3C (d) C/2

5. The equivalent capacity of the combination shown in figure is:



(a) C (b) 2C
(c) 3/2 C (d) C/2

6. A capacitor is charged by a battery to a potential V in a R-C circuit. The ratio of the energy supplied by the battery to that stored in the capacitor, is :
(a) 1 (b) 1.5
(c) 2 (d) 4

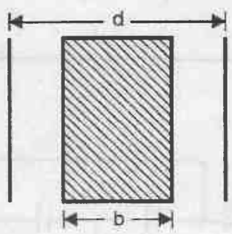
7. Two drops of a liquid are charged to the same potential of 100 V. They are then merged into one large drop, the potential of the large drop is :
(a) 172 V (b) 193 V
(c) 159 V (d) 100 V

8. A parallel plate capacitor has capacitance of 10^{-12} F. The separation of the plates is doubled and wax is inserted between them which increases the capacitance to 2×10^{-12} F. The dielectric constant of wax is :
(a) 2 (b) 3
(c) 4.0 (d) 8.0

9. A 60 μF capacitor has charge on each plate 3×10^{-6} C then the energy stored is :
(a) 1.2×10^{-4} J (b) 7.5×10^{-6} μJ
(c) 15×10^{-6} J (d) 2.4×10^{-4} J

10. If q is the charge on the capacitor and E is the magnitude of the electric field between the plates, the force on each plate of the capacitor is :
(a) qE (b) $2qE$
(c) $\frac{1}{2}qE$ (d) $\frac{1}{4}qE$

11. A slab of copper of thickness b is inserted in between the plates of parallel plate capacitor as shown in figure. The separation between the plates is 'd' if $b = \frac{d}{2}$, then the ratio of capacities of capacitors after and before inserting the slab will be :
(a) $\sqrt{2} : 1$
(b) $2 : 1$
(c) $1 : 1$
(d) $1 : \sqrt{2}$



12. Two plates (area = S) charged to $+q_1$ and $+q_2$ ($q_2 < q_1$) are brought closer to form a capacitor of capacitance C. The potential difference across the plates is :
(a) $\frac{q_1 - q_2}{2C}$ (b) $\frac{q_1 - q_2}{C}$
(c) $\frac{q_1 - q_2}{4C}$ (d) $\frac{2(q_1 - q_2)}{C}$

13. Two capacitors (uncharged) of 2 μF and 3 μF are connected in series. A battery of 10 V is connected across the second capacitor. The charge on the first capacitor is :
(a) 30 μC (b) 20 μC
(c) 10 μC (d) zero

14. A dielectric slab of thickness b is inserted between the plates of a parallel plate capacitor of plate separation 'd', the capacitance of this capacitor is :
(a) $\frac{K \varepsilon_0 A}{Kd - b(K-1)}$ (b) $\frac{\varepsilon_0 A}{Kd + b(K-1)}$
(c) $\frac{\varepsilon_0 A}{Kd - b(K-1)}$ (d) $\frac{K \varepsilon_0 A}{Kd - b(K+1)}$

15. An air capacitor of capacitance 6 μF is immersed in oil whose dielectric constant is 2.0. The capacitance of oil capacitor will be :
(a) 2.5 μF (b) 8.5 μF
(c) 22 μF (d) 12.0 μF

16. The induced charge on the dielectric of a capacitor of capacitance 4 μF when charged by a battery of 50 V, is (dielectric constant of the dielectric = 4) :
(a) 100 μC (b) 200 μC
(c) 50 μC (d) 150 μC

17. A parallel plate capacitor having area A is given a charge q and $-q$ on its plates. Two plates exert force of attraction given by :
(a) $\frac{1}{4\pi\varepsilon_0} \frac{q^2}{A}$ (b) $\frac{\varepsilon_0 q^2}{2\pi A}$
(c) $\frac{q^2}{2\varepsilon_0 A}$ (d) $\frac{q^2}{\varepsilon_0 A}$

18. If a 2.0 microfarad condenser is charged to 200 V and its plates are connected by a wire, the heat produced in the wire is :
(a) 4×10^{-4} J (b) 4×10^{-2} J
(c) 4×10^{-3} J (d) 16×10^{-2} J

19. A 30 μF capacitor is charged by a constant current of 30 mA. If the capacitor is initially uncharged, how long does it take for the potential difference to reach 400 V ?
(a) 0.2 s (b) 0.4 s
(c) 0.6 s (d) 0.8 s

Level-2

1. Water is not used as a dielectric between the plates of a capacitor because its :
(a) dielectric constant is very low
(b) dielectric strength is very low
(c) dielectric constant is very high
(d) dielectric strength is very large

2. A parallel plate capacitor of capacitance C consists of two identical plates A and B. A charge q is given to plate A and charge $-2q$ is given to plate B. The space between plates is vacuum. The separation between plates is d. The electric intensity at a point situated between plates is :

(a) $\frac{q}{Cd}$ (b) $\frac{q}{2Cd}$

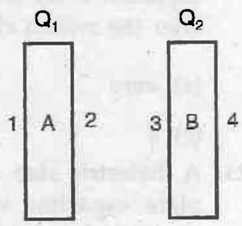
(c) $\frac{3q}{2Cd}$ (d) none of these

3. A capacitor of capacitance C is charged to a potential difference V from a cell and then disconnected from it. A charge $+Q$ is now given to its positive plate. The potential difference across the capacitor is now :

(a) V (b) $V+\frac{Q}{C}$

(c) $V+\frac{Q}{2C}$ (d) $V-\frac{Q}{C}$

4. Two large conducting plates A and B have charges Q_1 and Q_2 on them. The charges on the sides 1, 2, 3 and 4 respectively are :



(a) $q_1=q_4=\frac{Q_2+Q_1}{2}$ and $q_2=-q_3=\frac{Q_1-Q_2}{2}$

(b) $q_1=q_3=\frac{Q_1+Q_2}{2}$ and $q_2-q_4=\frac{Q_1-Q_2}{2}$

(c) $q_2=q_3=\frac{Q_1+Q_2}{2}$ and $q_1=q_4=\frac{Q_1-Q_2}{2}$

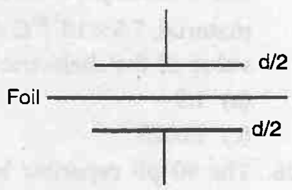
(d) $q_1=q_2=q_3=q_4=\frac{Q_1+Q_2}{2}$

5. Two identical metal plates are given positive charge Q_1 and Q_2 $(Q_2<Q_1)$ respectively. If they are now brought close together to form a parallel plate capacitor with capacitance C, the potential difference between them is :

(a) $\frac{Q_1+Q_2}{2C}$ (b) $\frac{Q_1+Q_2}{C}$

(c) $\frac{Q_1-Q_2}{C}$ (d) $\frac{Q_1-Q_2}{2C}$

6. A sheet of aluminium foil of negligible thickness is placed between the plates of a capacitor of capacitance C as shown in the figure then capacitance of capacitor becomes :



(a) 2C (b) C

(c) C/2 (d) zero

7. A metallic sheet is inserted between plates parallel to the plates of a parallel plate capacitor. The capacitance of the capacitor :

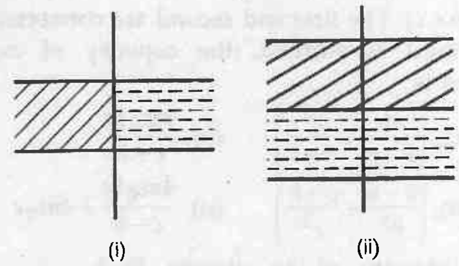
(a) increases

(b) is independent of the position of the sheet which can be placed any where between the plates

(c) is maximum when the metal sheet is in middle

(d) both (a) and (b) are correct

8. The ratio of capacitance of two capacitors filled with dielectrics of same dimensions but of different values K and $K/4$ arranged in two ways as shown in figure (i) and (ii), is :



(a) 5 : 2 (b) 25 : 16

(c) 5 : 4 (d) 2 : 5

9. A conducting sphere of radius 10 cm is given a charge of $+2\times10^{-8}$ C. What will be its potential ?

(a) 0.03 kV (b) 0.9 kV

(c) 1.8 kV (d) 3.6 kV

10. The capacitance (C) for an isolated conducting sphere of radius (a) is given by $4\pi\varepsilon_0 a$. If the sphere is enclosed with an earthed concentric sphere, the ratio of the radii of the spheres being $\frac{n}{(n-1)}$ then the capacitance of such a sphere will be increased by a factor ?

(a) n (b) $\frac{n}{(n-1)}$

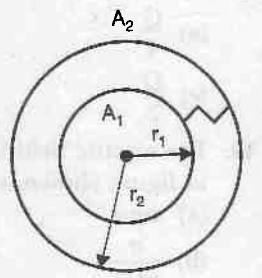
(c) $\frac{(n-1)}{n}$ (d) an

11. If n identical drops of mercury are combined to form a bigger drop then the capacity of bigger drop, if capacity of each drop of mercury is C, is :

(a) $n^{1/3}C$ (b) $n^{2/3}C$

(c) $n^{1/4}C$ (d) nC

12. Two spherical conductors A_1 and A_2 of radii r_1 and r_2 are placed concentrically in air. The two are connected by a copper wire as shown in figure. Then the equivalent capacitance of the system is :



(a) $\frac{4\pi\varepsilon_0 K r_1 r_2}{r_2-r_1}$

(b) $4\pi\varepsilon_0(r_2+r_1)$

(c) $4\pi\varepsilon_0 r_2$

(d) $4\pi\varepsilon_0 r_1$

13. A capacitor of capacitance C_0 is charged to a potential V_0 and then isolated. A small capacitor C is then charged from C_0, discharged and charged again, the process being repeated n times. Due to this, potential of the larger capacitor is decreased to V. Value of C is :

(a) $C_0\left(\frac{V_0}{V}\right)^{1/n}$ (b) $C_0\left[\left(\frac{V_0}{V}\right)^{1/n}-1\right]$

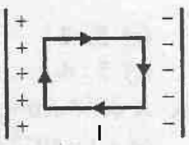
(c) $C_0\left[\left(\frac{V_0}{V}\right)-1\right]^{n}$ (d) $C_0\left[\left(\frac{V}{V_0}\right)^{n}+1\right]$

14. Three concentric thin spherical shells of radii a, b, and c $(a < b < c)$. The first and second are connected by a wire and third is earthed, the capacity of capacitor so formed is :

(a) $4\pi\varepsilon_0\left(\frac{ab}{b-a}+\frac{c^2}{c-b}\right)$ (b) $\frac{4\pi\varepsilon_0 bc}{c-b}$

(c) $4\pi\varepsilon_0\left(\frac{b-a}{ab}+\frac{c-b}{c^2}\right)$ (d) $\frac{4\pi\varepsilon_0 bc}{c-b}+4\pi\varepsilon_0 c$

15. The intensity of an electric field inside a capacitor is E. The work required to make a charge q move in a closed rectangular circuit is :



(a) $2(l+b)\,q\,E$ (b) $2lq\,E$

(c) $2bq\,E$ (d) zero

16. Two spheres charged with 100 μC and – 100 μC are kept at a distance. The force acting on them is F_1. They are connected with a metallic wire and then conductor is removed. The force F_2 acting on them now will be :

(a) equal to F_1 (b) more than F_1

(c) zero (d) infinite

17. The plates of parallel plate capacitor is connected by a battery of emf V_0. The plates are lowered into a large vessel containing dielectric liquid with constant velocity u. Then :

(a) the capacitance of capacitor gradually decreases

(b) the current is drawn with constant rate from the battery

(c) the potential difference between plates increases

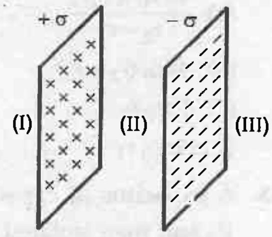
(d) the charge on plates gradually decreases

18. The amount of charge flow, when a conducting sphere of radius R and carrying a charge Q, is joined to an uncharged conducting sphere of radius $2R$ is :

(a) $\frac{Q}{4}$ (b) $\frac{Q}{3}$

(c) $\frac{Q}{2}$ (d) $\frac{2Q}{3}$

19. The electric field in region II as in figure shown, is :



(a) zero

(b) $\frac{\sigma}{4\pi\varepsilon_0}$

(c) $\frac{\sigma}{\varepsilon_0}$

(d) infinite

20. A capacitor of capacitance C is charged to a potential difference V. The flux of the electric field through a closed surface enclosing the capacitor is

(a) $\frac{CV}{\varepsilon_0}$ (b) $\frac{2CV}{\varepsilon_0}$

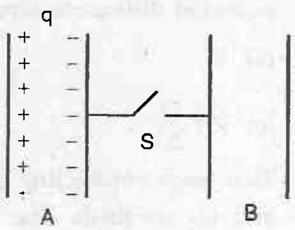
(c) $\frac{CV}{2\varepsilon_0}$ (d) zero

21. Two conducting plates x and y, each having large surface area A (on the side) are placed parallel to each other. The plate x is given a charge Q whereas the other is neutral. The electric field at a point in between the plates is given by :

(a) $\frac{Q}{2A}$ (b) $\frac{Q}{2A\,\varepsilon_0}$ towards left

(c) $\frac{Q}{2A\,\varepsilon_0}$ towards right (d) $\frac{Q}{2\varepsilon_0}$ towards right

22. Consider the situation shown in figure. The capacitor A has a charge q on it whereas B is uncharged. The charge remain present on the capacitor B for a long time after the switch closed, is :



(a) zero (b) $\frac{q}{2}$

(c) q (d) $2q$

*23. A dielectric slab of thickness d is inserted in a parallel plate capacitor whose negative plate is at $x=0$ and positive plate is at $x=3d$. The slab is equidistant from the plates. The capacitor is given some charge, as x goes from 0 to $3d$, then :

(a) the direction of the electric field remains the same

(b) the electric potential increases continuously

(c) the electric potential increases at first, then decreases and again increases

(d) both (a) and (b) are correct

24. Two capacitors A and B having capacitances 10 μF and 20 μF are connected in series with a 12 V battery. The ratio of the charges on A and B is :

(a) 0.5 : 1 (b) 1 : 1

(c) 2 : 1 (d) 2 : 4

25. A 6×10^{-4} F parallel plate air capacitor is connected to a 500 V battery. When air is replaced by another dielectric material, 7.5×10^{-4} C charge flows into the capacitor. The value of the dielectric constant of the material is :

(a) 1.5 (b) 2.0

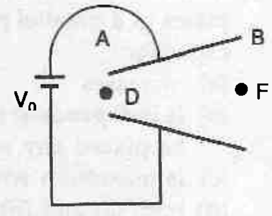
(c) 1.0025 (d) 3.5

26. The 90 pF capacitor is connected to a 12V battery. How many electrons are transferred from one plate to another ?

(a) 1.1×10^{9} (b) 6.7×10^{9}

(c) 4×10^{19} (d) 5×10^{19}

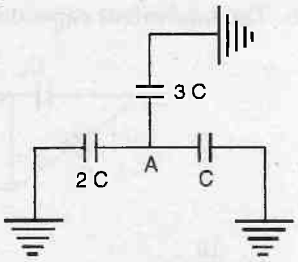
27. In the given figure, a capacitor of non-parallel plates is shown. The plates of capacitor are connected by a cell of emf V_0. If σ denotes surface charge density and E denotes electric field, then :



(a) $\sigma_A > \sigma_B$ (b) $E_F > E_D$

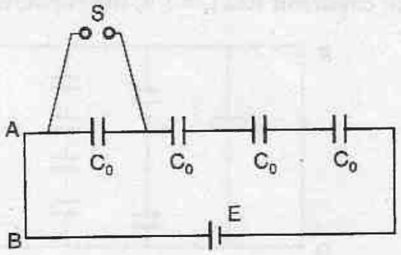
(c) $E_F = E_D$ (d) $\sigma_A = \sigma_B$

* **28.** In the given arrangement of capacitors 6 μC charge is added to point *A*, the charge on upper capacitor is :



(a) 3 μC
(b) 1 μC
(c) 2 μC
(d) 6 μC

29. In the given figure, find the charge flowing through section *AB* when switch *S* is closed :



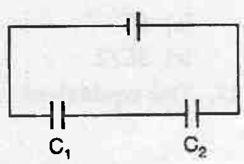
(a) $C_0 E/12$ (b) $C_0 E/4$
(c) $C_0 E/3$ (d) none of these

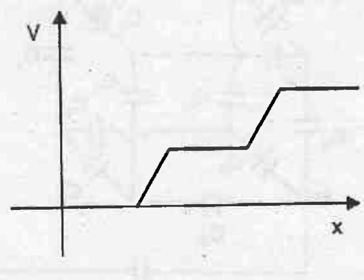
30. When a capacitor is connected to a battery, then :
(a) no current flows in the circuit at all
(b) the current flows in the circuit for some time then decreases to zero
(c) the current keeps on increasing, reaching a maximum value when the capacitor is charged to the voltage of the battery
(d) an alternating current flows in the circuit

31. Two capacitors of equal capacity are connected in series, they have some resultant capacity. Now they are connected in parallel. The resultant capacity becomes :
(a) four times of the previous value
(b) one-fourth of the previous value
(c) twice of the previous value
(d) half of the previous value

32. Two capacitors having capacitances 8 μF and 16 μF have breaking voltages 20 V and 80 V. They are combined in series. The maximum charge they can store individually in the combination is :
(a) 160 μC (b) 200 μC
(c) 1280 μC (d) none of these

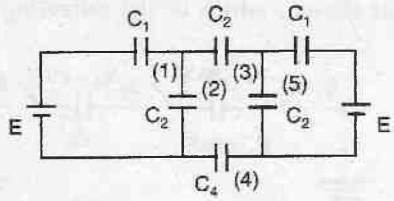
* **33.** Figure shows two capacitors connected in series and joined to a battery. The graph shows the variation of potential as one moves from left to right on the branch containing the capacitors :





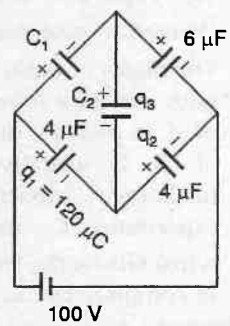
(a) $C_1 > C_2$
(b) $C_1 = C_2$
(c) $C_1 < C_2$
(d) information is not sufficient to decide the relation between C_1 and C_2

34. The circuit shown in the figure is in the steady state, the charge in capacitors 1, 5 and 4 will be :



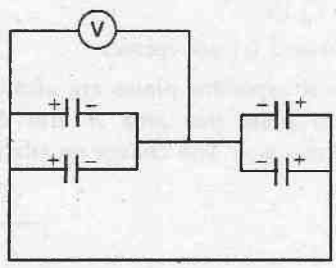
(a) EC_1, EC_2, EC_4
(b) $\dfrac{EC_1C_2}{C_1+C_2}, \dfrac{EC_1C_2}{C_1+C_2}$, zero
(c) $\dfrac{2EC_1C_2C_4}{2C_1(C_2+C_4)+C_2C_4}$, zero, $\dfrac{2EC_1C_2C_4}{2C_1(C_2+C_4)+C_2C_4}$
(d) none of the above

35. In the circuit shown, q_2 and q_3 are respectively



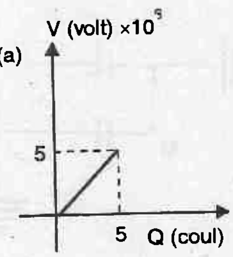
(a) $q_2 = 120$ μC, $q_3 = 240$ μC
(b) $q_2 = 280$ μC, $q_3 = -160$ μC
(c) $q_2 = 120$ μC, $q_3 =$ zero
(d) it is impossible to find q_2 and q_3 unless C_1 and C_2 are known

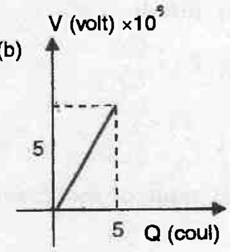
36. Each of the four capacitors in figure is rated 50 μF. The DC voltmeter reads 100 V. The charge on each plate of each capacitor is :

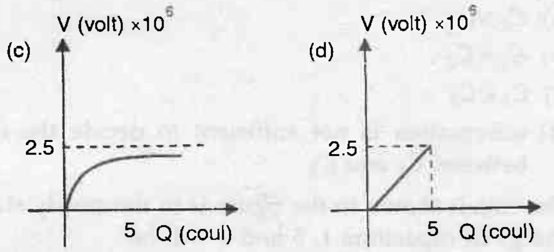


(a) 2×10^{-3} C (b) 5×10^{-3} C
(c) 0.2 C (d) 0.5 C

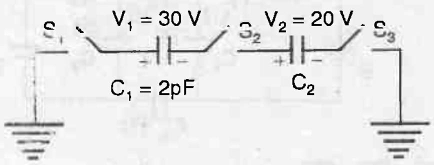
37. A condenser of 2 μF capacity is charged steadily from 0 to 5 coulomb, which of the following graphs correctly represents the variation of potential difference across its plates with respect to charge on the condenser?

(a)


(b)


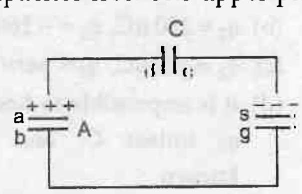


38. For circuit shown, which of the following statements is true ?



(a) With S_1 closed $V_1 = 15$ V, $V_2 = 20$ V
(b) With S_3 closed, $V_1 = V_2 = 25$ V
(c) With S_1 and S_2 closed, $V_1 = V_2 = 0$
(d) With S_1 and S_3 closed, $V_1 = 30$ V, $V_2 = 20$ V

* 39. Two capacitors A and B with capacities C_1 and C_2 are charged to potential difference of V_1 and V_2 respectively. The plates of capacitors are connected as shown in figure with one wire from each capacitor free. The upper plate of A is positive and that of B is negative. An uncharged capacitor of capacitance C_3 and lead wires fall on the free ends to complete circuit, then :



(a) final charge on each capacitor are same to each other
(b) the final sum of charge on plates a and d is C_1V_1
(c) the final sum of charge on plates b and g is $C_2V_2 - C_1V_1$
(d) both (b) and (c) are correct

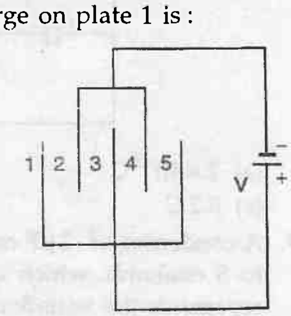
40. Five identical capacitor plates are arranged as shown in figure. Each plate has area A and distance between adjacent plates is d. The charge on plate 1 is :

(a) $\dfrac{\varepsilon_0 AV}{d}$

(b) $\dfrac{\varepsilon_0 AV^2}{d}$

(c) $\dfrac{\varepsilon_0 AV}{2d}$

(d) $\dfrac{\varepsilon_0 AV}{3d}$



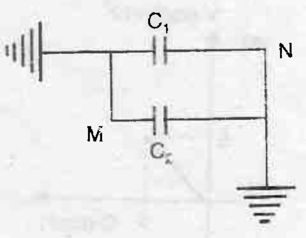
41. The equivalent capacitance between points M and N is :

(a) infinity

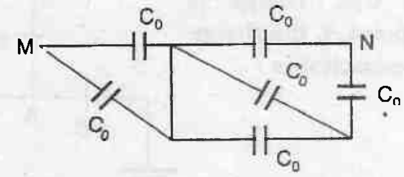
(b) $C_1 + \dfrac{C_2}{C_1}$

(c) $\dfrac{C_1C_2}{C_1 + C_2}$

(d) none of the above

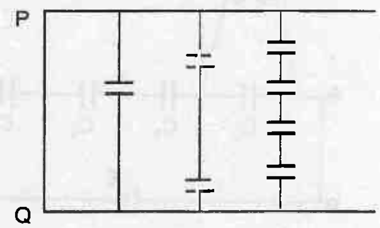


42. The equivalent capacitance between points M and N is :



(a) $\dfrac{10}{11}C_0$ (b) $2C_0$
(c) C_0 (d) none of these

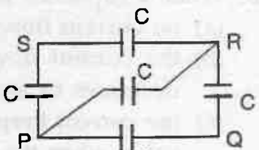
43. If each capacitor has $C = 1$ F, the capacitance across P and Q is :



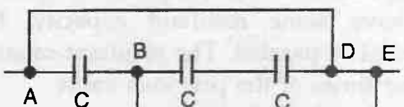
(a) 0.5 F (b) 1 F
(c) 2 F (d) infinity

44. For circuit shown equivalent capacitance between S and Q is :

(a) C
(b) $C/2$
(c) $2C$
(d) $3C/2$

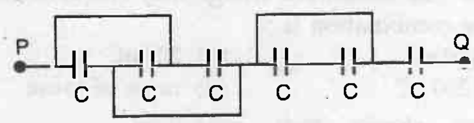


45. In the given figure, the equivalent capacity between A and B is :



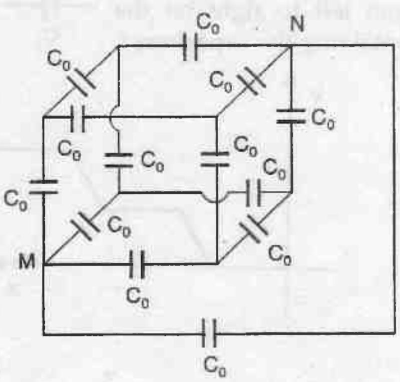
(a) $3C$ (b) $C/3$
(c) $3/2C$ (d) infinity

46. For circuit the equivalent capacitance between P and Q is :



(a) $6C$ (b) $4C$
(c) $3C/2$ (d) $6C/11$

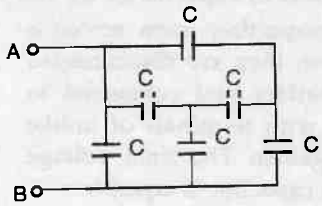
47. The equivalent capacitance between points M and N is :



(a) $\frac{11}{5}C_0$ (b) $\frac{6}{5}C_0$

(c) $\frac{5}{6}C_0$ (d) none of these

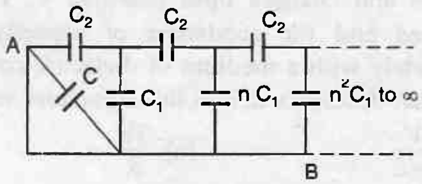
48. The equivalent capacitance between points A and B is :



(a) $C/4$ (b) $C/2$

(c) C (d) $2C$

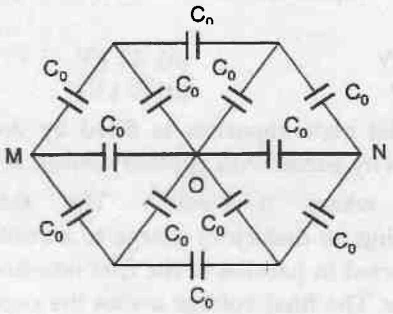
49. The equivalent capacitance between points A and B is :



(a) n^2C_1 (b) infinity

(c) $\left(\frac{2C+\sqrt{n^2C_1+1}}{2}\right)$ (d) zero

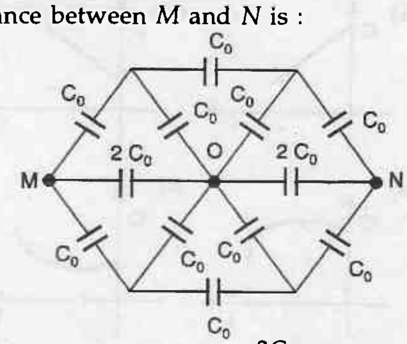
50. In the given arrangement of capacitors, equivalent capacitance between points M and N is :



(a) $\frac{5C_0}{4}$ (b) $\frac{3C_0}{4}$

(c) $\frac{4C_0}{5}$ (d) none of these

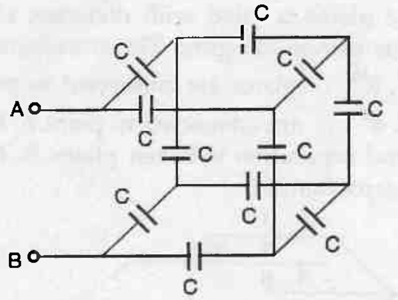
51. In the given arrangement of capacitors, equivalent capacitance between M and N is :



(a) $\frac{7C_0}{4}$ (b) $\frac{3C_0}{4}$

(c) $\frac{4C_0}{5}$ (d) none of these

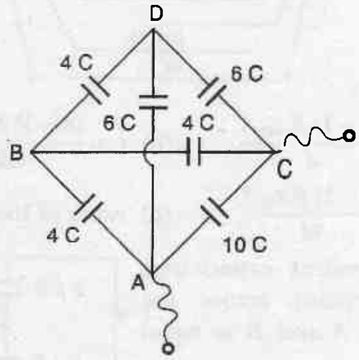
52. The equivalent capacitance between A and B is :



(a) $5C/7$ (b) $7C/5$

(c) $7C/12$ (d) $12C/7$

53. The equivalent capacitance between the points A and C is given by :

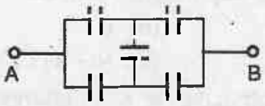


(a) $\frac{10}{3}C$ (b) $15\ C$

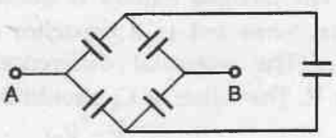
(c) $\frac{3}{10}C$ (d) $20\ C$

54. Four ways of making a network of capacitors of the same value are shown here. Three out of four are identical. The one which is different is :

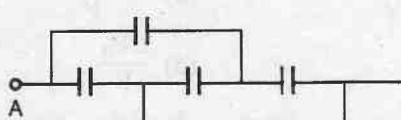
(a)



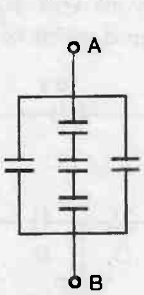
(b)



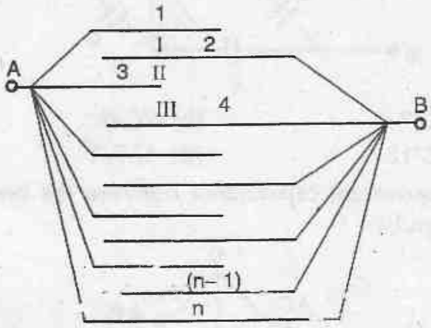
(c)



(d)



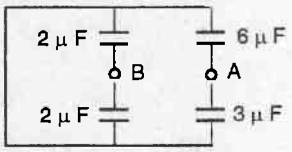
$*$ **55.** A capacitor is made up of n parallel plates and the space between the plates is filled with dielectric of dielectric constant K as shown in figure. The arrangement is such that 1^{st}, 3^{rd}, 5^{th}, ... plates are connected to point A and 2^{nd}, 4^{th}, 6^{th}, 8^{th}, ... are connected to point B. If the plate area is A and separation between plates is d then find equivalent capacitance :



(a) $C = \dfrac{(n-1) K \varepsilon_0 A}{d}$ (b) $C = \dfrac{(n-1) K \varepsilon_0 A}{2d}$

(c) $C = \dfrac{(n-1) K \varepsilon_0 A}{4d}$ (d) none of these

56. The equivalent capacitance of the circuit across the terminals A and B is equal to :



(a) 13 μF (b) $\dfrac{36}{13}$ μF

(c) 3 μF (d) 3/4 μF

57. A parallel plate capacitor is made by pilling n equally spaced plates of same area connected alternately. If the capacitance between any two consecutive plates is C, then the resulting capacitance will be :

(a) nC (b) C

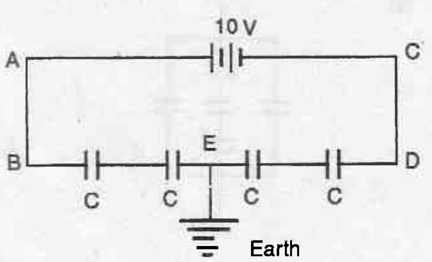
(c) $(n+1)$ C (d) $(n-1)$ C

58. A capacitor of capacitance C is charged to a potential difference V_0. The charged battery is disconnected and the capacitor is connected to a capacitor of unknown capacitance C_x. The potential difference across the combination is V. The value of C_x should be :

(a) $\dfrac{C(V_0 - V)}{V}$ (b) $\dfrac{C(V - V_0)}{V}$

(c) $\dfrac{CV}{V_0}$ (d) $\dfrac{CV_0}{V}$

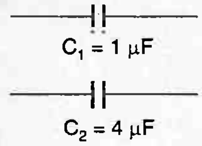
59. Four equal capacitors, each with a capacitance (C) are connected to a battery of emf 10 V as shown in the adjoining figure. The mid-point of the capacitor system is connected to earth. Then the potentials of B and D are respectively :



(a) +10 V, 0 V (b) +5 V, −5 V

(c) −5 V, +5 V (d) 0 V, 10 V

60. Two capacitors of capacitance C_1 and C_2 are charged to 60 V by connecting them across a battery. Now, they are disconnected from the battery and connected to each other with terminals of unlike polarity together. The final voltage across each capacitor is equal to :



(a) 45 V (b) 36 V

(c) 60 V (d) none of these

61. Two condensers of capacities 2C and C are joined in parallel and charged upto potential V. The battery is removed and the condenser of capacity C is filled completely with a medium of dielectric constant K. The potential difference across the capacitors will now be :

(a) $\dfrac{3V}{K+2}$ (b) $\dfrac{3V}{K}$

(c) $\dfrac{V}{K+2}$ (d) $\dfrac{V}{K}$

62. A capacitor of capacitance 1 μF withstands the maximum voltage 6 kV while a capacitor of 2 μF withstands the maximum voltage 4 kV. What voltage will the system of these two capacitors withstands if they are connected in series ?

(a) 10 kV (b) 12 kV

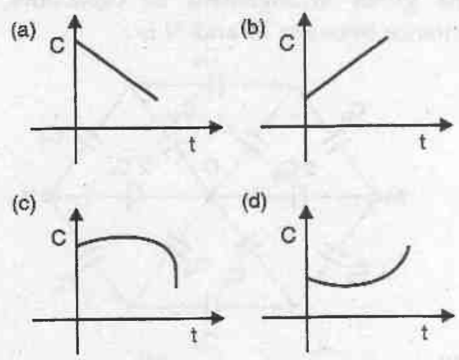
(c) 8 kV (d) 9 kV

63. A parallel plate capacitor is filled by dielectric whose permittivity varies with applied voltage according to law $E = \alpha V$ where $\alpha = 1 \text{ volt}^{-1}$. The same capacitor (containing no dielectric) charge to a voltage of 156 volt is connected in parallel to the first non-linear uncharged capacitor. The final voltage across the capacitor is :

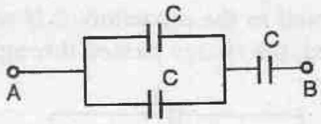
(a) 12 V (b) 120 V

(c) 25 V (d) 10 V

64. A dielectric slab is inserted between plates of a parallel plate capacitor with uniform variation of capacitance :

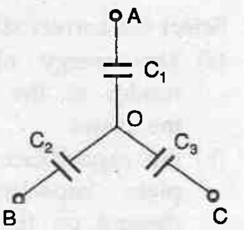


65. In the network shown we have three identical capacitors. Each of them can withstand a maximum 100 V potential difference. What maximum voltage can be applied across A and B so that no capacitor gets spoiled ?



(a) 150 V (b) 120 V
(c) 180 V (d) 0.200 V

66. Three uncharged capacitors of capacities C_1, C_2 and C_3 are connected as shown in the figure to one another and the points A, B and C are at potentials V_1, V_2 and V_3 respectively. Then the potential at O will be :



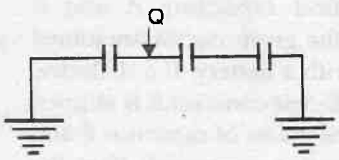
(a) $\dfrac{V_1C_1 + V_2C_2 + V_3C_3}{C_1 + C_2 + C_3}$

(b) $\dfrac{V_1 + V_2 + V_3}{C_1 + C_2 + C_3}$

(c) $\dfrac{V_1 (V_2 + V_3)}{C_1 (C_2 + C_3)}$

(d) $\dfrac{V_1 V_2 V_3}{C_1 C_2 C_3}$

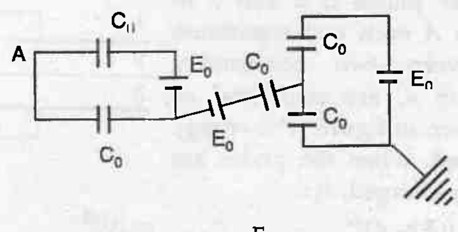
67. Three identical capacitors are first connected in series and then first and last conductors of combination are connected to the earth. A charge Q is given to second conductor of first capacitor. Then potential of this conductor is :



(a) $\dfrac{Q}{3C}$ (b) $\dfrac{Q}{C}$

(c) $\dfrac{2Q}{3C}$ (d) $\dfrac{3Q}{2C}$

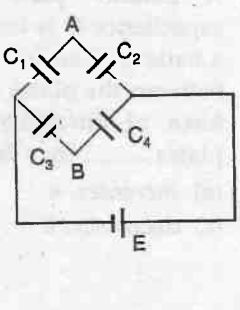
68. In the given circuit, potential of point A is :



(a) zero (b) $\dfrac{E_0}{2}$

(c) $2E_0$ (d) none of these

69. The potential difference between points A and B of the circuit is :



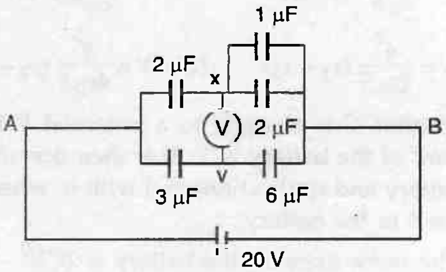
(a) $(C_2 - C_1)E$

(b) $(C_4 - C_3)E$

(c) $\dfrac{(C_2C_3 - C_1C_4)E}{(C_1 + C_2 + C_3 + C_4)}$

(d) $\dfrac{(C_2C_3 - C_1C_4)E}{(C_1 + C_2)(C_3 + C_4)}$

70. Calculate the reading of voltmeter between x and y then $(V_x - V_y)$ is equal to :



(a) 1.3 V (b) 13.33 V
(c) 3.33 V (d) 10.33 V

71. Three identical capacitors are connected together differently. For the same voltage to every combination, the one that stores maximum energy is :
(a) the three capacitors in series
(b) the three capacitors in parallel
(c) two capacitors in series with third capacitor in parallel with it
(d) two capacitors in parallel with the third capacitors in series with it

72. Two identical capacitors A and B are joined in parallel to a battery. If a dielectric slab of constant K is slipped between the plates of capacitor B and battery remains connected then the energy of capacitor A will :
(a) decrease
(b) increase
(c) remains the same
(d) first increase then will again come to original value after process is completed

73. A parallel plate capacitor is charged and the charging battery is then disconnected. If the plates of the capacitor are moved further apart by means of insulating handles, then :
(a) the voltage across the plate increases
(b) the capacitance increases
(c) the electrostatic energy stored in the capacitor increases
(d) both (a) and (c) are correct

74. Select correct statement for a capacitor having capacitance C, is connected to a source of constant emf E
(a) Almost whole of the energy supplied by the battery will be stored in the capacitor, if resistance of connecting wire is negligibly small
(b) Energy received by the capacitor will be half of energy supplied by the battery only when the capacitor was initially uncharged
(c) Strain energy in the capacitor must increases even if the capacitor had an initial charge
(d) None of the above

75. The work done against the electric force if the separation of the capacitor of area S is increased from x_1 to x_2 is : [Assume charge q on the capacitor is constant]

(a) $W = \frac{q^2}{\varepsilon_0 S}(x_2 - x_1)$ (b) $W = \frac{q}{\varepsilon_0 S}(x_2 - x_1)$

(c) $W = \frac{q^2}{2\varepsilon_0 S}(x_2 - x_1)$ (d) $W = \frac{q^2}{4\varepsilon_0 S}(x_2 - x_1)$

76. A capacitor C is charged to a potential V by a battery. The emf of the battery is V. It is then disconnected from the battery and again connected with it, when its polarity reversed to the battery :

(a) The work done by the battery is $2CV^2$

(b) The total charge passing through the battery is $2CV$

(c) The initial and final energy of a capacitor is same

(d) all of the above

77. A capacitor is connected to a battery. If U_C is energy stored in capacitor, U_B is energy supplied by battery, then :

(a) $U_C = U_B$ (b) $U_C = \frac{1}{2} U_B$

(c) $U_C > U_B$ (d) none of these

78. A condenser of capacity $50\,\mu F$ is charged to 10 V. Its energy is equal to :

(a) 2.5×10^{-3} J (b) 2.5×10^{-4} J

(c) 5×10^{-2} J (d) 1.25×10^{-8} J

79. A capacitor is charged by using a battery, which is then disconnected. A dielectric slab is then slided between the plates which results in :

(a) reduction of charge on the plates and increase of potential difference across the plates

(b) increase in the potential difference across the plates, reduction in stored energy, but no change in the charge on the plates

(c) decrease in the potential difference across the plates, reduction in stored energy, but no change in the charge on the plates

(d) none of the above

80. Two identical capacitors are joined in parallel, charged to a potential V, separated, and then connected in series, *i.e.* the positive plate of one is connected to the negative of the other

(a) The charge on the plates connected together are destroyed

(b) The charge on free plates are enhanced

(c) The energy-stored in the system is increased

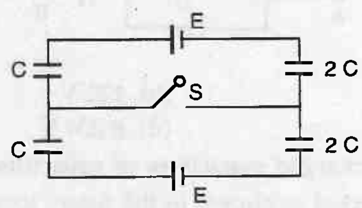
(d) The potential difference between the free plates is 2 V

81. An isolated metallic object is charged in vacuum to a potential V_0, its electrostatic energy being W_0. It is then disconnected from the source of potential, its charge being left unchanged and is immersed in a large volume of dielectric, with dielectric constant K. The electrostatic energy will be

(a) $K W_0$ (b) W_0/K

(c) $\frac{W_0}{2K}$ (d) W_0

82. The energy stored in the capacitors is U when S is open. Now S is closed, the charge passed through S is Q, then :



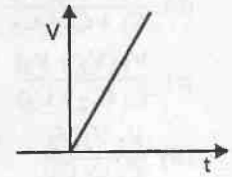
(a) $U = 0,\ Q = 2CE$ (b) $U = CE^2,\ Q = 0$

(c) $U = 0,\ Q = \frac{7}{6} CE$ (d) $U = 0,\ Q = \frac{2}{3} CE$

83. Select the correct statement :

(a) The energy of a capacitor resides in the field between the plates

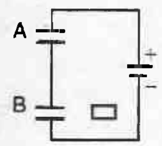
(b) the capacitance of a parallel plate capacitor does not depend on the metal of the plates



(c) If the current charging a capacitor is kept constant, the potential difference V across the capacitor varies with time according to the adjacent graph

(d) All of the above

84. Two identical capacitors A and B shown in the given circuit are joined in series with a battery. If a dielectric slab of dielectric constant K is slipped between the plates of capacitor B and battery remains connected, then the energy of capacitor A will :



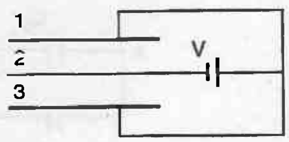
(a) decrease

(b) increase

(c) remain the same

(d) be zero since circuit will not work

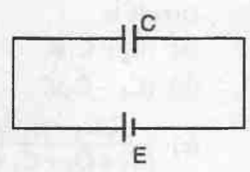
85. Three plates 1, 2 and 3 of area A each and separation between two consecutive plates d, are connected as shown in figure. The energy stored, when the plates are fully charged, is :



(a) $\frac{0.5\,\varepsilon_0 AV^2}{d}$ (b) $\frac{\varepsilon_0 AV^2}{d}$

(c) $\frac{2\varepsilon_0 AV^2}{d}$ (d) $\frac{\varepsilon_0 AV}{d}$

86. A parallel plate capacitor of capacitance C is connected across a battery of emf. If the separation between the plates is doubled, the force of attraction between the plates .... by a factor of .... :

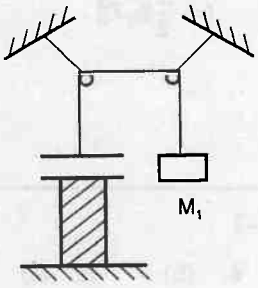


(a) increases, 4 (b) decreases, 4

(c) decreases, 2 (d) remains same

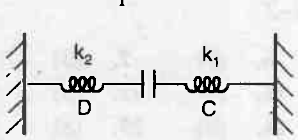
87. Force acting upon a charged particle, kept between the plates of a charged condenser is F. If one of the plates of the condenser is removed, force acting on the same particle will become :
(a) 0 (b) $F/2$
(c) F (d) $2F$

$\ast$ 88. In the given figure a capacitor of plate area A is charged upto charge q. The mass of each plate is m_2. The lower plate is rigidly fixed. Find the value of m_1, so that the system remains in equilibrium :



(a) $m_2 + \frac{q^2}{\varepsilon_0 Ag}$
(b) m_2
(c) $\frac{q^2}{2\varepsilon_0 Ag} + m_2$
(d) none of the above

89. In the given figure the capacitor of plate area A is charged upto charge q. The ratio of elongation (neglect force of gravity) in springs C and D at equilibrium position is :



(a) $\frac{k_1}{k_2}$ (b) $\frac{k_2}{k_1}$
(c) $k_1 k_2$ (d) none of these

90. A potential difference of 500 V is applied to a parallel plate condenser. The separation between plates is 2×10^{-3}m. The plates of the condenser are vertical. An electron is projected vertically upwards between the plates with a velocity of 10^5 m/s and it moves undeflected between the plates. The magnetic field acting perpendicular to the electric field has a magnitude of
(a) 1.5 Wb/m^2 (b) 2.0 Wb/m^2
(c) 2.5 Wb/m^2 (d) 3.0 Wb/m^2

91. If an electron enters a space between the plates of a parallel plate capacitor at an angle θ_1 with the plates and leaves at an angle θ_2 to the plates, the ratio of its kinetic energy while entering the capacitor to that while leaving will be :
(a) $\frac{\cos^2 \theta_2}{\cos^2 \theta_1}$ (b) $\frac{\cos^2 \theta_1}{\cos^2 \theta_2}$
(c) $\frac{\sin^2 \theta_2}{\sin^2 \theta_1}$ (d) $\frac{\sin^2 \theta_1}{\sin^2 \theta_2}$

92. A parallel plate condenser is charged by a battery. The battery is removed and a thick glass slab is placed between the plates. Now :
(a) the capacity of the condenser is increased
(b) the potential across the plates is decreased
(c) the electric field between the plates is decreased
(d) all of the above

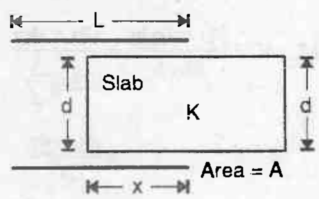
93. A parallel plate capacitor is connected to a battery of constant emf. Let the electric field at a given point between the plate be E_0, when there is no medium between the plates. The new electric field at that point, if a medium of dielectric constant A is introduced between them, is :
(a) $E_0/4$ (b) $E_0/2$
(c) E_0 (d) $4E_0$

94. A parallel plate capacitor is connected to a battery. The quantities charge, voltage, electric field and energy associated with the capacitor are given by Q_0, V_0, E_0 and U_0, respectively. A dielectric slab is introduced between plates of capacitor but battery is still in connection. The corresponding quantities now given by Q, V, E and U related to previous ones are :
(a) $Q > Q_0$ (b) $V > V_0$
(c) $E > E_0$ (d) $U < U_0$

95. An air filled parallel plate capacitor has a capacitance of 10^{-12} F. The separation of the plates is doubled and wax is inserted between them, which increases the capacitance to 2×10^{-12} F. The dielectric constant of wax is :
(a) 2 (b) 3
(c) 4 (d) 8

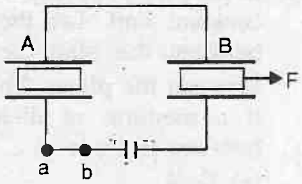
96. A parallel plate capacitor of plate separation d and plate area A is charged to a potential difference V and then the battery is disconnected. To fulfill the space between the plates of capacitor, a slab of dielectric constant K is inserted. If the magnitude of the charge on each plate, electric field between the plates (after the slab is inserted) and work done on the system in the process of insertion of a slab are Q, E, W respectively, then
(a) $Q = \varepsilon_0 \frac{AV}{d}$ (b) $W = \varepsilon_0 \frac{AV^2}{2d}\left(1 - \frac{1}{K}\right)$
(c) $E = \frac{V}{Kd}$ (d) all of the above

97. Between the plates of parallel plate capacitor, a dielectric slab of dielectric constant K is inserted. Plates have area A and distance between the plate is d and charge on the plate is Q. If the inserted length is x and the edge effect is ignored then the force on the slab is : (Given: $C_0 = \varepsilon_0 A/d$)



(a) attractive and equal to $\frac{Q}{2C_0 L}(K-1)$
(b) repulsive and equal to $\frac{Q}{2C_0 L}(K-1)$
(c) attractive and equal to $\frac{Q^2}{2C_0 L} \times \frac{(K-1)}{\left[1 + \frac{x}{L}(K-1)\right]^2}$
(d) repulsive and equal to $\frac{Q^2}{2C_0 L} \times \frac{(K-1)}{\left[1 + \frac{x}{L}(K-1)\right]^2}$

98. Inside two identical capacitors, two identical dielectric slabs are introduced as shown in figure. What will happen, if slab of capacitor B is pulled out, with the battery remain connected ?



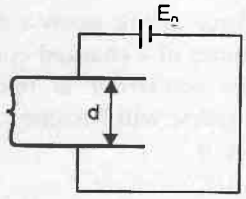
(a) During the process charge flows from a to b

(b) Finally charge on B will be less than charge on A

(c) During the process work done by external force F appear as heat in the circuit

(d) None of the above

99. A capacitor connected to cell of emf E_0 is immersed in a dielectric liquid having dielectric constant K. The liquid with in the gap is at an excess pressure of :



(a) $\frac{1}{2}\varepsilon_0 E_0^2\left(1-\frac{1}{K}\right)$ (b) $\frac{1}{2}\varepsilon_0 \frac{E_0^2}{d}\left(\frac{1}{K}-1\right)$

(c) $\frac{1}{2}\varepsilon_0 E_0^2$ (d) none of these

Answers

Level-1

1. (a)	2. (b)	3. (c)	4. (c)	5. (d)	6. (b)	7. (c)	8. (c)	9. (b)	10. (c)
11. (a)	12. (a)	13. (d)	14. (a)	15. (d)	16. (d)	17. (c)	18. (b)	19. (b)	

Level-2

1. (b)	2. (c)	3. (c)	4. (a)	5. (c)	6. (b)	7. (d)	8. (b)	9. (c)	10. (a)
11. (a)	12. (c)	13. (b)	14. (b)	15. (d)	16. (c)	17. (b)	18. (d)	19. (c)	20. (d)
21. (c)	22. (a)	23. (d)	24. (b)	25. (c)	26. (b)	27. (a)	28. (a)	29. (a)	30. (b)
31. (a)	32. (a)	33. (a)	34. (b)	35. (b)	36. (b)	37. (d)	38. (d)	39. (d)	40. (a)
41. (a)	42. (a)	43. (d)	44. (a)	45. (d)	46. (d)	47. (a)	48. (d)	49. (b)	50. (a)
51. (a)	52. (a)	53. (b)	54. (d)	55. (a)	56. (c)	57. (d)	58. (a)	59. (b)	60. (b)
61. (a)	62. (d)	63. (a)	64. (b)	65. (a)	66. (a)	67. (c)	68. (a)	69. (d)	70. (a)
71. (b)	72. (c)	73. (d)	74. (b)	75. (c)	76. (d)	77. (b)	78. (a)	79. (c)	80. (d)
81. (b)	82. (c)	83. (d)	84. (b)	85. (b)	86. (b)	87. (b)	88. (c)	89. (b)	90. (c)
91. (b)	92. (d)	93. (c)	94. (a)	95. (c)	96. (d)	97. (c)	98. (a)	99. (d)	

Solutions

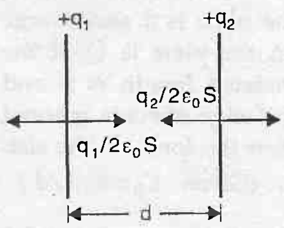
Level-1

2. $$10 = \frac{q}{4}+\frac{q}{6}+\frac{q}{12}$$

$\therefore$ $$q = 20\ \mu\text{C}$$

12. $$V = \frac{(q_1-q_2)d}{2\varepsilon_0 S} = \frac{(q_1-q_2)}{2\varepsilon_0 \frac{S}{d}}$$

$$= \frac{q_1-q_2}{2C}$$



19. $$I = \frac{Q}{t} = \frac{CV}{t}$$

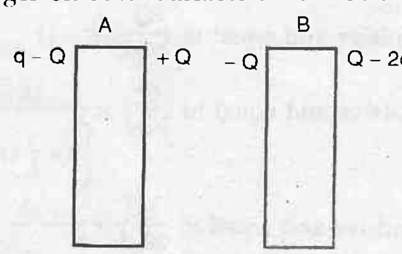
$\Rightarrow$ $$t = \frac{CV}{I}$$

$$= \frac{30\times10^{-6}\times 400}{30\times10^{-3}}$$

$$= 0.4\ \text{s}$$

Level-2

2. The charges on outer surfaces should be same.



$\therefore$ $$q - Q = Q - 2q$$

or $$3q = 2Q$$

$\therefore$ $$q = \frac{2}{3}Q$$

$\therefore$ $$Q = \frac{3}{2}q$$

$\therefore$ $$V = \frac{\text{charge on inner surface}}{C} = \frac{Q}{C} = \frac{3q}{2C}$$

Electric field is given by

$\therefore$ $$E = \frac{V}{d} = \frac{3q}{2Cd}$$

26

Current Electricity

Syllabus: *Current as a rate of flow of charges, source of energy, primary and secondary cell, grouping of cells, resistance of different materials, temperature dependence, specific resistance, Ohm's law, Kirchhoff's law, series and parallel circuits. Wheatstone bridge, measurement of voltages, currents, potentiometer, heating effects of current, electric power, simple concept of thermoelectricity (Seebeck effect and its explanation), thermocouple and chemical effects of current and laws of electrolysis.*

Review of Concepts

1. Electric Current:

(a) Electric current is the rate of transfer of charge through a certain surface.

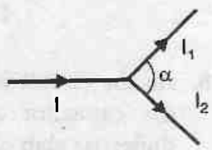
(b) The direction of electric current is as that of flow of positive charge.

(c) If a charge Δq cross an area in time Δt, then the average current $= \dfrac{\Delta q}{\Delta t}$

(d) Its unit is C/s or ampere.

(e) Electric current has direction as well as magnitude but it is a scalar quantity.

(f) Electric current obeys simple law of algebra.



i.e., $$I = I_1 + I_2$$

2. Types of Current:

(a) **Steady state current or constant current:** This type of current is not function of time.

$\therefore$ $$q = It$$

(b) **Transient or variable current:** This type of current passing through a surface depends upon time.

i.e., $$I = f(t)$$

or $$I = \lim_{\Delta t \to 0} \frac{\Delta q}{\Delta t} \Rightarrow \frac{dq}{dt}$$

(c) Average current $I = \dfrac{\int_0^t I\,dt}{\int_0^t dt}$

(d) **Convection Current:** The electric current due to mechanical transfer of charged particle is called convection current.

Convection current in different situations.

Case I: If a point charge is rotating with constant angular velocity ω.

$$I = \frac{q}{T}$$

$$T = \frac{2\pi}{\omega}$$

$$I = \frac{q\omega}{2\pi}$$

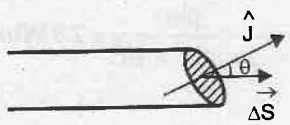
Case II: If a non-conducting ring having λ charge per unit length is rotating with constant angular velocity ω about an axis passing through centre of ring and perpendicular to the plane of ring.

$$I = R\lambda\omega$$

(e) **Direct Current (DC):** If the direction of current does not change then this type of current is known as direct current.

(f) **Alternating Current (AC):** Electric current reverses its direction after a fixed interval of time is known as alternating current.

3. Current Density: The average electric current density at a point is defined as the ratio of current through the area ΔS which is normal to the direction of charge flows and the ΔS.



$$j = \frac{\Delta I}{\Delta S}$$

or $$J = \frac{\Delta I}{\Delta S \cos\theta}$$

(a) Its unit A/m^2

(b) Electric current can be defined as flux of current density vector.

i.e., $$i = \int \vec{j} \cdot \vec{dS}$$

(c) Relation between drift velocity and current density

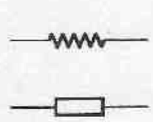
$$\vec{v}_d = -\frac{\vec{j}}{en}$$

Here, negative sign indicates that drifting of electrons takes place in the opposite direction of current density.

4. Electric Resistance: Electric resistance (R) is defined as the opposition to the flow of electric charge through the material.

(a) It is a microscopic quantity.

(b) Its symbol is



(c) Its unit is ohm.

(d) Electric resistance $R = \frac{\rho l}{A}$

where, R = resistance, ρ = resistivity of the material,

l = length of the conductor, A = area of cross-section

5. **Continuity Equation :**

$$\int_c \vec{j} \cdot \vec{dS} = -\frac{dq}{dt}$$

The continuity equation is based on conservation principle of charge.

6. **Drift Velocity (v_d) :** When a potential difference is applied between ends of metallic conductor, an electric field is established inside the metallic conductor. Due to this, electrons modify their random motion and starts to drift slowly in the opposite direction of electric field. The average velocity of drifting possesed by electrons is known as drift velocity.

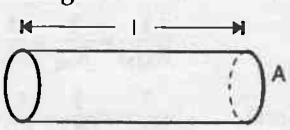
$$\vec{v}_d = \left(\frac{e\tau}{m}\right)\vec{E}$$

where, $\vec{v}_d$ = drift velocity, e = electron charge,

m = mass of electron,

$\vec{E}$ = electric field

7. **Variation of Resistance with Temperature :** Let a metallic conductor of length l and cross-sectional area A.



$$R_t = R_0\,(1 + \alpha t)$$

where, R_t = resistance of conductor at temperature t°C,

R_0 = resistance of conductor at 0°C,

α = temperature coefficient

Some Important Points :

(i) 'α' is proportionality constant known as temperature coefficient of resistance variation.

(ii) The value of α does not depend upon initial and final resistance of the conductor.

(iii) The value of α depends upon the unit which is chosen.

(iv) The value of α may be negative.

8. **Electric Conductance (G) :** It is reciprocal of resistance,

$$G = \frac{1}{R}$$

(a) Its unit is per ohm.

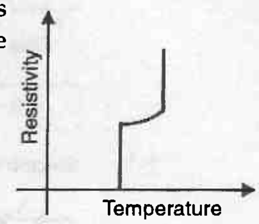
(b) Electric conductivity $\sigma = \frac{1}{\rho}$

9. **Thermistor :** When temperature increases, the resistivity of semiconductor decreases. This fact is employed to construct a thermometer to measure small changes in temperature. This device is knowon as thermistor.

10. **Superconductor :** The resistivity of few materials suddenly becomes zero below a certain temperature. This temperature is known as critical temperature. For this transition, the material in this state is known as super conductor.

(a) Mercury behaves as superconductor at 4°K.

(b) The variation of resistivity with temperature for superconductor.



11. **Ohm's Law :** According to ohm's law, electric current passing through a conductor is proportional to the potential difference between ends of the conductor.

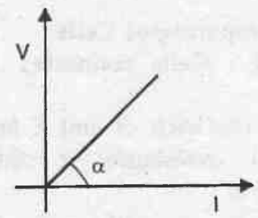
i.e., $V = IR$

In vector form:

$$E = \rho\,\vec{j}$$

where, $\rho = \frac{m}{ne^2\tau}$ = resistivity of material

(a) In case of ohm's law, V-I graph is straight line.



(b) Ohm's Law fails in case of vacuum tubes, crystal diodes, thyristors etc.

12. **EMF and P.D. of a Cell :** A device which supplies electric energy is called a seat of electromotive force or simply a seat of emf. The seat of emf is also called a cell.

(a) A battery is a device which manages a potential difference between its two terminals.

(b) e = EMF of the battery is the work done by the force per unit charge.

(c) When the terminals of a cell are connected to an external resistance, the cell is said to be in closed circuit.

(d) EMF has no electrostatic origin.

13. **Internal Resistance of a Cell (r) :** Internal resistance of a cell is the resistance of its electrolyte.

The internal resistance of cell :

(a) varies directly as concentration of the solution of the cell.

(b) varies directly as the separation between electrodes *i.e.*, length of solution between electrodes.

(c) varies inversely as the area of immersed electrodes.

(d) is independent of the material of electrodes.

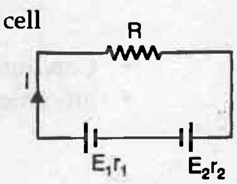
14. **Potential Difference Across the Cell:** When a battery being charged, the terminal voltage is greater than its emf $V = E + Ir$.

Potential difference across the first cell

$V_1 = E_1 + Ir_1$ (discharging of cells)

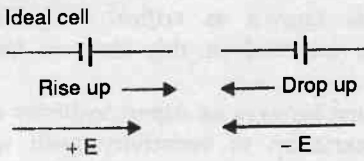
Potential difference across the second cell

$V_2 = E_2 - Ir_2$ (charging of cells)

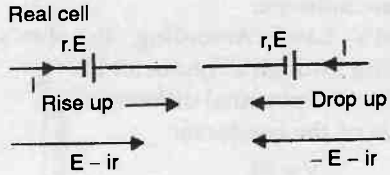


Concept of rise up and drop up of voltage :

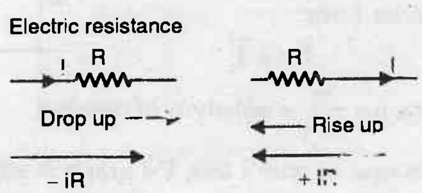
(a)



(b)



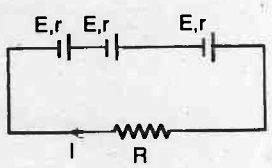
(c)



15. Comparing of Cells :

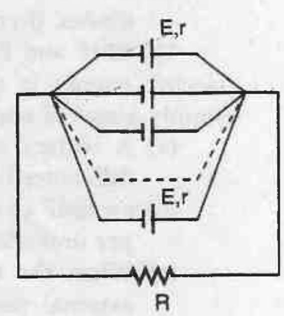
Case I : Cells connected in series

Let n cells each of emf E and internal resistance r then current is



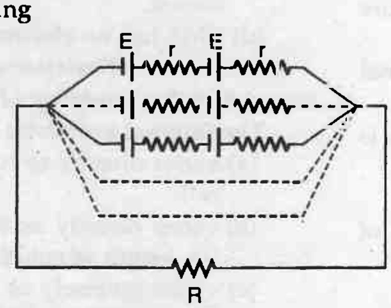
$$I = \frac{nE}{nr + R}$$

Case II: Cells connected in parallel then current is



$$I = \frac{E}{\left(R + \frac{r}{n}\right)}$$

Case III: Mixed grouping



Equivalent internal resistance $= \frac{nr}{m}$

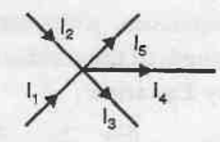
$$I = \frac{nE}{\frac{nr}{m} + R}$$

- Condition for maximum current. $nr = mR$
- Efficiency of a cell (η)

$$\eta = \frac{\text{useful power}}{\text{total power produced}}$$

16. Kirchhoff's Law: Kirchhoff's law is able to solve complicated circuit problems.

(i) First Law:



Incoming current = Outgoing current

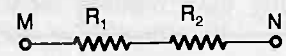
$$I_1 + I_2 = I_3 + I_4 + I_5$$

This law is based upon conservation principle of charge.

(ii) Second Law: (Loop rule or voltage law.) This law is based upon conservation principle of energy.

17. Grouping of Resistors :

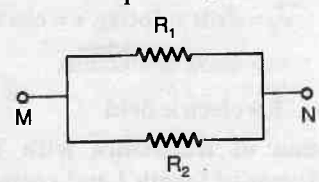
Case I: Resistors in series



$$R_{MN} = R_{eq} = R_1 + R_2$$

In general, $R_{eq} = R_1 + R_2 + \ldots + R_n$

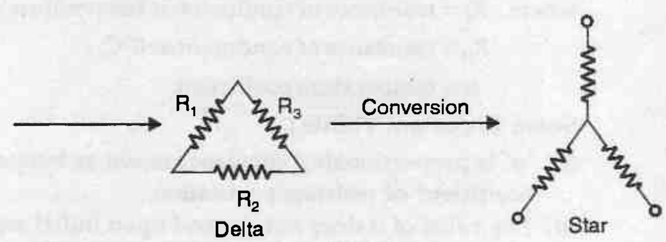
Case II: Resistors in parallel.

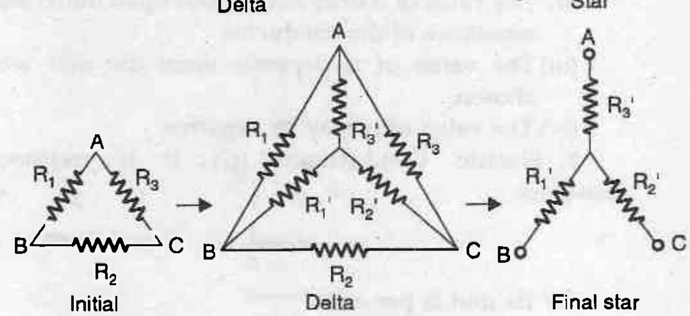


$$\frac{1}{R_{MN}} = \frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$

In general, $\frac{1}{R_{MN}} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_n}$

(a) Star-delta Conversion :





where $R_1' = \frac{R_1R_2}{R_1 + R_2 + R_3}$

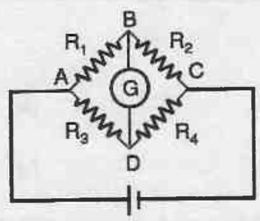
$$R_2' = \frac{R_2R_3}{R_1 + R_2 + R_3}; \quad R_3' = \frac{R_1R_3}{R_1 + R_2 + R_3}$$

(b) When wire is drawn n times, then resistance becomes n^2R.

(c) When a wire of resistance R is folded n times such that the new length is $1/n$ of its original length, then the new resistance $= \frac{R}{n^2}$.

(d) If $A_1, A_2, \ldots A_n$ be n junctions of a network of wires, then these can be connected by at most ${}^nC_2 = \frac{n(n-1)}{2}$ linear conductors.

18. Wheatstone Bridge:



$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

19. Heating Effect of Current:

Heat produced $Q = \frac{W}{J} = \frac{Vit}{J} = \frac{i^2Rt}{J}$

(a) Power $(P) = Vi = i^2R = \frac{V^2}{R}$

(b) Its unit is watt.

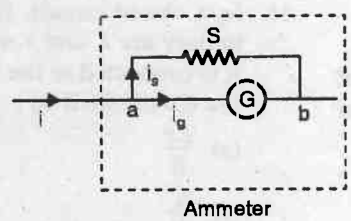
(c) A current i enters the top of a copper sphere of radius r and leaves through the diametrically opposite point. All parts of sphere are not affected equally in dissipating joule's heat.

20. Moving Coil Gavanometer: A galvanometer is used to detect the current and has moderate resistance.

A. Conversion of galvanometer into an ammeter: An ammeter is a low resistance galvanometer and used to measure current directly in ampere.

(a) It is always connected in series with the circuit.

(b) To convert a galvanometer into ammeter a low resistance, called shunt (S) is connected in parallel to the galvanometer as shown in figure.



Here, $i_g = \frac{S}{(S+G)} i$

and $R_A = \frac{(S)(G)}{(G+S)}$

where, R_A = resistance of ammeter,

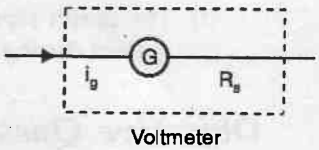
S = resistance of shunt

G = resistance of galvanometer

B. Conversion of galvanometer into voltmeter: A voltmeter is a high resistance galvanometer and is connected between two points across which potential difference is to be measured.

(a) A voltmeter is always connected in parallel to the circuit.

(b) To convert a galvanometer into a voltmeter, high resistance R in series is connected with the galvanometer.



Here, $i_S = \frac{V}{R_S + G}$

$R_V = R_S + G$

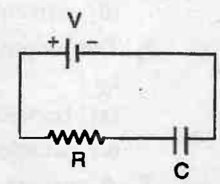
where, R_V = resistance of voltmeter.

21. Charging of a Capacitor: Let q be the charge of capacitor and i the current flowing in circuit after time t during the charging process.

The potential difference across resistance, $V_R = Ri$

The potential difference across the capacitor $V_C = \left(\frac{q}{C}\right)$

(a) The equation of charging of capacitor



$$q = q_0(1 - e^{-t/RC})$$

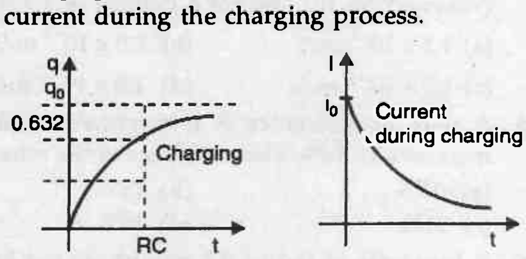
where $RC = T$ = the capacitive time constant of the circuit.

(b) The time constant is the time in which the charge on the capacitor reaches 0.632 time the initial. The current during the process of charging.

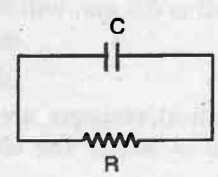
$$i = i_0 e^{-t/RC}$$

where, $i_0 = V/R$ – maximum current

(c) The graph representing the variation of charge and current during the charging process.



22. Discharging of Capacitor :



(a) In this process the capacitor is gradually discharged.

(b) The discharging current ceases when the potential difference across the capacitor plates reduce to zero.

(c) The equation represents the discharging of capacitor through resistance R

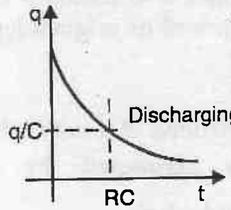
$$q = q_0 e^{-t/RC}$$

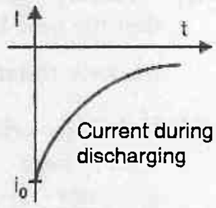
where $RC = T$ = time constant

(d) Here, time constant is the time in which charge capacitor falls to 0.368 times of its initial value during the discharging process.

(e) The current at any instant $i = \frac{dq}{dt} = -i_0 e^{-t/RC}$

(f) The graph representing the variation of charge and current during discharging process.





Objective Questions

Level-1

1. A steady current flows in a metallic conductor of non-uniform cross-section. The quantity constant along the length of the conductor is :
   (a) current, electric field and drift speed
   (b) drift speed only
   (c) current and drift speed
   (d) current only

2. The length of a conductor is halved. Its conductance will be :
   (a) halved (b) unchanged
   (c) doubled (d) quadrupled

3. A current of 3.2 A is flowing through a conductor, the number of electrons flowing per second is :
   (a) 51.2×10^{19} (b) 5.12×10^{24}
   (c) 3.2×10^{19} (d) 2×10^{19}

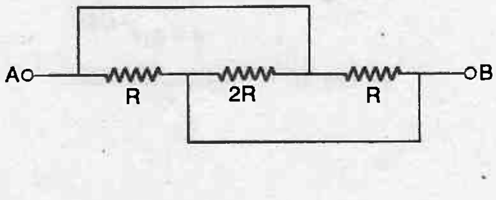
4. If the number of free electrons is $5 \times 10^{28}\ m^{-3}$ then the drift velocity of electron in a conductor of area of cross-section $10^{-4}\ m^2$ for a current of 1.2 A is :
   (a) 1.5×10^{-2} m/s (b) 1.5×10^{-3} m/s
   (c) 1.5×10^{-4} m/s (d) 1.5×10^{-6} m/s

5. A wire of resistance R is stretched so that its length increases by 10%. The resistance of the wire increases by :
   (a) 11% (b) 15%
   (c) 21% (d) 28%

6. A fuse wire of radius 0.2 mm blows out for a current of 5 A. For what current, another fuse wire of same material but of radius 0.3 mm will blow out ?
   (a) 5 A (b) 3.2 A
   (c) 4.33 A (d) 11.2 A

7. Two identical resistors are connected in parallel then connected in series. The effective resistances are in the ratio :
   (a) 1 : 2 (b) 2 : 1
   (c) 1 : 4 (d) 4 : 1

8. The effective equivalent resistance between A and B in the figure, is :



   (a) $\frac{3}{2}R$ (b) $\frac{2}{3}R$
   (c) $\frac{2}{5}R$ (d) $2R$

9. Three 2 Ω resistors are connected to form a triangle. The resistance between any two corners is :
   (a) 6 Ω (b) 2 Ω
   (c) $\frac{3}{4}$ Ω (d) $\frac{4}{3}$ Ω

10. The resistance of two conductors in series is 40 Ω and this becomes 7.5 Ω in parallel, the resistances of conductors are :
    (a) 20 Ω, 20 Ω (b) 10 Ω, 30 Ω
    (c) 15 Ω, 25 Ω (d) 18 Ω, 22 Ω

11. A wire has resistance 12 Ω. It is bent in the form of a circle. The effective resistance between the two points on any diameter of the circle is :
    (a) 12 Ω (b) 24 Ω
    (c) 6 Ω (d) 3 Ω

12. When cells are connected in series :
    (a) the emf increases
    (b) the P.D. decreases
    (c) the current capacity increases
    (d) the current capacity decreases

13. In a closed circuit, the emf and internal resistance of a battery are E and r respectively. If an external resistance R is connected to the battery, the current flowing through the circuit shall be :
    (a) $\frac{Er}{R}$ (b) $\frac{E}{R+r}$
    (c) $\frac{E}{rR}$ (d) $\frac{ER}{r}$

14. A carbon resistor has colour strips as violet, yellow, brown and golden. The resistance is :
    (a) 641 Ω (b) 741 Ω
    (c) 704 Ω (d) 407 Ω

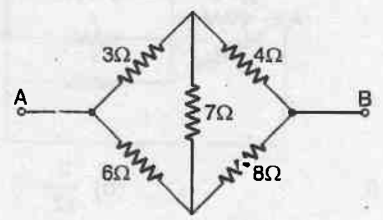
15. A wire $l = 8$ m long of uniform cross-sectional area $A = 8\ mm^2$, has a conductance of $G = 2.45\ \Omega^{-1}$.The resistivity of material of the wire will be ?
    (a) 2.1×10^{-7} s (b) 2.1×10^{-7} s
    (c) 4.1×10^{-7} s (d) 5.1×10^{-7} s

16. A car has a fresh battery of emf 12 V and internal resistance of 0.05 Ω. If the starter of motor draws a current of 90 A, the terminal voltage when the starter is on, will be :

(a) 12 V (b) 10.5 V
(c) 8.5 V (d) 7.5 V

17. The momentum acquired by the electrons in 10 cm of the wire when a current of 1 amp, starts to flow, is :
(a) 5.6×10^{-13} kg m/s (b) 5.6×10^{-7} kg m/s
(c) 2.8×10^{-13} kg m/s (d) 2.8×10^{-7} kg m/s

18. Five resistances have been connected as shown in figure, the effective resistance between A and B is :
(a) $26\,\Omega$
(b) $4.6\,\Omega$
(c) $7.3\,\Omega$
(d) $2.8\,\Omega$



19. If R_1 and R_2 be the resistances of the filaments of 200 W and 100 W electric bulbs operating at 220 V then :
(a) R_1 is equal to R_2
(b) R_1 is twice that of R_2
(c) R_2 is twice that of R_1
(d) there is no relation between R_1 and R_2

20. The sensitivity of galvanometer of resistance $406\,\Omega$ is increased by 30 times. The shunt used is :
(a) $88\,\Omega$ (b) $14\,\Omega$
(c) $6\,\Omega$ (d) $16\,\Omega$

21. A 50 V battery is connected across a $10\,\Omega$ resistor, the current is 4.5 A. The internal resistance of the battery is :
(a) zero (b) $0.5\,\Omega$
(c) $1.1\,\Omega$ (d) $5.0\,\Omega$

22. A galvanometer of resistance $400\,\Omega$ can measure a current of 1mA. To convert it into a voltmeter of range 8 V, the required resistance is :
(a) $4600\,\Omega$ (b) $5600\,\Omega$
(c) $6600\,\Omega$ (d) $7600\,\Omega$

23. A battery of emf 1.2 V and internal resistance $0.5\,\Omega$ is connected to resistance of $0.5\,\Omega$, the P.D. across the resistor is :
(a) 1.2 volt (b) 1.1 volt
(c) 1.05 volt (d) 1 volt

24. A 220 V and 100 W lamp is connected to 220 V power supply. What is the power consumed ?
(a) 100 W (b) 200 W
(c) More than 100 W (d) None of these

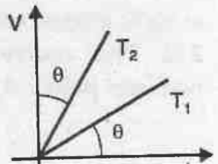
Level-2

1. A solid cylinder whose radius is R, rotates with a constant angular velocity ω. The potential difference between surface of cylinder and the axis is :
(a) $\dfrac{mR^4\omega^2}{2e}$ (b) $\dfrac{m\,\omega^2R^2}{2e}$
(c) $\dfrac{m\,\omega^2R^2}{e}$ (d) none of these

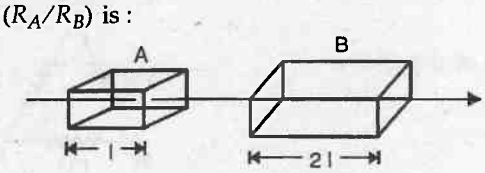
2. Mark correct option or options :
(a) In the absence of an electric field, electrons move in straight lines between collisions
(b) Relaxation time is of order 10^{-14} second
(c) Resistivity is inversely proportional to relaxation time when number of electrons per unit volume of material remains constant
(d) All the above

3. What is the drift velocity of electrons if the current flowing through a copper wire of 1 mm diameter is 1.1 A ? Assume that each atom of copper contributes one electron : (Given : density of Cu = 9 g/cm^3 and atomic weight of Cu = 63)
(a) 0.3 mm/s (b) 0.5 mm/s
(c) 0.1 mm/s (d) 0.2 mm/s

4. The V-I graph for a conductor at temperature T_1 and T_2 are as shown in the figure, $(T_2 - T_1)$ is proportional to :
(a) $\dfrac{\cos 2\theta}{\sin^2\theta}$ (b) $\dfrac{\sin 2\theta}{\sin^2\theta}$
(c) $\dfrac{\cot 2\theta}{\sin^2\theta}$ (d) $\dfrac{\tan 2\theta}{\sin^2\theta}$



5. Two square metal plates (A) and (B) are of the same thickness and material. The side of (B) is twice that of (A). These are connected as shown in series. If the resistances of (A) and (B) are denoted by (R_A) and (R_B), then (R_A/R_B) is :



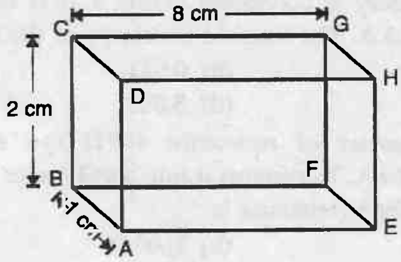
(a) 1/2 (b) 2/1
(c) 1/1 (d) 4/1

6. Which of the following arrangements is correct on the basis of conductivity of materials ?
(a) silver > copper > aluminium > tungsten > water
(b) silver > aluminium > copper > water
(c) copper > silver > tungsten > water
(d) water > silver > tungsten > water

7. A nichrome wire 50 cm long and 1 mm^2 in cross-section carries a current of 4 A when connected to a 2 V storage battery. The resistivity of nichrome is
(a) $1 \times 10^{-6}\,\Omega$ m (b) $2 \times 10^{-7}\,\Omega$ m
(c) $4 \times 10^{-7}\,\Omega$ m (d) $5 \times 10^{-7}\,\Omega$ m

8. A wire with a resistance of $20\,\Omega$ is drawn out so that its length becomes thrice its original length. The new resistance is :
(a) $60\,\Omega$ (b) $\dfrac{20}{3}\,\Omega$
(c) $180\,\Omega$ (d) $18\,\Omega$

9. If R_1 be the resistance of the shown conductor between faces $ABCD$ and $EFGH$ and R_2 between faces $BCGF$ and $ADHE$, $\frac{R_1}{R_2}$ will be :

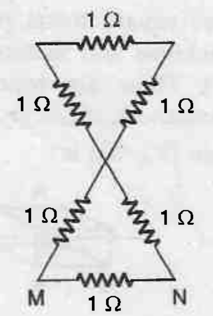


(a) 1 (b) 4
(c) 16 (d) 64

10. A wire of resistance $4\,\Omega$ is stretched to twice its original length. What is the resistance of the wire now ?
(a) $1\,\Omega$ (b) $14\,\Omega$
(c) $8\,\Omega$ (d) $16\,\Omega$

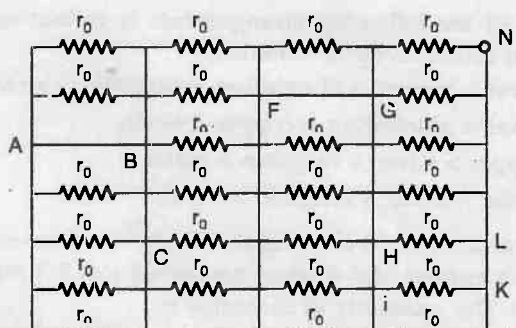
11. The ratio of the lengths, densities, masses and resistivities of two wires A and B are $1:2$, $1:2$, $1:1$, $1:4$ respectively. The ratio of their resistances are :
(a) $1:32$ (b) $1:16$
(c) $8:1$ (d) $4:1$

12. The equivalent resistance between points M and N is :



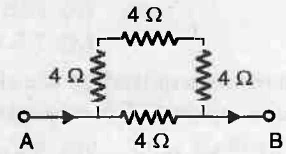
(a) $2\,\Omega$
(b) $3\,\Omega$
(c) $\frac{2}{3}\,\Omega$
(d) none of the above

13. In the given circuit, the equivalent resistance between points M and N is :



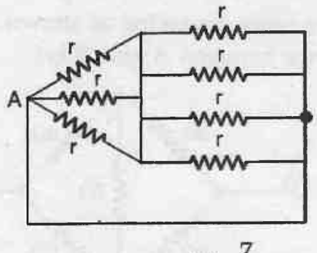
(a) infinity (b) $\frac{2}{3}r_0$
(c) zero (d) none of these

14. Four resistances each of value $4\,\Omega$, are connected as shown in figure. The equivalent resistance between points A and B is :



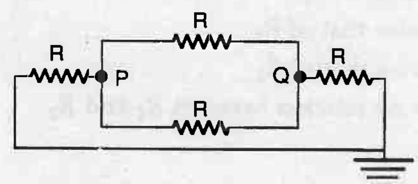
(a) $2\,\Omega$
(b) $3\,\Omega$
(c) $4\,\Omega$
(d) $16\,\Omega$

15. The equivalent resistance between points A and B is :



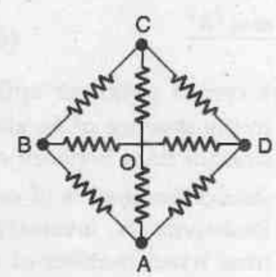
(a) 0 (b) $\frac{7}{12}r$
(c) $7r$ (d) $\frac{3r}{4}$

16. The net resistance between points P and Q in the circuit shown in the figure is :



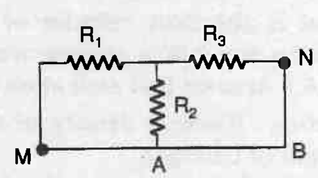
(a) $R/2$ (b) $2R/5$
(c) $3R/5$ (d) $R/3$

17. In the arrangement shown, the magnitude of each resistance is $1\,\Omega$. The equivalent resistance between O and A is given by :



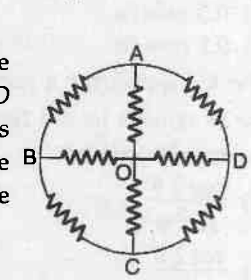
(a) $\frac{14}{15}\,\Omega$
(b) $\frac{7}{15}\,\Omega$
(c) $\frac{2}{3}\,\Omega$
(d) $\frac{5}{6}\,\Omega$

18. In the given circuit, the equivalent resistance between points M and N is :



(a) zero
(b) ∞
(c) $R_1 + \frac{R_2 R_3}{R_2 + R_3}$
(d) none of these

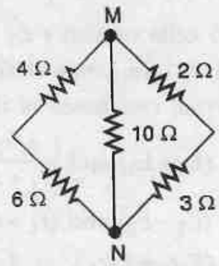
19. $ABCD$ is a uniform circular wire of resistance $4\,\Omega$ and OAC, BOD are two wires forming diameters at right angles, each of resistance $2\,\Omega$. The equivalent resistance between points A and D is :



(a) $\frac{15}{8}\,\Omega$ (b) $\frac{15}{7}\,\Omega$

(c) $1\,\Omega$ (d) $\frac{2}{3}\,\Omega$

20. The equivalent resistance between M and N will be :



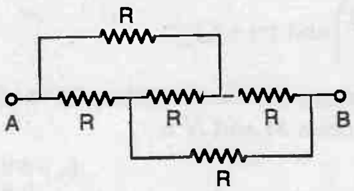
(a) $\frac{26}{15}\,\Omega$

(b) $\frac{8}{5}\,\Omega$

(c) $2\,\Omega$

(d) none of the above

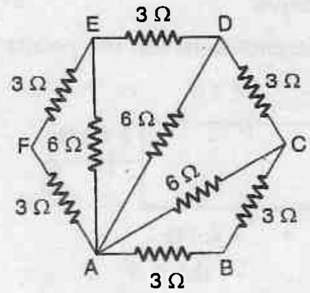
21. Figure shows five resistances, each of resistance R. The equivalent resistance between points A and B is :



(a) R (b) $5R$

(c) $R/5$ (d) $2R/3$

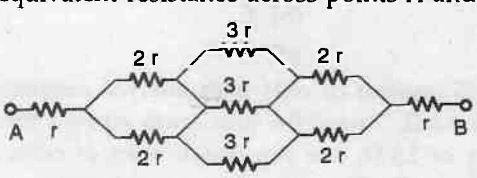
22. The equivalent resistance between points A and B is : :



(a) $2\,\Omega$ (b) $4\,\Omega$

(c) $3\,\Omega$ (d) $5\,\Omega$

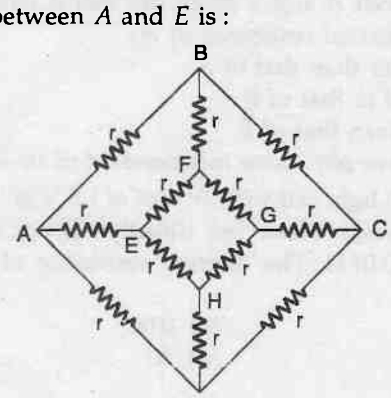
23. The equivalent resistance across points A and B is :



(a) $5r$ (b) $6r$

(c) $4r$ (d) $3r$

24. In the network of resistors, each of value r, equivalent resistance between A and E is :



(a) $\frac{7}{12}r$ (b) $\frac{7}{3}r$

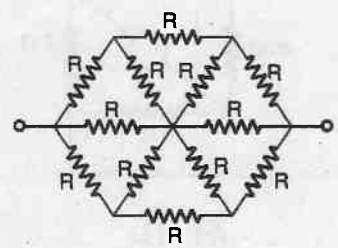
(c) $\frac{5}{6}r$ (d) $\frac{3}{4}r$

25. A steady current of 10 A is passed through a water voltameter for 300 sec. Assume relative molecular mass of H_2 is 2.016 and molar volume = 22.4 litre (volume of 1 mole of an ideal gas at STP.). Estimate the volume of H_2 evolved at standard temperature and pressure (Given : Faraday's constant = 96500 C/mole)

(a) 0.178 litre (b) 0.278 litre

(c) 1.78 litre (d) 2.78 litre

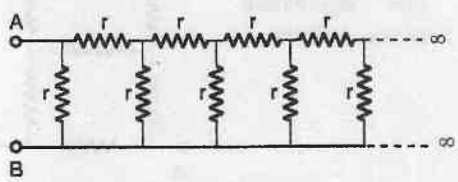
26. A regular hexagon with diagonal is prepared with identical wires, each having equal resistance R. The equivalent resistance between points A and B is :



(a) R (b) $2R$

(c) $0.8R$ (d) $0.4R$

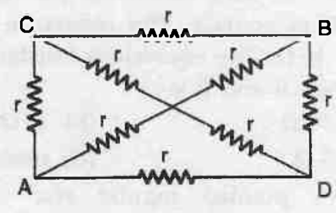
27. The equivalent resistance between A and B is :



(a) $(\sqrt{3}-1)\,r$ (b) $(\sqrt{3}+1)\,r$

(c) $\sqrt{3}\,r$ (d) none of these

28. The equivalent resistance between points A and B : (shown in figure) is :



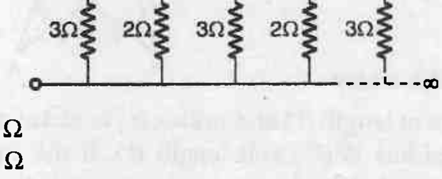
(a) $\frac{2}{3}r$

(b) $\frac{3}{2}r$

(c) $\frac{4}{5}r$

(d) none of the above

29. The equivalent resistance of this infinite network is very nearly equal to :



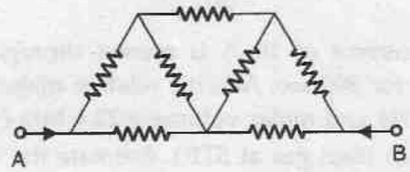
(a) $1\,\Omega$

(b) $2\,\Omega$

(c) $3\,\Omega$

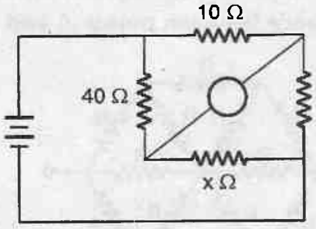
(d) $4\,\Omega$

30. In the network shown in the adjoining figure, each resistance is 1 Ω. The effective resistance between A and B is :



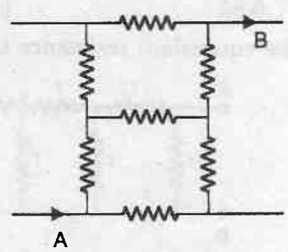
(a) $\frac{4}{3}\,\Omega$ (b) $\frac{3}{2}\,\Omega$
(c) 7 Ω (d) $\frac{8}{7}\,\Omega$

31. In the figure, galvanometer reads zero. The resistance X is :



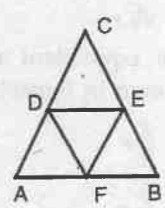
(a) 7 Ω (b) 21 Ω
(c) 14 Ω (d) 28 Ω

32. Seven resistances, each of value 5 Ω, are connected as shown in figure. The equivalent resistances between points A and B is :



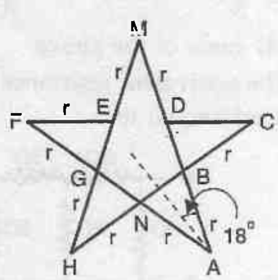
(a) 5 Ω
(b) 7 Ω
(c) 14 Ω
(d) 35 Ω

33. Two equilateral triangles ABC, DEF have same centroid. The ratio of sides are 4 : 2. The resistance per unit length in contact. The resistance in AB is 10 Ω. The equivalent resistance between A and B is :



(a) 5.56 Ω (b) 10 Ω
(c) 8.5 Ω (d) none of these

34. A five pointed regular star made from a uniform wire is shown in the figure. The resistance of the section BN is : (Given : sin 18° = 0.31)



(a) 0.62 r
(b) 0.82 r
(c) 0.97 r
(d) none of the above

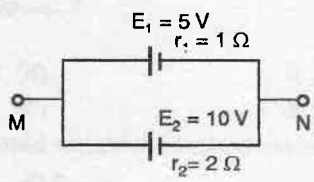
35. A copper wire of length (l) and radius (r) is nickel plated till its final radius is (R) and length (l). If the specific resistance of nickel and copper be k_n and k_c, the conductance of nickelled wire is :

(a) $\frac{\pi r^2}{l k_c}$ (b) $\frac{\pi [R^2 - r^2]}{l k_n}$
(c) $\frac{\pi}{l}\left(\frac{r^2}{k_c} + \frac{R^2 - r^2}{k_n}\right)$ (d) $\frac{l k_c}{\pi r^2} + \frac{l k_n}{\pi (R^2 - r^2)}$

36. Two cells of emf's E_1 and E_2 and internal resistance r_1 and r_2 are connected in parallel. Then the emf and internal resistance of the equivalent source are :

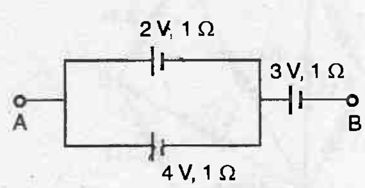
(a) $(E_1 + E_2)$ and $\left(\frac{r_1 r_2}{r_1 + r_2}\right)$
(b) $(E_1 - E_2)$ and $(r_1 + r_2)$
(c) $\left(\frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}\right)$ and $\left(\frac{r_1 r_2}{r_1 + r_2}\right)$
(d) $\left(\frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}\right)$ and $(r_1 + r_2)$

37. In the given circuit, the electromotive force of equivalent cell between points M and N is :



(a) $\frac{20}{3}$ V
(b) $\frac{3}{20}$ V
(c) zero
(d) none of the above

38. The potential difference between the points A and B is :



(a) 2 V (b) 6 V
(c) 4 V (d) 3 V

39. N identical cells, each of emf E, are connected in parallel. The emf of the combination is :
(a) NE (b) E
(c) N^2E (d) E/N

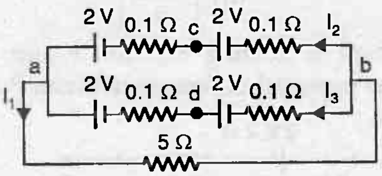
40. There are 45 number of cells with internal resistance of each cell is 0.5 Ω. To get the maximum current through a resistance of 2.5 Ω, one can use m rows of cells, each row having n cells. The values of m and n are :
(a) $m = 3$, $n = 15$ (b) $m = 5$, $n = 9$
(c) $m = 9$, $n = 5$ (d) $m = 15$, $n = 3$

41. A big dry cell A and a small dry cell B have the same emf. The internal resistance of A :
(a) is greater than that of B
(b) is equal to that of B
(c) is less than that of B
(d) may have any value independent of its size

42. A new flash light cell with an emf of 1.5 V gives a current of 15 A when connected directly to an ammeter of resistance 0.04 Ω. The internal resistance of the cell in ohm is :
(a) 0.04 (b) 0.06
(c) 0.10 (d) 10

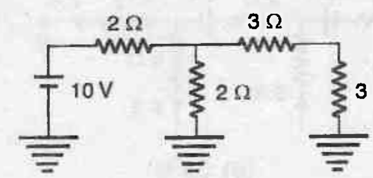
43. A cell supplies a current of 0.9 A through a 2 Ω resistor and a current of 0.3 A through a 7 Ω resistor. What is the internal resistance of the cell ?
(a) 0.5 Ω (b) 1.0 Ω
(c) 1.2 Ω (d) 2.0 Ω

44. In circuit shown in figure, the values of I_1, I_2 and I_3 are :



(a) 0.784 A, 0.392 A, 0.392 A
(b) 0.468 A, 0.529 A, 0.240 A
(c) 0.396 A, 0.729 A, 0.126 A
(d) none of the above

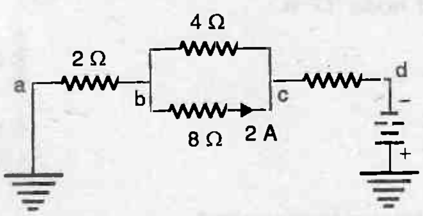
45. In the circuit shown, the current in 3 Ω resistance is :



(a) 1 A (b) 1/7 A
(c) 5/7 A (d) 15/7 A

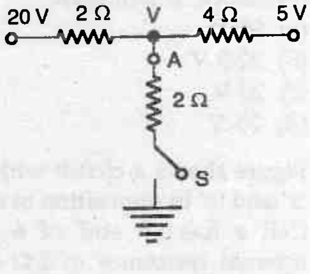
46. A, B, C, D are four points in succession at equal distances along a wire and A, C and B, D are also joined by two other wires of the same length as the distance between those pairs of point measured along the original wire. A current I enters the network thus, formed, at A and leaves at D. The electric current in BC is :
(a) $\frac{I}{5}$ (b) $\frac{I}{2}$
(c) $\frac{I}{4}$ (d) zero

47. What current is flowing through 2 Ω resistance ?



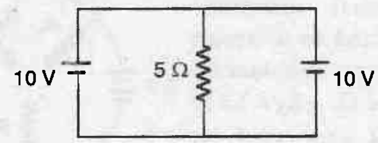
(a) 2 amp (b) 4 amp
(c) 6 amp (d) 8 amp

48. A switch S is closed in the circuit shown in figure, current passed through point A is :



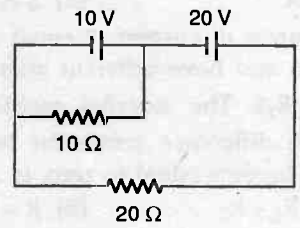
(a) 4.5 A
(b) 6.0 A
(c) 3.0 A
(d) zero

49. The current through the 5 Ω resistor is :



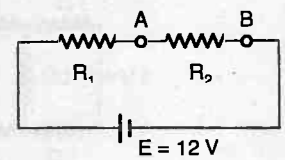
(a) 2 A (b) 4 A
(c) 0 (d) 1 A

50. In the shown network, current through 20 Ω resistor equals :



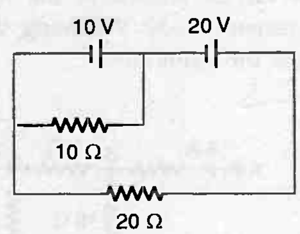
(a) $\frac{3}{2}$ A
(b) $\frac{2}{2}$ A
(c) 1 A
(d) $\frac{2}{3}$ A

51. When an ammeter of negligible internal resistance is inserted in series with circuit it reads 1 A. When the voltmeter of very large resistance is connected across R_1 it reads 3 V. But when the points A and B are short circuited by a conducting wire then the voltmeter measures 10.5 V across the battery. The internal resistance of the battery is equal to :



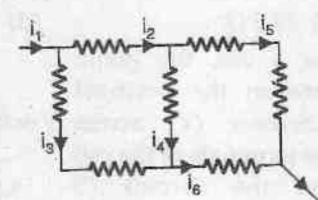
(a) $\frac{3}{7}$ Ω (b) 5 Ω
(c) 3 Ω (d) none of these

52. In the shown network current through 10 Ω resistor equals :



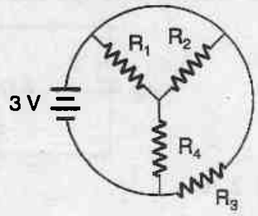
(a) $\frac{3}{2}$ A
(b) $\frac{5}{2}$ A
(c) 1 A
(d) $\frac{2}{3}$ A

53. A piece of uniform wire is made up into two squares with a common side as shown in the figure. Each side has a resistance R. A current enters the rectangular system at one of the corners and leaves through the diagonally opposite corner. Find the current through the common side (I_4) in terms of the entering current I_1 :



(a) $\frac{I_1}{4}$ (b) $\frac{I_1}{5}$
(c) $\frac{I_1}{7}$ (d) $\frac{I_1}{6}$

54. A battery of cells with an e.m.f. 3 V and internal resistance $1/4\,\Omega$ is connected to a circuit consisting four resistances, $R_1 = 1\,\Omega$, $R_2 = 3\,\Omega$, $R_3 = 1.5\,\Omega$ and $R_4 = 0.75\,\Omega$ connected as shown in the figure. What is the current in unbranched circuit?

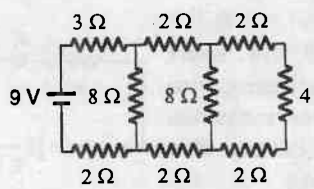


(a) 3 A (b) 6 A
(c) 1.5 A (d) 2 A

55. Two sources of current of equal e.m.f., E are connected in series and have different internal resistances R_1 and R_2 $(R_2 > R_1)$. The external resistance R at which the potential difference across the terminals of one of the sources become equal to zero, is :

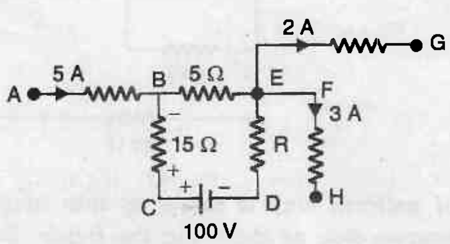
(a) $R = R_1 + R_2$ (b) $R = R_2 - R_1$
(c) $R = \dfrac{R_1}{R_2}$ (d) $R = R_1$

56. In the circuit shown in the figure, the current through :



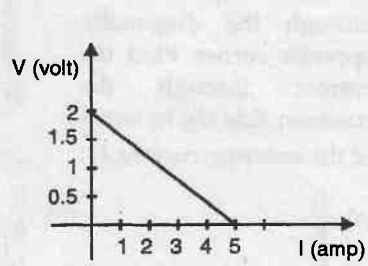
(a) the $3\,\Omega$ resistor is 0.5 A
(b) the $3\,\Omega$ resistor is 0.25 A
(c) the $4\,\Omega$ resistor is 0.5 A
(d) the $4\,\Omega$ resistor is 0.25 A

57. In the circuit shown in the figure, the voltage across $15\,\Omega$ resistor is 30 V having the polarity as indicated. What is the value of R?



(a) $10\,\Omega$ (b) $35\,\Omega$
(c) $17.5\,\Omega$ (d) $37.5\,\Omega$

58. For a cell, the graph between the potential difference (V) across the terminals of the cell and the current (I) drawn from the cell is shown in figure. The emf and the internal resistance of the cell are :

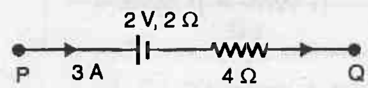


(a) $2\text{ V}, 0.4\,\Omega$ (b) $2\text{ V}, 0.5\,\Omega$
(c) $> 2\text{ V}, 0.4\,\Omega$ (d) $< 2\text{ V}, 0.4\,\Omega$

59. The ratio of the terminal potential difference to emf, if a cell of emf E and internal resistance 'r' is connected in series with an external resistance nr, is :

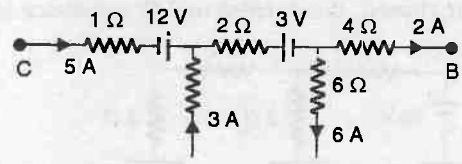
(a) $\dfrac{1}{n}$ (b) $\dfrac{1}{(n+1)}$
(c) $\dfrac{n}{(n+1)}$ (d) $\left(\dfrac{n+1}{n}\right)$

60. If 3 A of current is flowing between P and Q in the circuit, then the potential difference between P and Q is :



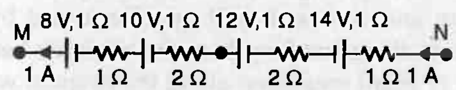
(a) 30 V (b) 22 V
(c) 20 V (d) 15 V

61. Potential difference $(V_C - V_B)$ in the circuit is :



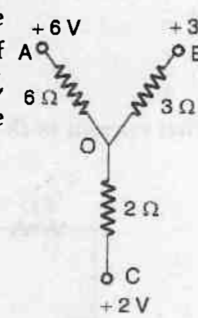
(a) 15 V (b) 38 V
(c) 20 V (d) 9 V

62. In the figure given below, the potential difference between points M and N is :



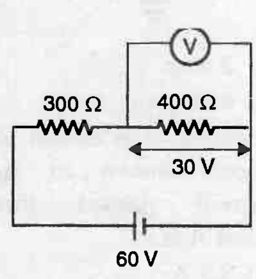
(a) 8 volt (b) 7 volt
(c) 6 volt (d) 9 volt

63. A circuit shown in the figure, is in the form of letter Y. The three terminals of the circuit A, B, C have potential 6 V, 3 V and 2 V respectively. The potentials of node 'O' is :



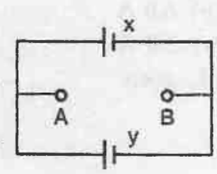
(a) $V_o = 5\text{ V}$
(b) $V_o = 6\text{ V}$
(c) $V_o = 3\text{ V}$
(d) $V_o = 2\text{ V}$

64. When a voltmeter is connected across a $400\,\Omega$ resistance, it reads 30 V. When it is connected with $300\,\Omega$ resistance, it will read :



(a) 30 V
(b) 22.5 V
(c) 20 V
(d) 25 V

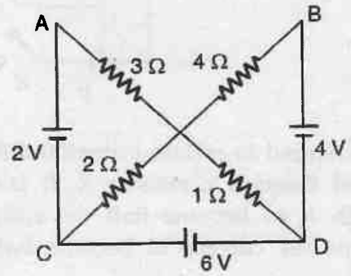
65. Figure shows a circuit with two cells 'x' and 'y' in opposition to each other. Cell x has an emf of 6 volts and internal resistance of $2\,\Omega$ and cell y has an emf of 4 V and internal



resistance of 8 Ω. What is the voltage between terminals A and B ?

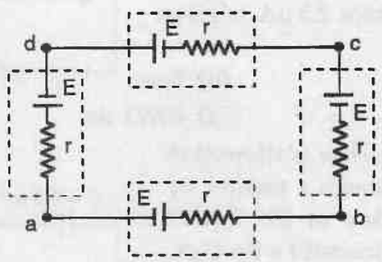
(a) 5.4 V (b) 5.6 V
(c) 5.6 V (d) 6.0 V

66. The potential difference between the points 'A' and 'B' is :



(a) 5 V (b) 4 V
(c) 3 V (d) 2 V

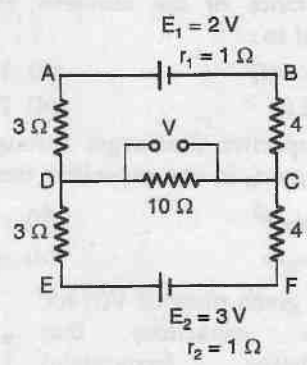
67. Figure shows four batteries of emf E and internal resistance 'r' are connected in series. The voltage across each battery is :



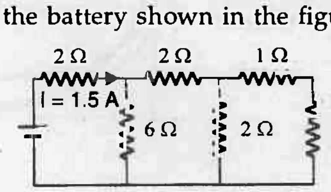
(a) 2 V (b) 0 V
(c) 1.5 V (d) 0.75 V

68. In the circuit shown in the figure, the potential drop V, across the resistor of 10 Ω is :

(a) 1.89 V
(b) 1.79 V
(c) 1.69 V
(d) 1.99 V



69. The emf of the battery shown in the figure :



(a) 6 V (b) 12 V
(c) 18 V (d) 8 V

70. For accurate measurements, the resistance of a voltmeter should be :

(a) as large as possible
(b) equal to the resistance across which the potential difference is to be measured
(c) as small as possible
(d) infinity

71. To convert a galvanometer into an ammeter, we should connect :

(a) a low resistance in series with it
(b) a high resistance in series with it
(c) a low resistance in parallel with it
(d) a high resistance in parallel with it

72. To convert a galvanometer into voltmeter, one should connect :

(a) a low resistance in series with it
(b) a high resistance in series with it
(c) a low resistance in parallel with it
(d) a high resistance in parallel with it

73. The certain galvanometer has a resistance of 400 Ω and deflects full scale for a current of 0.2 mA through it. The shunt resistance required to convert it into an ammeter is :

(a) 0.0135 Ω (b) 0.027 Ω
(c) 0.0405 Ω (d) 0.054 Ω

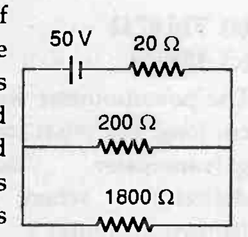
74. The 80 Ω galvanometer deflects full scale for a potential of 20 mV. A voltmeter deflecting full scale of 5 V is to made using this galvanometer. We must connect :

(a) a resistance of 19.92 kΩ parallel to the galvanometer
(b) a resistance of 19.92 kΩ in series with the galvanometer
(c) a resistance of 20 kΩ parallel to the galvanometer
(d) a resistance of 20 kΩ in series with the galvanometer

75. A DC milliammeter has a resistance of 12 Ω and gives a full scale deflection for a current of 0.01 A. To convert it into a voltmeter giving a full scale deflection of 3 V, the resistance required to be put in series with the instrument is :

(a) 102 Ω (b) 288 Ω
(c) 300 Ω (d) 412 Ω

76. A voltmeter having resistance of 1800 ohm is employed to measure the potential difference across 200 Ω resistance which is connected to D.C. power supply of 50 V and internal resistance ◦ 20 Ω. What is percentage change in p.d. across 200 Ω resistance as a result of connecting voltmeter across it ?

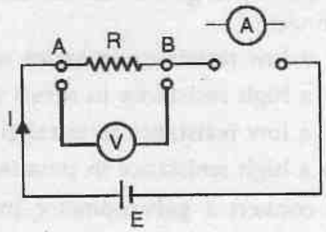


(a) 1% (b) 5%
(c) 10% (d) 20%

77. When battery and galvanometer are interchanged in the case of Wheatstone bridge, then :

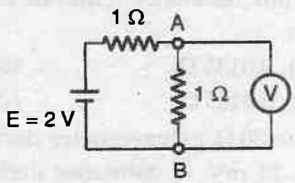
(a) if the bridge was in adjustment before interchange, it will not be in adjustment after interchange
(b) if the bridge was in adjustment before interchange, it will be in adjustment after interchange
(c) if the bridge was in adjustment before interchange, it may or may not be in adjustment after interchange
(d) all the above

78. In the circuit when ammeter and voltmeters are out and circuit is completed, the current through the cell is I_0 and $V_A - V_B = V_0$. Consider the symbols : x means — (A) — is brought in the circuit, y means — (V) — is brought in the circuit. Then :



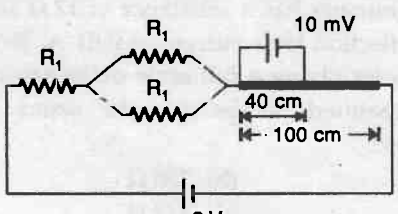
(a) x causes $I < I_0$, $V_A - V_B < V_0$
(b) y causes $I > I_0$, $V_A - V_B < V_0$
(c) $x + y$ causes $I = I_0$, and $V_A - V_B = V_0$
(d) both (a) and (b) are correct

79. In the given circuit, voltmeter and the electric cell are ideal. The reading of voltmeter is :



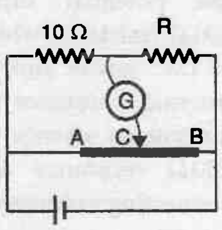
(a) 1 V
(b) 2 V
(c) 3 V
(d) none of the above

80. A potentiometer wire of length 100 cm has a resistance of 10 Ω. It is connected in series with resistance (shown in figure) and a cell of emf 2 V and negligible resistance. A source of emf 10 mV is balanced against a length of 40 cm of potentiometer wire. What is the value of R_1 ?



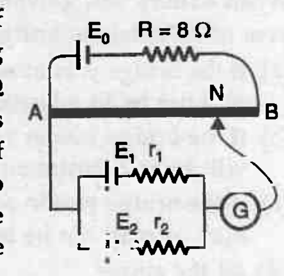
(a) 526.67 Ω (b) 790 Ω
(c) 1580 Ω (d) zero

81. The potentiometer wire AB is 100 cm long. For what value of R, the galvanometer shows no deflection, when $AC = 40$ cm (shown in figure) ?



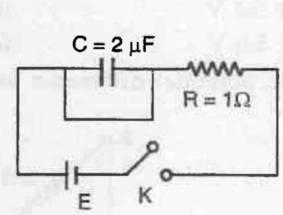
(a) 13 Ω (b) 17 Ω
(c) 15 Ω (d) 21 Ω

82. A battery of emf $E_0 = 12$ V is connected across a 4 m long uniform wire having resistance 4 Ω/m. The cells of small emf $E_1 = 2$ V and $E_2 = 4$ V having internal resistance 2 Ω and 6 Ω respectively, are connected as shown in figure. If galvanometer shows no deflection at the point N, the distance of point N from the point A is equal to :



(a) 1/6 cm (b) 1/3 cm
(c) 25 cm (d) 50 cm

83. The capacitive time constant of the RC circuit shown in the figure is :

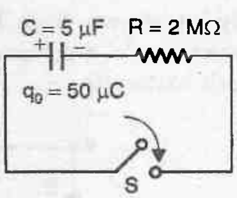


(a) zero
(b) infinity
(c) 2 sec
(d) 2 μ sec

84. A capacitor is charged to certain potential difference and then discharged through a resistor R. It takes 2 μs for current through R to become half its initial value. It would take 4 μs for current to become half its initial value if :

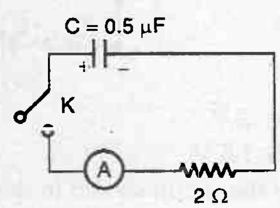
(a) C is doubled (b) R is doubled
(c) either (a) or (b) (d) both R and C are doubled

85. For the arrangement shown in the figure, the switch is closed at $t = 0$. The time after which the current becomes 2.5 μA is given by :



(a) 10 sec (b) 5 sec
(c) 7 sec (d) 0.693 sec

86. A charge capacitor is allowed to discharge through a resistor by closing the key at the instant $t = 0$. At the instant $t = (\ln 4)$ μs, the reading of the ammeter falls half the initial value. The resistance of the ammeter is equal to :

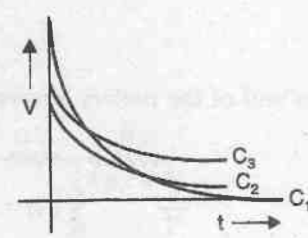


(a) 1 MΩ (b) 1 Ω
(c) 2 Ω (d) 2 MΩ

87. A capacitor discharges through a resistor. The stored energy u_0 in one capacitive time constant falls to :

(a) u_0/e^2 (b) $e\,u_0$
(c) u_0/e (d) none of these

88. The given plots of $V(t)$ for three capacitors that discharge (separately) through the same resistor. Then :

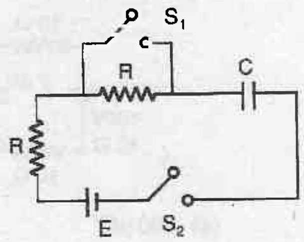


(a) $C_1 > C_2 > C_3$
(b) $C_1 = C_2 = C_3$
(c) $C_1 < C_2 < C_3$
(d) none of the above

89. A silver and copper voltameters are connected in parallel to a 12 V battery of negligible resistance. At what rate is energy being delivered by the battery, if in 30 minutes, 1 g of silver and 1.8 g of copper are deposited ? (Assume electrochemical equivalent of silver = 11.2×10^{-7} kg/C, electrochemical equivalent of copper = 6.6×10^{-7} kg/C)

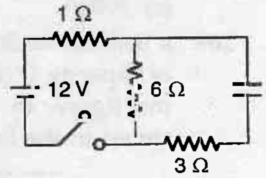
(a) 42.2 J/s (b) 40.4 J/s
(c) 24.1 J/s (d) 20.4 J/s

$*$ **90.** At $t=0$, S_2 is closed. At $t=2\,RC$, S_1 is closed. The charge on the capacitor is $q\,(t)$. Then :



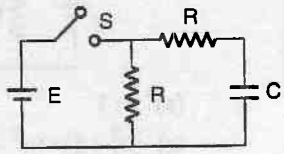
(a) $q=0.63CE$ at $t=2RC$
(b) $q=CE$ at $t\to\infty$
(c) $q=CE\left(1-\dfrac{0.37}{e}\right)$ at $t=3RC$
(d) all of the above

91. When the switch is closed, the initial current through the 1 Ω resistor is :



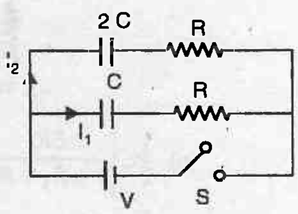
(a) 12 A (b) 4 A
(c) 3 A (d) $\dfrac{10}{7}$ A

92. A capacitor C is connected to two equal resistances as shown in the figure. What is the ratio of time constant during charging and discharging of the capacitor ?



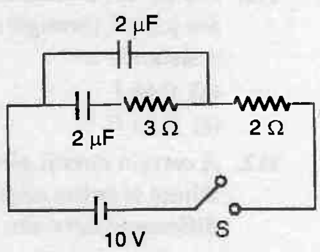
(a) 1 : 1 (b) 2 : 1
(c) 1 : 2 (d) 4 : 1

93. In the circuit shown in figure, switch S is closed at time $t=0$. Let I_1 and I_2 be the currents at any finite time t, then ratio I_1/I_2 :



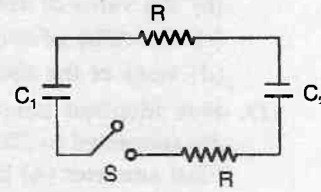
(a) is constant
(b) increases with time
(c) decreases with time
(d) first increases and then decreases

94. Current through the battery, at the instant when the switch 'S' is closed is :



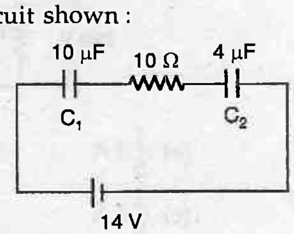
(a) zero (b) 2 A
(c) 4 A (d) 5 A

95. In the circuit shown in the figure $C_1=2C_2$. Capacitor C_1 is charged to a potential of V. The current in the circuit just after the switch S is closed is :



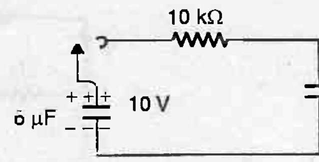
(a) zero (b) $2V/R$
(c) infinite (d) $V/2R$

96. In the steady state in the circuit shown :



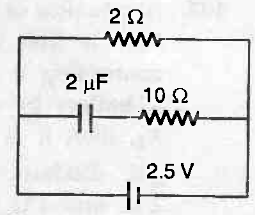
(a) p.d. across C_1 is 4 V
(b) p.d. across 10 Ω is 2 V
(c) p.d. across C_2 is 4 V
(d) charge on C_1 or C_2 is 0 μC

97. When the switch is closed, the final charge on the 3 μF capacitor in the steady state is :



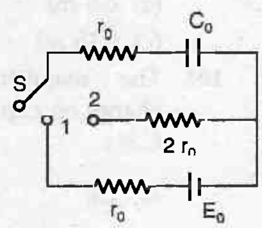
(a) 10 μC (b) 20 μC
(c) 30 μC (d) 40 μC

98. A capacitor of capacitance 2 μF is connected as shown in figure. The internal resistance of the cell is 0.5 Ω. The amount of charge on the capacitor plates is :



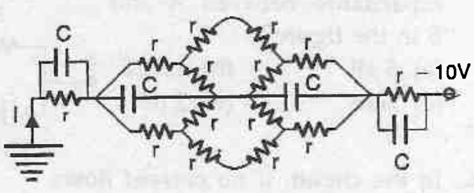
(a) zero (b) 2 μC
(c) 4 μC (d) 6 μC

99. In the given circuit, switch S is at position '1' for long time. Find total heat generated in resistor of resistance $(2r_0)$, when switch 'S' is shifted from position 1 to position 2 :



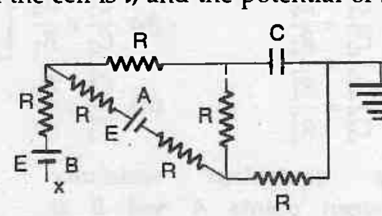
(a) $\dfrac{C_0\,E_0^2}{2}$
(b) $C_0\,E_0^2$
(c) $\dfrac{C_0\,E_0^2}{3}$
(d) none of these.

100. In the figure $r=10\,\Omega$ and $C=2$ mF, the value of the steady state current I is :



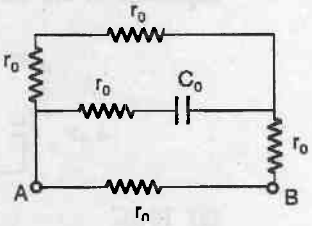
(a) 2 A (b) 1 A
(c) zero (d) none of these

101. In the steady state, the charge on the capacitor is q, the current in the cell is i, and the potential of x is V_x. Then :



(a) $q=CE,\ i=0,\ V_x=E$
(b) $q=\dfrac{CE}{4},\ i=\dfrac{E}{4R},\ V_x=\dfrac{-E}{2}$
(c) $q=0,\ i=\dfrac{E}{4R},\ V_x=0$
(d) none of the above

102. The equivalent resistance between points A and B in the steady state is :



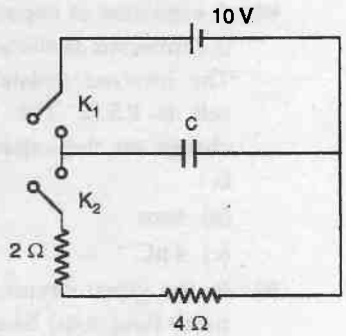
(a) $\frac{3}{4}r_0$

(b) $\frac{4}{3}r_0$

(c) $\frac{5}{3}r_0$

(d) none of the above

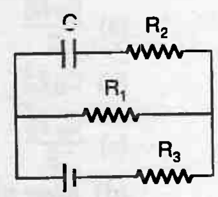
103. A capacitor of capacitance 3 μF is first charged by connecting it across a 10 V battery by closing key K_1, then it is allowed to get discharged through 2 Ω and 4 Ω resistors by closing the key K_2. The total energy dissipated in the 2 Ω resistor is equal to :



(a) 0.5 mJ (b) 0.05 mJ

(c) 0.15 mJ (d) none of these

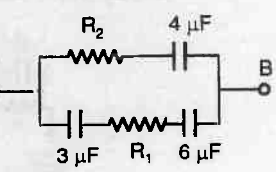
104. The magnitude of saturation charge on capacitor of capacitance C is :



(a) CE (b) $\frac{CER_1}{R_1+R_3}$

(c) $\frac{CER_2}{R_1+R_3}$ (d) $\frac{CER_1}{R_2+R_3}$

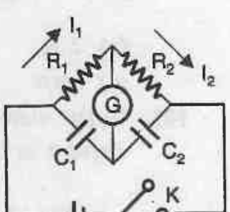
105. What is the equivalent capacitance between A and B in the figure ?



(a) 6 μF (b) 1.5 μF

(c) zero (d) 2 μF

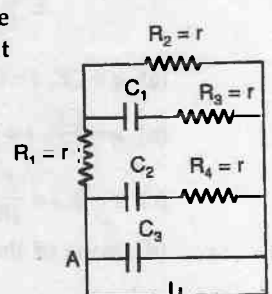
106. In the circuit, if no current flows through the galvano- meter when the key k is closed, the bridge is balanced. The balancing condition for bridge is :



(a) $\frac{C_1}{C_2}=\frac{R_1}{R_2}$ (b) $\frac{C_1}{C_2}=\frac{R_2}{R_1}$

(c) $\frac{C_1^2}{C_2^2}=\frac{R_1^2}{R_2^2}$ (d) $\frac{C_1^2}{C_2^2}=\frac{R_2}{R_1}$

107. The equivalent resistance between points A and B at steady state will be :



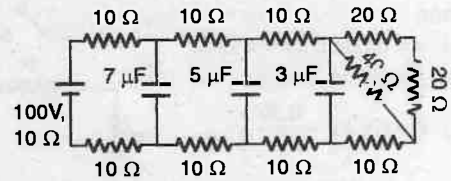
(a) $2r$

(b) $\frac{3}{5}r$

(c) $\frac{5}{3}r$

(d) none of the above

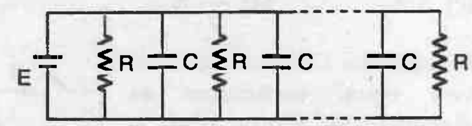
108. For the circuit shown in figure, charge on the 5 μF capacitor is :



(a) 100 μC (b) 250 μC

(c) 300 μC (d) 500 μC

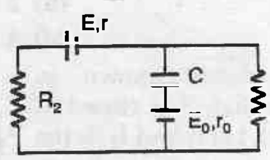
109. n resistors each of resistance R are joined with capacitors of capacity C (each) and a battery of emf E as shown in the figure. In steady state condition, ratio of charges stored in the first and last capacitor is :



(a) $n:1$ (b) $(n-1):R$

(c) $(n^2+1):(n^2-1)$ (d) $1:1$

110. In steady state, the energy stored in the capacitor is :



(a) $\frac{1}{2}C\left[\frac{ER_1}{r+R_1+R_2}\right]^2$ (b) $\frac{1}{2}C\left[E_0+\left(\frac{E}{r+R_1+R_2}\right)R_1\right]^2$

(c) $\frac{1}{2}CE_0^2$ (d) none of these

111. A 4 μF condenser is charged to 400 V and then its plates are joined through a resistance. The heat produced in the resistance is :

(a) 0.64 J (b) 0.32 J

(c) 0.16 J (d) 1.28 J

112. A certain circuit element has a current $i = 2.5 \sin \omega t$ (mA), where ω is the angular frequency in rad/s and a voltage difference between terminals $V = 45 \sin \omega t$ (V), then :

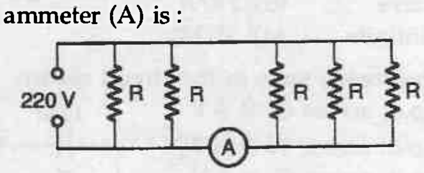
(a) the value of average power is 56.25 mW

(b) the value of average power is zero

(c) the value of average power is 112.5 mW

(d) none of the above

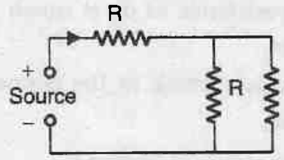
113. Five identical lamps each having resistance $R = 1100\ \Omega$ are connected to 220 V as shown in figure. The reading of ideal ammeter (A) is :



(a) $\frac{1}{5}I$ A (b) $\frac{2}{5}I$ A

(c) $\frac{3}{5}I$ A (d) I A

114. The charge supplied by source varies with time t as $Q - at - bt^2$. The total heat produced in resistor $2R$ is



(a) $\frac{a^2R}{6b}$ (b) $\frac{a^3R}{27b}$

(c) $\frac{a^3R}{3b}$ (d) none of these

115. A resistance R carries a current I. The heat loss to the surroundings is $\lambda(T - T_0)$, where λ is a constant, T is the temperature of the resistance and T_0 is the temperature of the atmosphere. If the coefficient of linear expansion is α., the strain in the resistance is:

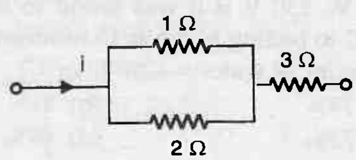
(a) proportional to the length of the resistance wire.

(b) equal to $\frac{\alpha}{\lambda}I^2R$

(c) equal to $\frac{1}{2}\frac{\alpha}{\lambda}I^2R$

(d) equal to $\alpha\lambda$ (IR)

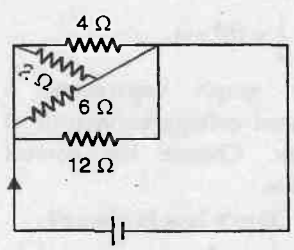
116. In the circuit shown in figure, power developed across 1 Ω, 2 Ω, 3 Ω resistances are in the ratio of:



(a) 1 : 2 : 3 (b) 4 : 2 : 27

(c) 6 : 4 : 9 (d) 2 : 1 : 27

117. The resistance in which the maximum heat is produced is given by:



(a) 2 Ω

(b) 6 Ω

(c) 4 Ω

(d) 12 Ω

118. A constant voltage is applied between the two ends of a uniform metallic wire. Some heat is produced in it. The heat developed is double if:

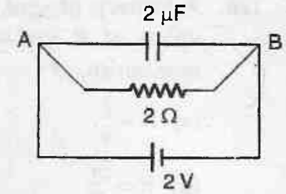
(a) both the length and radius of the wire are halved.

(b) both the length and radius of the wire are doubled

(c) the radius of the wire is doubled

(d) the length of the wire is doubled and the radius of the wire is halved.

119. At steady state, energy stored in capacitor is:



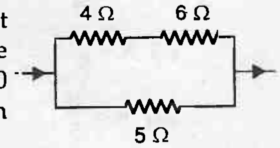
(a) 4×10^{-6} J

(b) 2 J

(c) 4 J

(d) zero

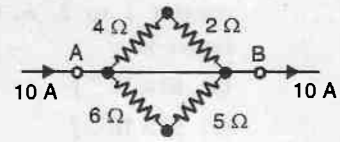
120. In the circuit shown, the heat produced in the 5 Ω resistor due to current flowing in it is 10 cal/s. The heat generated in 4 Ω resistor is



(a) 1 cal/s (b) 2 cal/s

(c) 3 cal/s (d) 4 cal/s

121. In the circuit that is given, the heat developed per second between A and B will be:



(a) 650 J/s

(b) 500 J/s

(c) 900 J/s

(d) 0 J/s

122. A constant current is passed through a uniform metallic wire. If both the length and radius of the wire are doubled, then:

(a) the heat developed in wire will be doubled

(b) the electric field in the wire will be doubled

(c) the heat developed will be halved

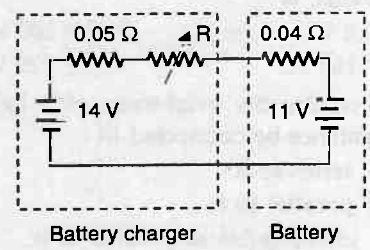
(d) the electric field in the wire will be quadrupled

123. Two bulbs when connected in parallel to a source take 100 W each. The total power consumed when they are connected in series with the same source is:

(a) 25 W (b) 50 W

(c) 100 W (d) 200 W

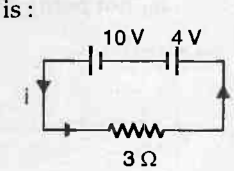
124. The figure shows a battery charger. The value of R so, that 25 W of power is delivered to the 11 V ideal voltage source is:



(a) $R = 1.23\ \Omega$ (b) $R = 2.23\ \Omega$

(c) $R = 3.32\ \Omega$ (d) $R = 1.03\ \Omega$

125. The power consumed by 4 V battery in the circuit as shown is:



(a) 8 W

(b) 7 W

(c) 6 W

(d) 5 W

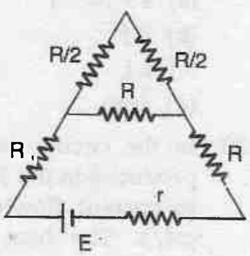
126. A battery of emf E is connected across the circuit.. The value of R for which heat generated in the circuit is maximum, is :

(a) $R = \frac{r}{4}$

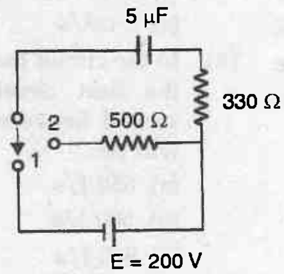
(b) $R = \frac{5r}{2}$

(c) $R = \frac{r}{5}$

(d) $R = \frac{2r}{5}$



127. The amount of heat generated in 500 Ω resistance, when the key is thrown over from contact 1 to 2, as shown in figure is :



(a) 40×10^{-3} J

(b) 50×10^{-3} J

(c) 60×10^{-3} J

(d) 30×10^{-3} J

128. Which bulb will fuse, when two bulbs rated as (25 W and 220 V) and (100 W and 220 V) are connected in series to 40 V ?

(a) 20 W (b) 25 W

(c) 30 W (d) 15 W

129. A lamp having tungsten filament consumes 50 W. Assume the temperature coefficient of resistance for tungsten is $4.5 \times 10^{-3}/°C$ and the room temperature is 20°C. If the lamp burns, the temperature of its filament becomes 2500°C, then the power consumed at the moment switch is on, is :

(a) 608 W (b) 710 W

(c) 215 W (d) 580 W

130. The power consumed by the combination, when three electric lamps of 40 W, 60 W and 100 W are connected in parallel, is :

(a) 0 W (b) 200 W

(c) 160 W (d) 120 W

131. To reduce the brightness of a light bulb, an auxiliary resistance be connected in :

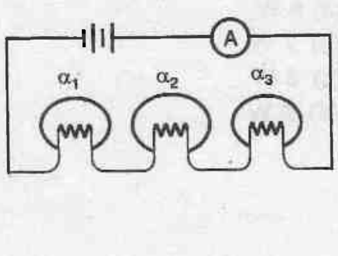
(a) series to it

(b) parallel to it

(c) either series or parallel to it

(d) both (a) and (c) are correct

132. In the circuit below, ammeter A reads 0.5 A. Bulbs α_1 and α_2 are brightly lit, but α_3 is not. What is the reason for α_3 not being lit ?



(a) The ammeter is faulty

(b) The filament of α_3 is broken

(c) The resistance of α_3 is much greater than that of α_1 and α_2

(d) There is a break in the connecting wire between α_2 and α_3

133. Choose the correct option :
Three bulbs of 100 W, 200 W and 40 W are connected in series to the main supply of 200 V. The current will be :

(a) maximum through 100 W

(b) maximum through 200 W

(c) maximum through 40 W

(d) same in all

134. An electric bulb is marked 100 W, 230 V. The resistance of the bulb is :

(a) 229 Ω (b) 329 Ω

(c) 429 Ω (d) 529 Ω

135. If two identical heaters each rated as (1000 W-220 V) are connected in parallel to 220 V, then the total power consumed is :

(a) 200 W (b) 2500 W

(c) 250 W (d) 2000 W

136. What must be the efficiency of an electric kettle marked 500 W, 230 V, if it was found to bring 1 kg of water at 15°C to boiling point in 15 minutes ? (given specific heat capacity of water = 4200 J/kg°C)

(a) 79% (b) 81%

(c) 72% (d) 69%

137. The heat produced by a heater of 100 W in 7 minutes is :

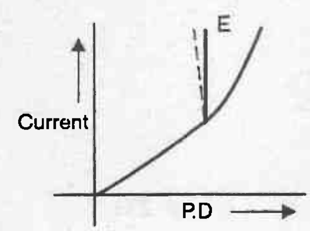
(a) 10^4 cal

(b) 10^5 cal

(c) 1.2×10^4 cal

(d) $\frac{1}{2} \times 10^4$ cal

138. The graph represents a current voltage behaviour of water. Choose the correct option :



(a) Ohm's law is obeyed

(b) electrolytes in general do not obey ohm's law

(c) dissociation takes place at E, and it obeys Ohm's law thereafter

(d) Ohm's law is not valid for low voltage

139. If an electric heater is rated at 1000 W, then the time required to heat one litre of water from 20°C to 100°C will be :

(a) 136 s

(b) 236 s

(c) 336 s

(d) 436 s

140. A fuse wire of circular cross-section and having diameter of 0.4 mm, allows 3 A of current to pass through it. But if another fuse wire of same material and circular cross-section and having diameter of 0.6 mm is taken, then the amount of current passed through the fuse is :

(a) 3 A (b) $3 \times \sqrt{\frac{3}{2}}$ A

(c) $3 \times \left(\frac{3}{2}\right)^{3/2}$ A (d) $3 \times \left(\frac{3}{2}\right)$ A

141. An electric kettle boils some water in 16 minutes. Due to some defect, it becomes necessary to remove 10% turns of heating coil of the kettle . Now, how much time will it take to boil the same mass of water :

(a) 17.7 minute (b) 14.4 minute
(c) 20.9 minute (d) 13.7 minute

142. The metal rod of cross-section $10^{-4}\,m^2$ and the specific resistance of material of rod is 150×10^{-8} m, has a uniform temperature gradient of 1°C/m. When a current of 0.05 A is sent through hot to the cold junction, temperature gradient is unaltered. Thomson coefficient for the material of the rod is :

(a) 5.5×10^{-4} V (b) 6.32×10^{-4} V
(c) 18.7×10^{-4} V (d) 7.5×10^{-4} V

143. When the temperature difference between hot and cold junctions of a thermo-couple is 100 K, an emf of 1 V is generated. Assume the cold junction is heated by 20 K, the percentage change in thermo emf is :

(a) 20% (b) 30%
(c) 40% (d) 25%

144. The temperature of cold junction of thermo-couple is 0°C. If the neutral temperature is 270°C, then the inversion temperature is :

(a) 540°C (b) 520°C
(c) 640°C (d) 580°C

145. The junctions of Ni-Cu thermo-couple are maintained at 0°C and 100°C. The Seebeck emf developed in the temperature is :

$$a_{\text{Ni-Cu}} = 16.3 \times 10^{-6}\ \text{V/°C}$$

$$b_{\text{Ni-Cu}} = -0.021 \times 10^{-6}\ \text{V/°C}$$

(a) 2.73×10^{-3} V (b) 1.42×10^{-3} V
(c) 3.68×10^{-3} V (d) 2.23×10^{3} V

146. When the cold junction is at 0° C, the equation of thermo emf is represented by $E = AT + BT^2$. The neutral temperature is :

(a) $-\frac{A}{2B}$ (b) $-\frac{A}{3B}$
(c) $-\frac{2A}{B}$ (d) $-A/B$

147. When one ampere current flows for one minute through a silver voltameter, it deposites 0.067 g of silver on the cathode, then how much charge will flow to deposite 108 g of silver?

(a) 10.6×10^4 C/g_{eq} (b) 9.67×10^4 C/g_{eq}
(c) 8.7×10^4 C/g_{eq} (d) 4.3×10^4 C/g_{eq}

148. A 20 Ω resistance takes 5 minutes to boil a given amount of water. How much resistance will be required to boil the same amount of water using the same source in 1 minute ?

(a) 4 Ω (b) 5 Ω
(c) 6 Ω (d) 3 Ω

149. A silver plating bath that deposites 2.60 g of silver in 40 minute, is connected in series with an ammeter, which reads 0.90 A. By what percent is the ammeter reading is incorrect ? (Given : Atomic weight of silver = 108, 1 farad = 96500 C)

(a) 7% less than true value
(b) 7% greater than true value
(c) 8% greater than true value
(d) 5% greater that true value

150. The amount of chlorine produced per-second through electrolysis in a plate which consumes 100 kW power at 200 V is : (Given : Electrochemical equivalent of chlorine $= 0.367 \times 10^{-3}$ g/C)

(a) 18.35 g (b) 1.835 g
(c) 183.5 g (d) 0.1835 g

151. A piece of metal weighing 200 g is to be electroplated with 5% of its weight in gold. How long it would take to deposite the required amount of gold, if the strength of the available current is 2 A ?
(Given : Electrochemical equivalent of H $= 0.1044 \times 10^{-4}$ g/C, atomic weight of gold = 197.1, atomic weight of hydrogen = 1.008)

(a) 7347.9 s (b) 7400.5 s
(c) 7151.7 s (d) 70 s

Answers

Level-1

1. (d)	2. (c)	3. (d)	4. (d)	5. (c)	6. (a)	7. (c)	8. (c)	9. (d)	10. (b)
11. (d)	12. (a)	13. (b)	14. (b)	15. (c)	16. (d)	17. (a)	18. (b)	19. (c)	20. (b)
21. (c)	22. (d)	23. (b)	24. (a)						

Level-2

1. (b)	2. (d)	3. (c)	4. (a)	5. (c)	6. (a)	7. (a)	8. (c)	9. (d)	10. (d)
11. (a)	12. (c)	13. (c)	14. (b)	15. (a)	16. (b)	17. (c)	18. (a)	19. (d)	20. (b)
21. (a)	22 (a)	23. (a)	24. (a)	25. (a)	26. (c)	27. (a)	28. (a)	29. (b)	30. (d)
31. (d)	32. (b)	33. (a)	34. (a)	35. (c)	36. (c)	37. (c)	38. (a)	39. (b)	40. (a)
41. (c)	42. (b)	43. (a)	44. (a)	45. (c)	46. (a)	47. (c)	48. (a)	49. (a)	50. (a)
51. (a)	52. (b)	53. (b)	54. (a)	55. (b)	56. (d)	57. (c)	58. (a)	59. (c)	60. (c)
61. (c)	62. (c)	63. (c)	64. (b)	65. (c)	66. (b)	67. (b)	68. (b)	69. (a)	70. (d)
71. (c)	72. (b)	73. (b)	74. (b)	75. (b)	76. (a)	77. (a)	78. (a)	79. (a)	80. (a)
81. (c)	82. (c)	83. (b)	84. (c)	85. (c)	86. (c)	87. (a)	88. (c)	89. (c)	90. (d)
91. (b)	92. (c)	93. (c)	94. (d)	95. (d)	96. (a)	97. (b)	98. (c)	99. (c)	100. (d)
101. (b)	102. (a)	103. (c)	104. (b)	105. (a)	106. (b)	107. (a)	108. (b)	109. (d)	110. (b)
111. (b)	112. (b)	113. (c)	114. (b)	115. (b)	116. (b)	117. (a)	118. (a)	119. (a)	120. (b)
121. (d)	122. (c)	123. (b)	124. (a)	125. (a)	126. (b)	127. (c)	128. (b)	129. (a)	130. (b)
131. (a)	132. (c)	133. (d)	134. (d)	135. (d)	136. (a)	137. (a)	138. (b)	139. (c)	140. (c)
141. (b)	142. (d)	143. (a)	144 (a)	145. (b)	146. (a)	147. (b)	148. (a)	149. (a)	150. (d)
151. (a)									

Solutions

Level-1

3. $n = \frac{i}{e}$

$= \frac{3.2}{1.6 \times 10^{-19}}$

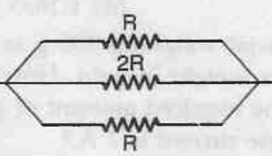
$= 2 \times 10^{19}$

4. $v_d = \frac{I}{neA}$

$= \frac{1.2}{5 \times 10^{28} \times 1.6 \times 10^{-19} \times 10^{-4}}$

$= 1.5 \times 10^{-6}$ m/s

8.



$$\frac{1}{R'} = \frac{1}{R} + \frac{1}{2R} + \frac{1}{R}$$

$$\frac{1}{R'} = \frac{2+1+2}{2R}$$

$$= \frac{5}{2R}$$

$$\Rightarrow \quad R' = \frac{2R}{5}$$

13. Total resistance $= R + r$

$$\therefore \quad i = \frac{E}{R+r}$$

15. $\rho = \frac{RA}{l} = \frac{A}{Gl}$

$$= \frac{8 \times 10^{-6}}{2.45 \times 8} = 4.1 \times 10^{-7} \text{ s}$$

16. $V = E - Ir = 12 - 5 \times 10^{-2} \times 90 = 7.5$

17. $p = nA\,l\,mv_d = \frac{iml}{e} = \frac{1 \times (9 \times 10^{-31}) \times (0.10)}{1.6 \times 10^{-19}}$

$= 5.6 \times 10^{-13}$ kg m/s

18. $\frac{1}{R} = \frac{1}{7} + \frac{1}{14} = \frac{2+1}{14}$

$R = \frac{14}{3} = 4.6\ \Omega$

19. $R = \frac{V^2}{P}$

$$\therefore \quad R_1 = \frac{220 \times 220}{200} = \frac{22 \times 22}{2} \quad \ldots\text{(i)}$$

and $R_2 = \frac{220 \times 220}{100} = 22 \times 22 \quad \ldots\text{(ii)}$

From equations (i) and (ii), we get

$$\therefore \quad R_2 = 2R_1$$

21. $\frac{50}{10+r} = 4.5$

$$\Rightarrow \quad 45 + 4.5r = 50$$

$$4.5r = 50 - 45 = 5$$

$$r = \frac{5}{4.5} = 1.1\ \Omega$$

22. $I_g(G + R) = V$

$10^{-3}(400 + R) = 8$

$R = 8000 - 400 = 7600\ \Omega$

24. Consumed power $= \frac{V^2}{R}$

$$= \frac{(220)^2}{(220)^2} \times 100 \text{ W} = 100 \text{ W}$$

27

Magnetic Field

Syllabus: Oersted's experiment, Biot-Savart's law (Magnetic field due to a current element), magnetic field due to a straight wire, circular loop and solenoid, force on a moving charge in a uniform magnetic field (Lorentz force), forces and torques on currents in a magnetic field, force between two current carrying wire

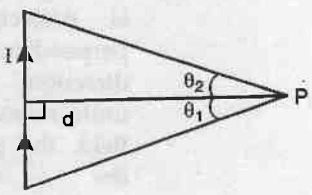
Review of Concepts

1. Magnetic Field : In magnetics, there are basically two methods of calculating magnetic field at some point. One is **Biot Savart's law** which gives the magnetic field due to an infinitesimally small current carrying wire at some point and the other is **Ampere's law**, which is useful in calculating the magnetic field of a highly symmetric configuration carrying a steady current.

2. Applications of Biot Savart's Law :

(a) Magnetic field due to a straight thin conductor is

$$B = \frac{\mu_0 I}{4\pi d}(\sin\theta_1 + \sin\theta_2)$$



(i) For an infinitely long straight wire,

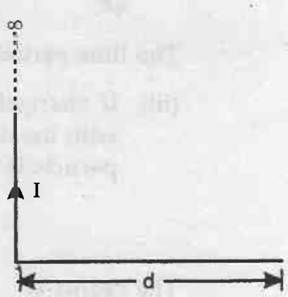
$$\theta_1 = \theta_2 = 90^\circ$$

$$\therefore \quad B = \frac{\mu_0 I}{2\pi d}$$

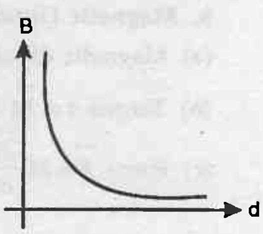
(ii) When wire is semi-infinite,

$$\theta_1 = 0 \quad \text{and} \quad \theta_2 = \frac{\pi}{2}$$

$$\therefore \quad B = \frac{\mu_0 I}{4\pi d}\left(\sin 0 + \sin\frac{\pi}{2}\right) = \frac{\mu_0 I}{4\pi d}$$

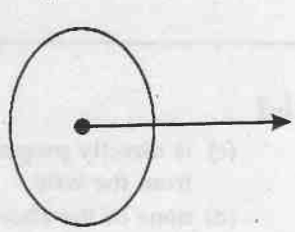


(iii) $B \propto \frac{1}{d}$, *i.e.*, *B-d* graph for an infinitely long straight wire is a rectangular hyperbola as shown in figure.



(b) Magnetic field on the axis of a circular coil having *N* turns is

$$B = \frac{\mu_0 N I R^2}{2(R^2 + x^2)^{3/2}}$$



(i) At the centre of the loop, $x = 0$

$$\therefore \quad B = \frac{\mu_0 N I}{2R}$$

(ii) For $x >> R$, $\quad x^2 + R^2 \approx x^2$

$$\therefore \quad B = \frac{\mu_0 N I R^2}{2x^3} = \left(\frac{\mu_0}{4\pi}\right)\left(\frac{2NI\pi R^2}{x^3}\right) = \left(\frac{\mu_0}{4\pi}\right)\left(\frac{2M}{x^3}\right)$$

Here, M = magnetic moment of the loop

$$= NIA = NI\pi R^2$$

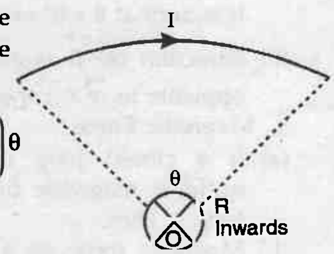
This result was expected since, the magnetic field on the axis of dipole is

$$\frac{\mu_0}{4\pi}\frac{2M}{x^3}$$

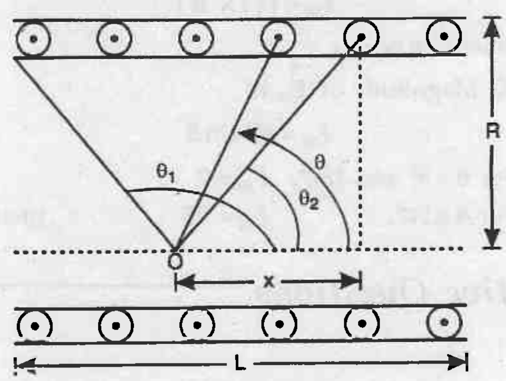
(iii) Magnetic field due to an arc of a circle at the centre is

$$B = \left(\frac{\theta}{2\pi}\right)\frac{\mu_0 I}{2R} = \frac{\mu_0}{4\pi}\left(\frac{I}{R}\right)\theta$$

$$\text{or } B = \left(\frac{\mu_0}{4\pi}\right)\left(\frac{I}{R}\right)\theta$$



(c) Field along the axis of a solenoid is



$$B = \frac{\mu_0 N I}{2}(\cos\theta_2 - \cos\theta_1)$$

(i) For a long solenoid ($L >> R$),
i.e., $\theta_1 = 180°$ and $\theta_2 = 0°$

$$B = \mu_0 NI$$

(ii) At the ends of solenoid,

$$\theta_2 = 0°, \quad \theta_1 = 90°$$

we get $B = \frac{1}{2}\mu_0 NI$ (for $L >> R$)

3. Applications of Ampere's Circuital Law :

(a) Magnetic field due to a long metal rod of radius R carrying a current I :

(i) If $r < R$, $B = \left(\frac{\mu_0 I}{2\pi R^2}\right) r$, *i.e.*, $B \propto r$

(ii) If $r = R$ (*i.e.*, at the surface)

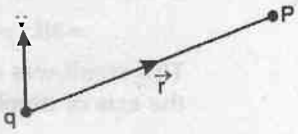
$$B = \frac{\mu_0 I}{2\pi R}$$

(b) Magnetic field of a solenoid wounded in the form of a helix is

$$B = \mu_0 NI$$

4. Magnetic Field of a Moving Point Charge :

$$\vec{B} = \frac{\mu_0}{4\pi} \cdot \frac{q}{r^3} (\vec{v} \times \vec{r})$$



Note down the following points regarding this equation.

(a) Magnitude of B is,

$$= \frac{\mu_0}{4\pi} \frac{qv \sin\theta}{r^2}$$

It is zero at $\theta = 0°$ and $180°$ and maximum at $\theta = 90°$.

(b) Direction of $\vec{B}$ is along $\vec{v} \times \vec{r}$ if q is positive and opposite to $\vec{v} \times \vec{r}$ if q is negative.

5. Magnetic Force :

(a) If a closed loop of any shape is placed in a uniform magnetic field, the magnetic force on the loop is zero.

(b) Magnetic force on a current carrying conductor is given by

$$\vec{F}_m = I(\vec{l} \times \vec{B})$$

where $I = ne.Av_d$

(i) Magnitude of $\vec{F}_m$ is

$$F_m = ilB \sin\theta$$

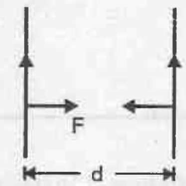
For $\theta = 0°$ and $180°$, $F_m = 0$

For $\theta = 90°$, $F_m = ilB$ (maximum)

(ii) Here $\vec{l}$ is a vector that points in the direction of the current I and has a magnitude equal to the length.

(c) The force of magnetic interaction between two parallel wires is

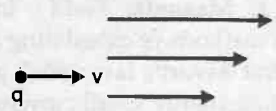
$$F = \frac{\mu_0 I_1 I_2}{2\pi d} \text{ per unit length}$$



(d) The magnetic force on a moving charged particle

$$\vec{F} = q\vec{v} \times \vec{B}$$

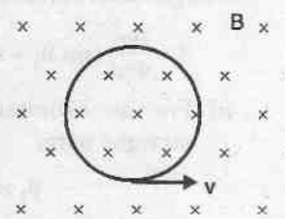
(i) If charged particle is projected in the direction of magnetic field



$\therefore$ $F = qvB \sin\theta$

Here, $\theta = 0 \quad \therefore \quad F = 0$

(ii) If charged particle is projected in perpendicular direction of uniform magnetic field, the path of the charged particle is circular. The radius is



$$r = \frac{mv}{qB} \quad \text{or} \quad r = \frac{\sqrt{2mE_k}}{qB}$$

The time period is $T = \frac{2\pi m}{qB}$.

(iii) If charged particle is projected at an angle θ with the direction of magnetic field, the path of particle is helical. The pitch is

$$P = \frac{2\pi mv \cos\theta}{qB}$$

The radius is $r = \frac{mv \sin\theta}{qB}$

6. Magnetic Dipole :

(a) Magnetic dipole moment is $M = NIA$.

(b) Torque $\tau = \vec{M} \times \vec{B}$.

(c) Force $\vec{F} = M\frac{\partial \vec{B}}{\partial i}$

Objective Questions

Level-1

1. The strength of the magnetic field around a straight wire :
(a) is same everywhere around the wire
(b) obeys inverse square law
(c) is directly proportional to the square of the distance from the wire
(d) none of the above

2. A magnetic needle is kept in non-uniform magnetic field. It experiences :
(a) a force and torque
(b) a force but not a torque
(c) a torque but not a force
(d) neither a force nor a torque

3. A long wire carries a current of 20 A along the axis of a solenoid, the field due to the solenoid is 4 mT. The resultant field at a point 3 mm from the solenoid axis is :
(a) 1.33 mT (b) 4.2 mT
(c) 2.1 mT (d) 8.4 mT

4. A circular current carrying coil has a radius R. The distance from the centre of the coil on the axis where the magnetic induction will be $\frac{1}{8}$th of its value at the centre of the coil, is :
(a) $R\sqrt{3}$ (b) $\frac{R}{\sqrt{3}}$
(c) $\frac{2R}{\sqrt{3}}$ (d) $(2\sqrt{3})R$

5. Through two parallel wires P and Q, 10 A and 2 A of currents are passed respectively in opposite directions. If the wire P is infinitely long and the length of the wire Q is 2 cm, the force on the conductor Q which is situated at 10 cm distance from P, will be :
(a) 8×10^{-5} N (b) 3×10^{-7} N
(c) 4×10^{-5} N (d) 4×10^{-7} N

6. Two circular coils A and B are made from similar wire but radius of B is twice that of A. The value of potential difference across them so that the magnetic induction at their centre may be same, will be :
(a) $V_B=2V_A$ (b) $V_B=3V_A$
(c) $V_B=4V_A$ (d) $V_B=\frac{1}{4}V_A$

7. A beam of protons with a velocity of 4×10^5 ms^{-1} enters a uniform magnetic field of 0.3 T. The velocity makes an angle of 60° with the magnetic field. The radius of the helical path taken by the proton is :
(a) 4.4 cm (b) 1.2 cm
(c) 4.4 cm (d) 2.2 cm

8. A coil carrying electric current is placed in uniform magnetic field. Then :
(a) torque is formed
(b) emf is induced
(c) both (a) and (b) are correct
(d) none of the above

9. A helium nucleus makes a full rotation in a circle of radius 0.8 m in two seconds. The value of the magnetic field B at centre of circle will be :
(a) $\frac{10^{-19}}{\mu_0}$ (b) $10^{-19}\mu_0$
(c) $2\times10^{-19}\mu_0$ (d) $\frac{2\times10^{19}}{\mu_0}$

10. A uniform magnetic field is at right angle to the direction of motion of proton. As a result, the proton describes a circular path of radius 2.5 cm. If the speed of the proton is doubled then the radius of the circular path will be :
(a) 0.5 cm (b) 2.5 cm
(c) 5.0 cm (d) 7.5 cm

11. An electron moving with velocity of 10^6 m/s enters a region where magnetic field exists. If it describes a circle of radius 0.10 m, the intensity of the magnetic field must be :
(a) 1.8×10^{-4} T (b) 5.6×10^{-5} T
(c) 14.4×10^{-5} T (d) 1.3×10^{-6} T

12. If a long copper rod carries a direct current, the magnetic field associated with the current will be :
(a) inside the rod only
(b) outside the rod only
(c) both inside and outside the rod
(d) neither inside nor outside the rod

13. If an electron describes half a revolution in a circle of radius r in a magnetic field B, the energy acquired by it is :
(a) zero (b) $\frac{1}{2}mv^2$
(c) $\frac{1}{2}\left(\frac{1}{2}mv^2\right)$ (d) $\pi r\,(Bev)$

14. If the total magnetic field due to the earth is 28 Am^{-1}, then the total magnetic induction due to the earth is :
(a) 3.52×10^{-7} T
(b) 3.52×10^{-5} T
(c) 3.52×10^{-2} T
(d) 3.52×10^{-4} T

15. An electron accelerated through a potential difference V enters into a uniform transverse magnetic field and experiences a force F. If the accelerating potential is increased to $2V$, the electron in the same magnetic field will experience a force :
(a) F (b) $\frac{F}{2}$
(c) $\sqrt{2}F$ (d) $2F$

16. A wire of length L m carrying a current I amp is bent in the form of a circle. The magnitude of magnetic moment is :
(a) $\frac{IL^2}{4\pi}$ (b) $\frac{IL^2}{2\pi}$
(c) $\frac{IL}{4\pi}$ (d) $I\pi L^2$

17. The restoring couple in the moving coil galvanometer is because of :
(a) magnetic field
(b) material of the coil
(c) twist produced in the suspension
(d) current in the coil

12. A photograph record of radius R which carries a uniformly distributed charge Q is rotating with constant angular speed ω. What is the magnetic field at the centre of disc ?

(a) $\frac{\mu_0 \omega Q}{2\pi R}$ (b) $\frac{\mu_0 \omega Q}{2\pi}$

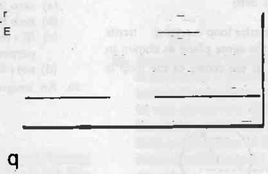
(c) $\frac{\mu_0 \omega Q}{2\pi \omega}$ (d) $\frac{\mu_0 \omega Q}{4\pi}$

13. Electric current I passes through a cylindrical wire of radius a. The current density at a point in the wire, proportional to the distance of the point from the axis of the wire. The magnetic field at the surface of the wire is :

(a) $\frac{\mu_0 I}{2\pi a}$ (b) $\frac{\mu_0 I}{4\pi a}$

(c) $\frac{2\mu_0 I}{\pi a}$ (d) none of these

14. A charge q (> 0) moves towards the centre of a circular loop of radius R along its axis. The magnitude of B along the periphery of the loop is :



(a) zero (b) $\frac{\mu_0}{4\pi} \frac{qvR}{\sqrt{(R^2 + x^2)^3}}$

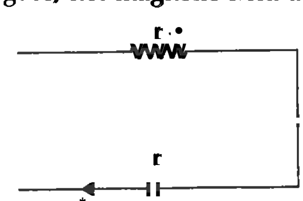
(c) $\frac{qvR}{\ldots}$ (d) none of these

15. Two mutually perpendicular conductors carry currents I_1 and I_2 along x-axis and y-axis respectively. The locus of points at which magnetic induction is zero is :

(a) $y = \frac{I_2}{I_1}x$ (b) $x = \frac{I_1}{I_2}y$

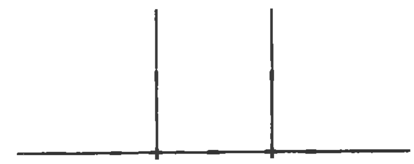
(c) $y = \frac{I_1}{I_2}x$ (d) $x^2 + y^2 = \frac{I_1}{I_2}$

16. In the given figure, net magnetic field at the point P is:



(a) not calculated
(b) zero
(c) non-zero
(d) infinity

17. In the given figure, all wires are infinitely long, having same electric current, C is a middle point of AB. The magnetic field at the point C is :



(a) > 0 (b) ≥ 0

(c) $= 0$ (d) none of these

18. Three infinitely long conductors A, B and C are carrying current I as shown in the figure. The position of the point lying in the straight line AC where magnetic field is zero, is in :

(a) between B and C at a distance of 3.2 cm from B
(b) between B and A at a distance of 3.2 cm from A
(c) between B and C at a distance of 1.3 cm from B
(d) between B and A at a distance of 1.3 cm from B

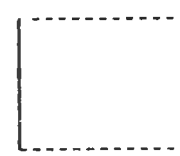
19. In the given figure,

$AB = CD = \left(\frac{\sqrt{3} - 1}{\sqrt{2}}\right)a,$

$OB = OC = a,$

$BC = \sqrt{2}a.$

The magnetic field at the point O is:



(a) 0 (b) $\frac{(\sqrt{3}-1)\mu_0 I}{4\pi a}$

(c) $\frac{\sqrt{3}\mu_0 I}{8\pi a}$ (d) none of these

20. Three infinitely long wires carrying same current I are passing through corners of a equilateral triangle. The magnetic field at the centre of the triangle is:

(a) zero (b) $\frac{3\mu_0 I}{2\pi a}$

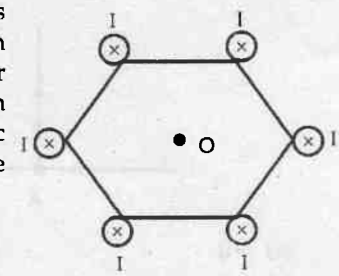
(c) $\frac{3\sqrt{2}\mu_0 I}{2\pi a}$ (d) none of these

21. An equilateral triangle of side a is formed by a piece of uniform resistance wire. Current I is feed in one corner and feed also at the other corner. The magnetic field at the centre O due to the current in the loop is :

(a) zero (b) $3\mu_0 I$

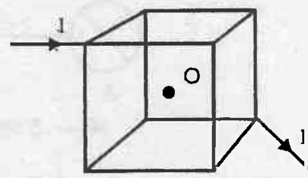
(c) $\frac{\sqrt{3}\mu_0 I}{4\pi a}$ (d) $\frac{\mu_0}{4\pi}\omega\theta$

22. Six infinitely long wires are passing through corners of a regular hexagon (shown in figure). The magnetic field at the centre of the hexagon is :



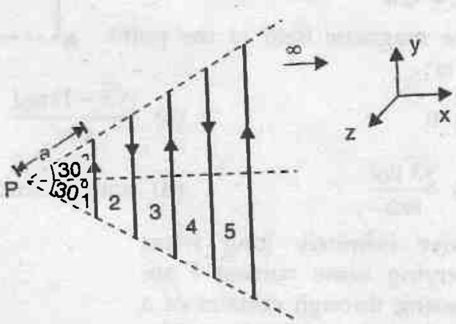
(a) zero
(b) infinity
(c) $\frac{3\mu_0 I}{4\pi a}$
(d) none of the above

23. A wire frame forms edges of a cube. Each edge has a length a and resistance r. A current I enters one corner and leaves at diagonally opposite corner. The magnitude of magnetic induction vector $\vec{B}$ at the centre O of the cube is :



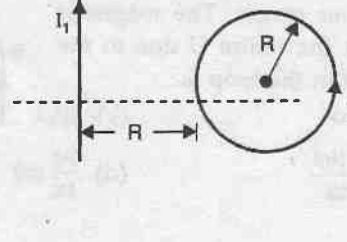
(a) $\frac{4I\mu_0}{a}$ (b) $\frac{I\mu_0}{2a}$
(c) $\frac{\mu_0 I}{3a}$ (d) zero

24. Infinite number of straight wires each carrying current I are equally placed as shown in the figure. Adjacent wires have current in opposite direction. Net magnetic field at point P is :



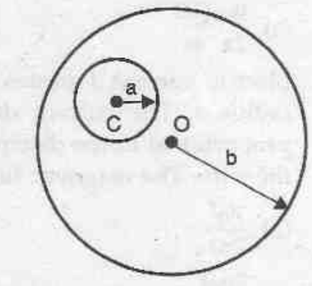
(a) $\frac{\mu_0 I \ln 2}{8\pi\sqrt{3}a}\hat{k}$ (b) $\frac{\mu_0 I \ln 4}{4\pi\sqrt{3}a}\hat{k}$
(c) $\frac{\mu_0 I \ln 4}{4\pi\sqrt{3}a}(\hat{k})$ (d) zero

25. A long straight wire and a circular loop carrying currents I_1 and I_2 respectively are in the same plane as shown in figure. If the magnetic field at the centre of the loop is zero, then :



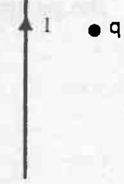
(a) $I_1 = I_2$ (b) $I_1 = 2I_2$
(c) $I_1 = 2\pi I_2$ (d) $I_2 = 2\pi I_1$

***26.** A long straight metal rod has a very long hole of radius a drilled along parallel to the rod axis as shown in the figure. If the rod carries a current I. The value of magnetic induction on the axis of hole, where $OC = c$:



(a) $\frac{\mu_0 I c}{\pi(b^2 - a^2)}$
(b) $\frac{\mu_0 I c}{2\pi(b^2 - a^2)}$
(c) $\frac{\mu_0 I(b^2 - a^2)}{2\pi c}$
(d) $\frac{\mu_0 I c}{2\pi a^2 b^2}$

27. A point charge q is placed near a long straight wire carrying current I, then :

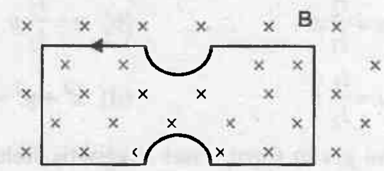


(a) there is small charge density on the surface of wire
(b) there is no charge density on the surface of wire
(c) no force is exerted by wire on the point charge q
(d) a large force is exerted by wire on the point charge q

28. A conducting circular loop of radius r carries a constant current I. It is placed in a uniform magnetic field B such that B_0 is perpendicular to the plane of the loop. The magnetic force acting on the loop is :

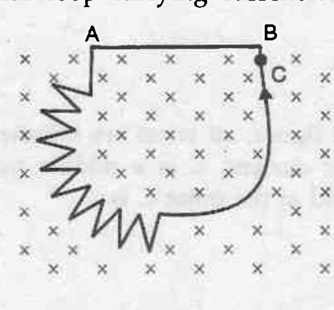
(a) IrB_0 (b) $2\pi IrB_0$
(c) πIrB_0 (d) zero

29. In the given figure, an irregular wire loop of current I is placed in a uniform magnetic field B acting perpendicular to the plane of the loop. The total magnetic force on loop is :



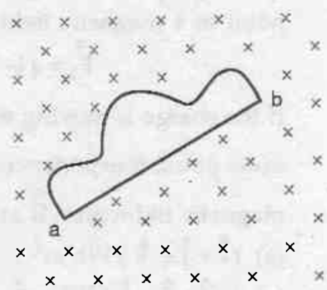
(a) zero in perpendicular direction of B
(b) zero but direction is in intermediate form
(c) $IB \times$ (total length of wire) and direction is perpendicular to B
(d) not calculated in the given condition

30. An irregular loop carrying current 5 A is placed in a



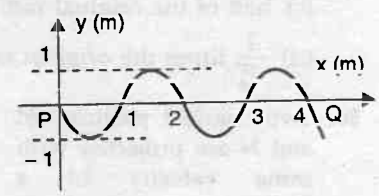
uniform magnetic field $B = 0.5$ T as such straight segment AB of length 10 cm is out of magnetic field (shown in the figure). The magnitude and the direction of the magnetic force acting on the loop are :
(a) 0 N and unlike parallel to BC
(b) 0.25 N and unlike parallel to BC
(c) 0.25 N and like parallel to BC
(d) sufficient information is not available

31. Figure shows a wire of arbitrary shape carrying a current I between points a and b. The length of the wire is L and the distance between points a and b is d. The wire lies in a plane at right angle to a uniform magnetic field B. Then the force on the wire is :



(a) ILB (b) IdB
(c) $I(L-d)B$ (d) none of these

32. A wire of sine-graph shape lies in x-y plane as shown in the figure. A constant and static magnetic field $\vec{B}$ having magnitude 2 T exists perpendicular to x-y plane. The magnitude of force on the wire PQ if a current 1 A goes from P to Q is equal to :

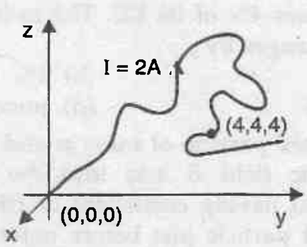


(a) 20 N (b) 9.2 N
(c) 8 N (d) 4.6 N

*** 33.** A wire of arbitrary shape carries a current $I = 2$ A, consider the portion of wire between (0, 0, 0) and (4 m, 4 m, 4 m). A magnetic field given by

$$\vec{B} = 1.2 \times 10^{-4}\ \text{T}\ \hat{i} + 2.0 \times 10^{-4}\ \text{T}\ \hat{j}$$

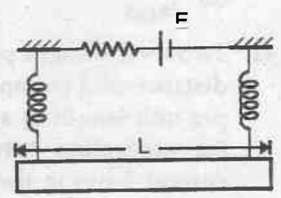
exists in the space. The force acting on the given portion is :



(a) incalculatable as length of wire is not known
(b) $\vec{F} = [(\hat{i} + \hat{j} + \hat{k}) \times (1.2\hat{i} + 2.0\hat{j})]$ N
(c) $\vec{F} = 8 \times 10^{-4} [(\hat{i} + \hat{j} + \hat{k}) \times (1.2\hat{i} + 2.0\hat{j})]$ N
(d) $\vec{F} = 8 \times 10^{-4} [(1.2\hat{i} + 2.0\hat{j}) \times (\hat{i} + \hat{j} + \hat{k})]$ N

34. 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 current I is placed with its edges parallel to the x-y axis. The magnitude of the net magnetic force experienced by the loop is :
(a) $2B_0 Il$ (b) $B_0 I_0 l$
(c) $B_0 Il$ (d) BIl

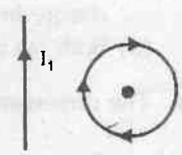
35. A straight rod of mass m and length L is suspended from the identical springs as shown in figure. The spring stretched a distance x_0 due to the weight of the wire. The circuit has total resistance R. When the magnetic field is perpendicular to the plane of paper is switched on springs are observed to extend further by the same distance, the magnetic field strength is :



(a) $\frac{2mgR}{LE}$ (b) $\frac{mgR}{LE}$
(c) $\frac{mgR}{2LE}$ (d) $\frac{mgR}{E}$

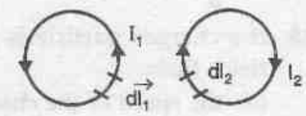
36. A wire of length 60 cm and mass 10 g is suspended in air by a pair of strings in a magnetic field of 0.4 T perpendicular to the paper, then :
(a) if electric current in the wire is 0.41 A, the strings may be completely tension- less
(b) if the direction of current in the wire is from left to right, the strings may be completely tensionless
(c) when the magnetic force is upward and just equal to weight of the rod, the strings will be tensionless
(d) all of the above

37. In the given figure, the loop is fixed but straight wire can move. The straight wire will :



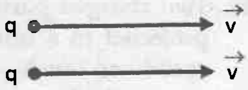
(a) remain stationary
(b) move towards the loop
(c) move away from the loop
(d) rotates about the axis

38. The force of interaction between current elements $I_1 dl_1$ and $I_2 dl_2$ are $\vec{F_1}$ and $\vec{F_2}$ respectively, then :



(a) $\vec{F_1} = -\vec{F_2}$
(b) $\vec{F_1} = 0$, $\vec{F_2} = 0$
(c) $\vec{F_1} \neq -\vec{F_2}$
(d) both (a) and (b) are correct

39. If two point charges q of a sufficiently large mass move parallel to one another with the same non-relativistic velocity $\vec{v}$ (shown in the figure), the ratio of the magnitude of the magnetic and electric interaction forces between charges is :



(a) $\frac{v}{c}$ (b) $\frac{c}{v}$
(c) $\frac{c^2}{v^2}$ (d) $\frac{v^2}{c^2}$

40. Two long parallel wires are placed on a smooth horizontal table. They have equal and opposite charges. Work required to increase the separation between wires from a to $2a$ if magnitude of charge per unit length on them is λ, will be :

(a) $\frac{\lambda^2 \ln 2}{4\pi\varepsilon_0}$ (b) $\frac{\lambda^2}{\pi\varepsilon_0} \ln 2$

(c) $\frac{\lambda^2}{4\pi\varepsilon_0 a}$ (d) $\frac{\lambda^2}{2\pi\varepsilon_0} \ln 2$

41. Two long straight parallel conductors are separated by a distance of 5 cm and carrying current 20 A. What work per unit length of a conductor must be done to increase the separation between conductors to 10 cm, if the current flows in the same direction ?

(a) $8 \times 10^{-5} \log_e 2$ (b) $\log_e 2$

(c) $10^{-7} \log_e 2$ (d) None of these

42. Two thin long parallel wires separated by a distance b are carrying a current I amp each. The magnitude of the force per unit length exerted by one wire on the other is :

(a) $\frac{\mu_0 I^2}{b^2}$ (b) $\frac{\mu_0 I^2}{2\pi b}$

(c) $\frac{\mu_0 I}{2\pi b}$ (d) $\frac{\mu_0 I}{2\pi b^2}$

43. Mark correct option or options :

(a) Electric field and magnetic field are basically independent
(b) Electric field and magnetic field are two aspects of the electromagnetic field
(c) Electric field and magnetic field may be produced by charge in rest
(d) Both (a) and (c) are correct

44. The dimensions of $\frac{1}{\sqrt{\mu_0 \varepsilon_0}}$ are same as :

(a) $\frac{E}{B}$ (b) $\frac{B}{E}$

(c) $\frac{E^2}{B^2}$ (d) $\sqrt{\left(\frac{E}{B}\right)}$

45. If a charged particle is projected in a region of magnetic field, then :

(a) the speed of the charged particle continuously changes
(b) the magnetic force on the charged particle must be zero
(c) the speed of the charged particle remains constant
(d) the magnetic force on the charged particle must not be zero

46. Two charged particles each of mass m and charge q are projected in a uniform magnetic field B with the same speed as such planes of motion of particles are perpendicular to magnetic field B, then

(a) they move on circular path of same radii
(b) the magnetic forces on them are same to each other
(c) the kinetic energy of particles are same to each other
(d) all of the above

47. Two protons are moving with same velocity in magnetic field of same magnitude, then :

(a) magnetic force on protons may be zero
(b) magnetic force on both must be same to each other
(c) magnetic force on both may or may not be same to each other
(d) both (a) and (c) are correct

48. A charge q is moving with a velocity $\vec{v}_1 = 1\hat{i}$ m/s at a point in a magnetic field and experiences a force

$$\vec{F}_1 = q[-1\hat{j} + 1\hat{k}] \text{ N}$$

If the charge is moving with a velocity $\vec{v}_2 = 1\hat{j}$ m/s at the same point, it experiences a force $\vec{F}_2 = q(1\hat{i} - 1\hat{k})$ N. The magnetic induction $\vec{B}$ at that point is :

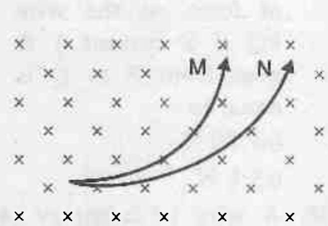
(a) $(\hat{i} + \hat{j} + \hat{k})$ Wb/m^2 (b) $(\hat{i} - \hat{j} + \hat{k})$ Wb/m^2

(c) $(-\hat{i} + \hat{j} - \hat{k})$ Wb/m^2 (d) $(\hat{i} + \hat{j} - \hat{k})$ Wb/m^2

49. A charged particle moving in a uniform magnetic field penetrates a layer of lead and loses one half of its kinetic energy. The radius of curvature changes to :

(a) twice the original radius
(b) $\sqrt{2}$ times the original radius
(c) half of the original radius
(d) $\frac{1}{\sqrt{2}}$ times the original radius

50. Two charged particles M and N are projected with same velocity in a uniform magnetic field. Then M and N are :



(a) an electron and a proton respectively
(b) a deuteron and a proton respectively
(c) a deuteron and an electron respectively
(d) a proton and α-particle respectively

51. A charged particle moving in a uniform magnetic field and losses 4% of its KE. The radius of curvature of its path changes by :

(a) 2% (b) 4%

(c) 10% (d) none of these

52. A charged particle of mass m and charge q in a uniform magnetic field B acts into the plane. The plane is frictional having coefficient of friction μ. The speed of charged particle just before entering into the region is v_0. The radius of curvature of the path after the time $\frac{v_0}{2\mu g}$ is :

(a) $\frac{mv_0}{qB}$ (b) $\frac{mv_0}{2qB}$

(c) $\frac{mv_0}{4qB}$ (d) none of these

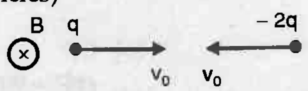
53. A particle of mass m and charge Q moving with velocity $\vec{v}$ describes a circular path of radius R when subjected to a uniform transverse magnetic field of inductance B.

The work done by the field when the particle completes one full circle is :

(a) $BQv\,(2\pi R)$ (b) $\left(\dfrac{mv^2}{R}\right)2\pi R$

(c) zero (d) $BQ\,(2\pi R)$

54. A charged particle $+q$ of mass m is placed at a distance d from another charged particle $-2q$ of mass $2m$ in a uniform magnetic field of induction vector B (as shown in figure). If particles are projected towards each other with equal speeds v_0, the maximum value of the projection speed v_0, so that the two particles do not collide, is : (Assume only magnetic force of interaction between particles)



(a) $\dfrac{qBd}{m}$ (b) $\dfrac{qBd}{2m}$

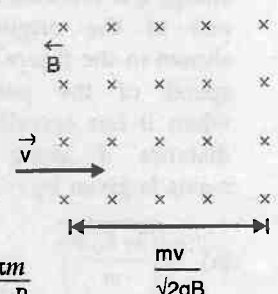
(c) $\dfrac{2qBd}{m}$ (d) none of these

55. A γ-ray photon is passing near a nucleus, and breaks into an electron and positron. The region contains a uniform magnetic field B perpendicular to the plane of motion. The time after which they again converted into γ-ray is : [The force of electrostatic interaction and gravitational interaction may be neglected]

(a) $\dfrac{2\pi m}{eB}$ (b) $\dfrac{\pi m}{2eB}$

(c) $\dfrac{4\pi m}{eB}$ (d) none of these

56. A positive charge q is projected in magnetic field of width $\dfrac{mv}{\sqrt{2}\,qB}$ with velocity v as shown in figure. Then time taken by charged particle to emerge from the magnetic field is :



(a) $\dfrac{m}{\sqrt{2}\,qB}$ (b) $\dfrac{\pi m}{4qB}$

(c) $\dfrac{\pi m}{2qB}$ (d) $\dfrac{\pi m}{\sqrt{2}\,qB}$

57. If a charged particle of charge 5 μC and mass 5 g is moving with constant speed 5 m/s in a uniform magnetic field B on a curve $x^2+y^2=25$, where x and y are in metre. The value of magnetic field will be

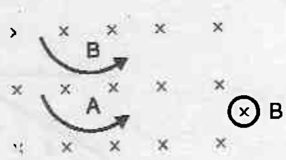
(a) 1 tesla

(b) 1 kilo tesla along z-axis

(c) 5 kilo tesla along the x-axis

(d) 1 kilo tesla along any line in the x-y plane

58. Two point charges A and B of same charge having magnitude of momenta p_1 and p_2 respectively and having same charge are moving in a plane containing uniform magnetic field perpendicular to the plane. Then (Trajectories as shown in figure)



(a) $p_1=p_2$ (b) $p_1>p_2$

(c) $p_1<p_2$ (d) none of these

59. A charged particle of mass m and charge q is accelerated through a potential difference of V volt. It enters a region of uniform magnetic field which is directed perpendicular to the direction of motion of the particle. The particle will move on a circular path of radius given by :

(a) $\sqrt{\left(\dfrac{Vm}{qB^2}\right)}$ (b) $\dfrac{2Vm}{qB^2}$

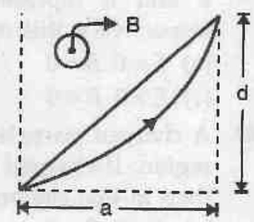
(c) $\sqrt{\left(\dfrac{2Vm}{q}\right)}\left(\dfrac{1}{B}\right)$ (d) $\sqrt{\left(\dfrac{Vm}{q}\right)}\left(\dfrac{1}{B}\right)$

60. A circular flexible loop of wire of radius r carrying a current I is placed in a uniform magnetic field B. If B is doubled, tension in the loop :

(a) remains unchanged (b) is doubled

(c) is halved (d) becomes 4 times

61. A charged particle q enters a region of uniform magnetic field B (out of the page) and is deflected a distance d after travelling a horizontal distance a. The magnitude of the momentum of the particle is :



(a) $\dfrac{qB}{2}\left[\dfrac{a^2}{d}+d\right]$

(b) $\dfrac{qB}{2}$

(c) zero

(d) not possible to be determined as it keeps changing

62. In a uniform magnetic field there are two charged particles moving with velocities $\vec{v}_1$ and $\vec{v}_2$ and carrying equal charges with $|\vec{v}_1|=|\vec{v}_2|=v$. The velocity of one particle forms an angle α_1 with direction of the field, while the velocity of other particle forms an angle α_2, then :

(a) both particles move on helical path of same radii

(b) both particles move on helical paths of different radii

(c) when $\alpha_1>\alpha_2$, then pitch of first particle is lesser than that of other

(d) none of the above

63. A charged particle follows a helical path of unequal pitch in a magnetic field. This means that :

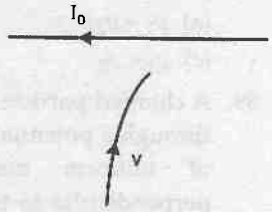
(a) the magnetic field is non-uniform

(b) the velocity vector is not parallel to the magnetic field

(c) the velocity vector is not perpendicular to the magnetic field

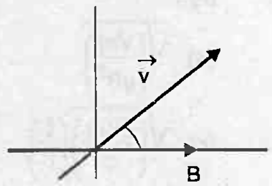
(d) all of the above

64. A long straight wire, carries a current I_0. A particle having a positive charge q and mass m kept at a distance y from the wire is projected towards it with a speed v. At the minimum separation, magnitude of velocity of the charge particle will be :



(a) zero (b) v
(c) ∞ (d) none of these

65. A charged particle enters into a uniform magnetic field B with velocity $\vec{v}$ at an angle θ as shown in figure. Then the ratio of radius to pitch of helix is :

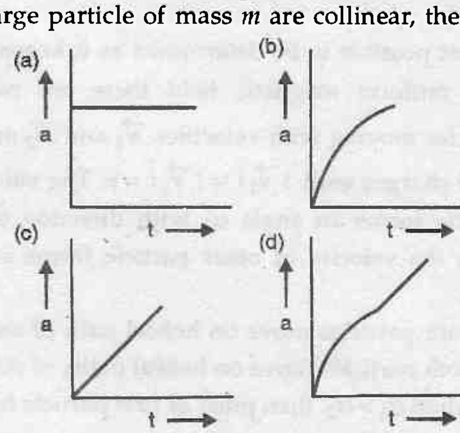


(a) $\dfrac{2\pi}{\tan\theta}$ (b) $\tan\theta$
(c) $\cot\theta$ (d) $\dfrac{\tan\theta}{2\pi}$

66. A proton moving with a constant velocity passes through a region of space without any change in its velocity. If E and B represent the electric and magnetic fields respectively, this region of space may have :
(a) $E = 0, B = 0$ (b) $E = 0, B \neq 0$
(c) $E \neq 0, B = 0$ (d) $E \neq 0, B \neq 0$

67. A charged particle is dropped from a small height in a region. If charged particle drops with constant velocity, then in that region :
(a) $E \neq 0, B = 0$ (b) $E \neq 0, B \neq 0$
(c) $E = \dfrac{mg}{q}$ (d) all of these

68. When electric field $\vec{E}$, magnetic field $\vec{B}$ and velocity $\vec{v}$ of charge particle of mass m are collinear, then :



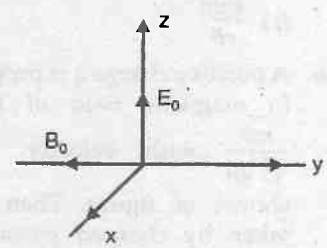
69. A long copper wire carries current in the east direction. The electrons are moving with a drift velocity $\vec{u}$. An observer now moves with the velocity $\vec{u}$. In the frame of this observer :
(a) electric field is present
(b) magnetic field due to wire is zero
(c) only magnetic field is present
(d) none of the above

70. A non-relativistic proton beam passes without deviation through the region of space where there are uniform transverse mutually perpendicular electric and magnetic field with $E = 120$ kV/m and $B = 50$ mT. Then the beam strikes a grounded target. The force with which the beam acts on the target if the beam current is equal to $I = 0.80$ mA is :
(a) 80 μN (b) 25 μN
(c) 20 μN (d) 35 μN

71. An α-particle and a proton are both simultaneously projected into a region of constant magnetic field, perpendicular to the direction of the field but in opposite directions. After 10^{-8} s, it is found that the velocity of α-particle has changed in the direction by 45°. The angle between the velocity vectors of the α-particle and the proton is :
(a) 90° (b) 45°
(c) 45° + 90° (d) $\dfrac{(45° + 90°)}{2}$

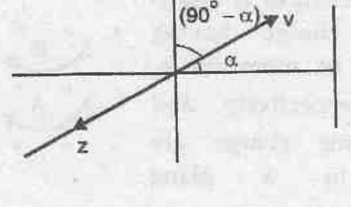
72. A positive charge is released from the origin at a place where uniform electric field E and a uniform magnetic field B exist along the positive y-axis and positive z-axis respectively, then :
(a) initially the charge particle tends to move along positive z-axis
(b) initially the charged particle tends to move along negative y-direction
(c) initially the charged particle tends to move along positive y-direction
(d) the charged particle moves in y-z plane

73. A particle of mass m and charge q is released from rest at the origin as shown in the figure. The speed of the particle when it has travelled a distance d along the z-axis is given by :



(a) $\sqrt{\left(\dfrac{2q\,E_0 d}{m}\right)}$ (b) $\sqrt{\left(\dfrac{E_0 d}{B_0}\right)}$
(c) $\sqrt{\left(\dfrac{m}{qE_0 d}\right)}$ (d) $\sqrt{\left(\dfrac{2m}{qE_0 d}\right)}$

*74. A non-relativistic charged particle of charge q and mass m originates at a point at origin of coordinate system. A magnetic field strength B is directed along x-axis. The charged particle moves with velocity v at an angle α to the x-axis. A screen is oriented at right angles to the axis and is situated at a distance x_0 from the origin of coordinate system. The coordinates of point P on the screen at which the charged particle strikes :



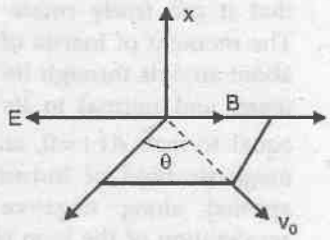
(a) $x_0, \dfrac{mv\sin\alpha}{qB}\sin\dfrac{qB}{m}t, \dfrac{mv\sin\alpha}{qB}\left[1-\dfrac{\cos qBt}{m}\right]$

(b) $x_0, \dfrac{mv\sin\alpha}{qB}\sin\dfrac{qBt}{m}, \dfrac{mv\sin\alpha}{qB}\left[\cos\dfrac{qB}{m}t-1\right]$

(c) $x_0, \dfrac{m\sin\alpha}{qB}\left[\cos\dfrac{qB}{m}t-1\right], \dfrac{mv\sin\alpha}{qB}\sin\dfrac{qB}{m}t$

(d) none of the above

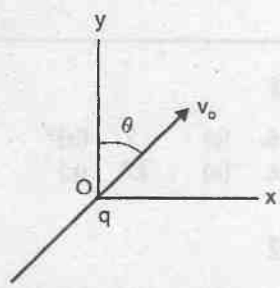
* **75.** In a certain region uniform electric field E and magnetic field B are present in the opposite direction. At the instant $t=0$, a particle of mass m carrying a charge q is given velocity v_0 at an angle θ, with the y-axis, in the y-z plane. The time after which the speed of the particle would be minimum is equal to :



(a) $\dfrac{mv_0}{qE}$ (b) $\dfrac{mv_0\sin\theta}{qE}$

(c) $\dfrac{mv_0\cos\theta}{qE}$ (d) $\dfrac{2\pi m}{qB}$

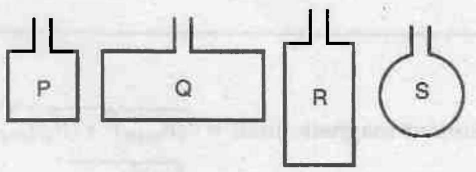
76. A particle of mass m, carrying a charge q is lying at the origin in a uniform magnetic field directed along x-axis. At the instant $t=0$ it is given a velocity v_0 at an angle θ with the y-axis, in the x-y plane. The coordinates of the particle after one revolution will be :



(a) $\left(0, 0\cdot\dfrac{2\pi mv_0\sin\theta}{qB}\right)$ (b) $\left(\dfrac{2\pi mv_0\sin\theta}{qB}, 0, 0\right)$

(c) $\left(\dfrac{2\pi mv_0\sin\theta}{qB}, 0, 4\right)$ (d) $(0, 0, 0)$

* **77.** Four wires each of length 2 m are bent into four loops P, Q, R and S and then suspended into uniform magnetic field. Some current is passed in each loop. Which statement is correct ?



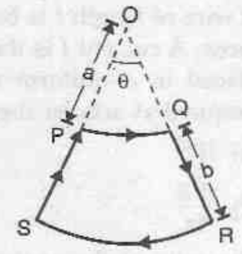
(a) Couple on loop P will be the highest

(b) Couple on loop Q will be the highest

(c) Couple on loop R will be the highest

(d) Couple on loop S will be the highest

78. The magnetic moment of the current carrying loop shown in the figure is equal to :



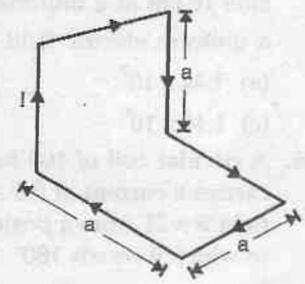
(a) $\dfrac{I(b^2+2ab)\theta}{2}$

(b) $Iab\theta$

(c) $\dfrac{I(a^2+ba)\theta}{2}$

(d) none of the above

79. The magnitude of magnetic moment of the current loop in the figure is :



(a) Ia^2

(b) $\sqrt{2}\,Ia^2$

(c) zero

(d) none of the abvoe

80. An insulating rod of length l carries a charge q distributed uniformly on it. The rod is pivoted at an end and is rotated at a frequency f about a fixed perpendicular axis. The magnetic moment of the system is :

(a) zero (b) πqfl^2

(c) $\dfrac{1}{2}\pi qfl^2$ (d) $\dfrac{1}{3}\pi qfl^2$

81. A conducting loop carrying a current is placed in a non-uniform magnetic field perpendicular to the plane of loop. Then :

(a) loop must experience force

(b) loop may experience torque

(c) loop must experience torque

(d) none of the above

82. A charged particle moves in a magnetic field in a plane perpendicular to the magnetic field. The orbital magnetic moment of circulating charge is directed :

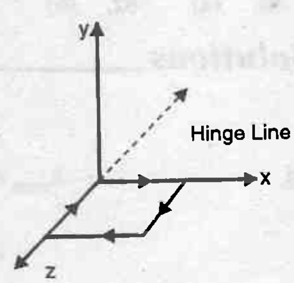
(a) parallel to magnetic field

(b) against the magnetic field

(c) perpendicular to magnetic field

(d) none of the above

83. In a non-uniform magnetic field $B=(B_0x)\,\hat{j}$, a square loop of side L has been placed as shown in figure. The loop can rotate about hinge line (z-axis). If 1 A current is flowing in the loop then the torque with respect to hinge line acting on the loop will be :



(a) B_0L^3 (b) $2B_0L^3$

(c) $3B_0L^3$ (d) zero

84. A wire of length l is bent to form a circular coil of some turns. A current I is then established in the coil and it is placed in a uniform magnetic field B. The maximum torque that acts on the coil is :

(a) IBl^2 (b) $4\pi IBl^2$

(c) $\frac{Il^2B}{4\pi}$ (d) zero

85. The ratio of the energy required to set-up in a cube of side 10 cm in a uniform magnetic field of $4\ Wb/m^2$ and a uniform electric field of of 10^6 V/m, is :

(a) 1.44×10^7 (b) 1.44×10^{-5}

(c) 1.44×10^6 (d) 1.44×10^3

86. A circular coil of 100 turns and effective diameter 20 cm carries a current of 0.5 A. It is to be turned in a magnetic field $B = 2T$ from a position in which θ equals zero to one in which θ equals 180°. The work required in this process is :

(a) π joule (b) 2π joule

(c) 4π joule (d) 8π joule

87. Mark correct option or options :

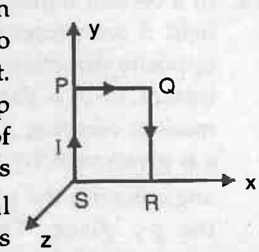
(a) The current sensitivity of a galvanometer is defined as the deflection in milimeters produced on a scale placed at a distance of one metre from the galvanometer mirror, when a current of 10^{-6} A passes through galvanometer coil

(b) Current sensitivity $= NAB/C$

(c) Charge sensitivity $= \frac{2\pi}{T}\times$ current sensitivity

(d) all the above

*** 88.** A square loop of mass m, side a and carrying current I, lies in the x-y plane as shown in the figure. It is hinged at y-axis, so that it can freely rotate about it. The moment of inertia of the loop about an axis through its centre of mass. and normal to its plane is equal to ma^2. At $t = 0$, an external magnetic field of induction B is applied along negative x-axis. The initial angular acceleration of the loop is equal to :



(a) $\frac{uI_0B}{m(2y+1)}$ (b) $\frac{I_0B}{my}$

(c) $\frac{uI_0\pi B}{m(2y+1)}$ (d) $\frac{uI_0B}{(2y+1)}$

Answers

Level-1

1. (a)	2. (a)	3. (b)	4. (a)	5. (a)	6. (c)	7. (b)	8. (a)	9. (b)	10. (c)
11. (b)	12. (c)	13. (a)	14. (b)	15. (c)	16. (a)	17. (c)			

Level-2

1. (a)	2. (b)	3. (d)	4. (b)	5. (c)	6. (b)	7. (d)	8. (a)	9. (b)	10. (b)
11. (d)	12. (a)	13. (a)	14. (b)	15. (c)	16. (b)	17. (c)	18. (a)	19. (b)	20. (a)
21. (a)	22. (a)	23. (d)	24. (a)	25. (c)	26. (b)	27. (a)	28. (d)	29. (b)	30. (b)
31. (b)	32. (c)	33. (c)	34. (c)	35. (b)	36. (d)	37. (b)	38. (c)	39. (d)	40. (d)
41. (a)	42. (b)	43. (b)	44. (a)	45. (c)	46. (d)	47. (d)	48. (a)	49. (d)	50. (d)
51. (a)	52. (b)	53. (c)	54. (b)	55. (a)	56. (b)	57. (b)	58. (c)	59. (c)	60. (b)
61. (a)	62. (c)	63. (d)	64. (b)	65. (d)	66. (a)	67. (d)	68. (a)	69. (c)	70. (c)
71. (c)	72. (c)	73. (a)	74. (b)	75. (c)	76. (b)	77. (d)	78. (a)	79. (b)	80. (d)
81. (a)	82. (b)	83. (d)	84. (c)	85. (c)	86. (b)	87. (d)	88. (a)		

Solutions

Level-1

3.
$$B_{wire} = \frac{\mu_0}{4\pi}\times\frac{2I}{r}$$
$$= \frac{10^{-7}\times2\times20}{3\times10^{-3}}$$
$$= \frac{4}{3}\times10^{-3}\ \text{T}$$

Field due to solenoid

$$B_{solenoid} = 4\text{mT}$$

$$\text{Resultant magnetic field} = \sqrt{(B_{wire})^2 + (B_{solenoid})^2}$$
$$= \sqrt{\left(\frac{4}{3}\right)^2 + (4)^2}\ \text{mT} = 4.2\ \text{mT}$$

4. Magnetic field on the axis of a circular coil having n turns is

$$B = \frac{\mu_0}{4\pi}\frac{2\pi ni R^2}{(R^2+x^2)^{3/2}}$$
$$\frac{1}{8}\cdot\frac{\mu_0}{4\pi}\frac{2\pi ni}{R} = \frac{\mu_0}{4\pi}\frac{2\pi ni R^2}{(R^2+x^2)^{3/2}}$$

28

Magnetostatics

Syllabus: *Bar magnet, magnetic field, lines of force, torque on a bar magnet in a magnetic field, earth's magnetic field, tangent galvanometer, vibration magnetometer, para, dia and ferro-magnetism, magnetic induction, magnetic susceptibility.*

Review of Concepts

1. Magnetic lines of force:

(a) The magnetic lines of force are the curves such that the tangent drawn on it at any point indicates the direction of magnetic field.

(b) The magnetic lines of force form closed curves.

(c) The lines of force never cross each other.

2. Work done in rotating a magnet and Potential energy:

(a) Work done $W = MB(1 - \cos\theta)$

Case I: If $\theta = 90°$ (*i.e.*, the magnet is rotated from the direction of magnetic field and brought perpendicular to it), then the work done

$$W = MB(1 - \cos 90°) = MB$$

Case II: If $\theta = 180°$ (*i.e.*, if the **magnet** is rotated from direction of magnetic field by an angle 180°), then the work done

$$W = MB(1 - \cos 180°)$$
$$= 2MB \text{ (maximum work)}$$

(b) Potential energy

$$U = -MB\cos\theta$$

Case I: If $\theta = 0°$, $U = -MB$ (minimum, stable equilibrium)

Case II: If $\theta = 90°$, $U = -MB\cos 90° = 0$ (standard position)

Case III: If $\theta = 180°$, $U = MB$ (maximum, unstable equilibrium)

3. Torque on a bar magnet:

$$\tau = NIAB\sin\theta$$

where $A = lb$ = area of a coil having N turns.

In vector form;

$$\vec{\tau} = NI\vec{\mathbf{A}} \times \vec{\mathbf{B}} = \vec{\mathbf{M}} \times \vec{\mathbf{B}}$$

where $\vec{\mathbf{M}} = NI\vec{\mathbf{A}}$

= magnetic moment of current carrying coil

$= m \times 2l$ = pole strength × effective length

4. Magnetic field due to a single magnetic dipole:

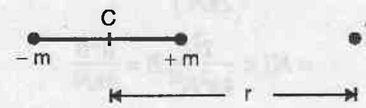
$$B = \frac{\mu_0}{4\pi}\frac{m}{r^2}$$

Unit: Its S.I. unit is tesla or Wbm^{-2} or $\text{NA}^{-1}\text{m}^{-1}$

$$10^4 \text{ gauss} = 1\ \text{NA}^{-1}\text{m}^{-1} = 1 \text{ tesla}$$

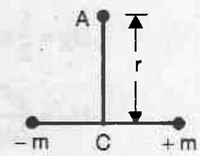
5. Magnetic field at a point dut to a magnet:

(a) End-on position:



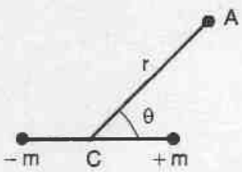
$$B = \frac{\mu_0 M}{2\pi r^3}$$

(b) Broad side-on position:



$$B = \frac{\mu_0}{4\pi}\frac{M}{r^3}$$

(c) At any point $A(r, \theta)$:



$$B = \frac{\mu_0}{4\pi}\frac{M}{r^3}\sqrt{3\cos^2\theta + 1}$$

6. Tangent law:

$$B = B_H \tan\theta$$

7. Deflection magnetometer:

(a) Tan A-position:

$$\frac{\mu_0}{2\pi}\frac{M}{r^3} = B_H\tan\theta \qquad \text{(For magnetic dipole)}$$

(b) Tan B-position:

$$\frac{\mu_0}{4\pi}\frac{M}{r^3} = B_H\tan\theta \qquad \text{(For magnetic dipole)}$$

8. Oscillation magnetometer:

$$T = 2\pi\sqrt{\left(\frac{I}{MB}\right)}$$

Here, T = time period, I = moment of inertia of magnet, B = magnetic field, M = magnetic dipole moment

9. Angle of dip:

(a) $B_H = B\cos\delta$

(b) $B_V = B\sin\delta$

(c) $\therefore \tan\delta = \frac{B_V}{B_H}$

Here, δ = angle of dip.

(i) The direction of B_H is from south to north.

(ii) The direction of B_V is downward in northern hemisphere and upward in southern hemisphere.

10. Relation between some magnetic parameters :

(a) $B = \mu_0 (H + I)$

(b) $\chi = \frac{I}{H}$

(c) $\mu_r = 1 + \chi$

(d) $B = \mu H = \mu_0 \mu_r H$

Here : μ = magnetic permeability,
H = magnetising force,
I = Intensity of magnetisation,
μ_r = relative magnetic permeability,
χ = magnetic susceptibility

11. Force between two short magnetic dipoles (magnets) at separation r and having magnetic moments M_1 and M_2:

(a) When they are on coaxial position

$$F = \frac{\mu_0}{4\pi} \cdot \frac{6M_1M_2}{r^4}$$

(b) When they are on broad side-on position,

$$F = \frac{\mu_0}{4\pi} \frac{3M_1M_2}{r^4}$$

12. Vibration magnetometer :

(a) If small magnet is placed in magnetic maridian and vibrates in horizontal plane

$$T = 2\pi \sqrt{\left(\frac{I}{MH}\right)}$$

where, $I = M_0 \left(\frac{l^2 + b^2}{12}\right)$ its breadth is negligible,

$$I = \frac{M_0 l^2}{12}$$

(b) If magnet is placed parallel to magnetic meridian and oscillates in vertical plane,

$$T = 2\pi \sqrt{\left(\frac{I}{MB_e}\right)}$$

(c) If magnet is placed perpendicular to magnetic meridian and oscillates in vertical plane

$$T = 2\pi \sqrt{\left(\frac{I}{MV}\right)}$$

(d) Comparison of magnetic moments by sum and difference method

$$\frac{M_1}{M_2} = \frac{T_1^2 + T_2^2}{T_1^2 - T_2^2}$$

Objective Questions

Level-1

1. If magnetic lines of force are drawn by keeping magnet vertical, then number of neutral points will be :
(a) one (b) two
(c) four (d) five

2. Ratio between total intensity of magnetic field at equator to poles is :
(a) 1 : 1 (b) 1 : 2
(c) 2 : 1 (d) 1 : 4

3. A magnetic needle having length $2L$, magnetic moment M and pole strength m units, is broken into two pieces at the middle. The magnetic moment and pole strength of each piece will be respectively :
(a) $\frac{M}{2}$ and $\frac{m}{2}$ (b) M and $\frac{m}{2}$
(c) $\frac{M}{2}$ and m (d) M and m

4. The vertical component of the earth's magnetic field is zero at a place where the angle of dip is :
(a) 0° (b) 45°
(c) 60° (d) 90°

5. A compass needle will show, which of the following directions at the earth's magnetic pole ?
(a) Vertical
(b) No particular direction
(c) Bent at 45° to the vertical
(d) Horizontal

6. Which one of the following is a vector quantity ?
(a) Pole strength
(b) Permeability
(c) Magnetic lines of forces
(d) Magnetic pole

7. If the distance between two similar magnetic poles held one cm apart be doubled, then the force of interaction between them will be :
(a) doubled
(b) halved
(c) unchanged
(d) one quarter of the original value

8. The time period of a magnet placed in vibration magnetometer will be infinity at :
(a) magnetic equator (b) magnetic poles
(c) equator (d) all places

9. Of the following, the most suitable material for making permanent magnet is :
(a) steel (b) soft iron
(c) copper (d) nickel

10. The sensitivity of a tangent galvanometer is increased if :
(a) number of turns decreases
(b) number of turns increases
(c) field increases
(d) none of the above

11. A dip circle is at right angle to the magnetic meridian. The apparent dip angle is :
(a) 0° (b) 30°
(c) 60° (d) 90°

12. The dipole moment of a short bar magnet is 1.25 Am^2. The magnetic field on its axis at a distance or 0.5 m from the centre of the magnet, is :
(a) 1×10^{-4} N/Am (b) 4×10^{-2} N/Am
(c) 2×10^{-6} N/Am (d) 6.64×10^{-8} N/Am

13. The magnetic moment of atomic neon is :
(a) zero (b) $\frac{\mu B}{2}$
(c) μB (d) $\frac{3\mu B}{2}$

14. Time period for a magnet is T. If it is divided in two equal parts perpendicular to its axis, then time period for each part will be :
(a) $4T$ (b) $\frac{T}{4}$
(c) $\frac{T}{2}$ (d) T

15. The angle of dip at a place is 40.6° and the intensity of the vertical component of the earth's magnetic field $V = 6 \times 10^{-5}$ T. The total intensity of the earth's magnetic field at this place is :
(a) 7×10^{-5} T (b) 6×10^{-5} T
(c) 5×10^{-5} T (d) 9.2×10^{-5} T

16. The number of turns and radius of cross-section of the coil of a tangent galvanometer are doubled, the reduction factor K will be :
(a) remain same (b) be doubled
(c) be quadrupled (d) be one fourth

17. A magnet of magnetic moment $50\,\hat{i}$ Am^2 is placed along the x axis in a magnetic field $\vec{B} = (0.5\,\hat{i} + 3.0\,\hat{j})$ T. The torque acting on the magnet is :
(a) $175\,\hat{k}$ N-m (b) $150\,\hat{k}$ N-m
(c) $75\,\hat{k}$ N-m (d) $25\sqrt{37}\,\hat{k}$ N-m

18. A bar magnet of magnetic moment M is placed in a magnetic field of induction B, the torque exerted on it is :
(a) $\vec{M} \cdot \vec{B}$ (b) $-\vec{M} \cdot \vec{B}$
(c) $\vec{M} \times \vec{B}$ (d) none of these

19. When magnetic moments of two magnets are compared using equal distance method, the deflections produced are 45° and 30°. If the lengths of magnets are in the ratio 1 : 2, the ratio of their pole strengths is :
(a) 3 : 1 (b) 3 : 2
(c) $\sqrt{3} : 1$ (d) $2\sqrt{3} : 1$

20. If the angular momentum of an electron is J then the magnitude of the magnetic moment will be :
(a) $\frac{eJ}{m}$ (b) $\frac{eJ}{2m}$
(c) $eJ\,2m$ (d) $\frac{2m}{eJ}$

21. The relative permeability is represented by μ_r and susceptibility is denoted by χ for a magnetic substance, then for a paramagnetic substance :
(a) $\mu_r < 1, \chi < 0$ (b) $\mu_r < 1, \chi > 0$
(c) $\mu_r > 1, \chi < 0$ (d) $\mu_r > 1, \chi > 0$

22. If the angle of dip at a certain place is 45° then the horizontal component H, vertical component V and total intensity I of earth's magnetic field have the correct relationship given by :
(a) $H = \sqrt{2}\,V$ (b) $I = \sqrt{2}\,H$
(c) $I = 2V$ (d) $V = \sqrt{2}\,H$

23. A tangent galvanometer having radius r and N as number of turns when used, it will have its reduction factor as :
(a) $\frac{\mu_0 H}{rN}$ (b) $\frac{2\pi r}{N}$
(c) $\frac{2rH}{\mu_0 N}$ (d) $\frac{2\pi r H}{\mu_0 N}$

24. The certain amount of current when flowing in a properly set tangent galvanometer, produces a deflection of 45°. The current be reduced by a factor of $\sqrt{3}$, the deflection would :
(a) decrease by 30° (b) decrease by 15°
(c) increase by 15° (d) increase by 30°

25. A short bar magnet placed with its axis at 30° with a uniform external magnetic field of 0.16 T experiences a torque of magnitude 0.032 J. The magnetic moment of the bar magnet will be :
(a) 0.23 J/T (b) 0.40 J/T
(c) 0.80 J/T (d) zero

26. Relative permeability of iron is 5500, then its magnetic susceptibility will be :
(a) 5500×10^{7} (b) 5500×10^{-7}
(c) 5501 (d) 5499

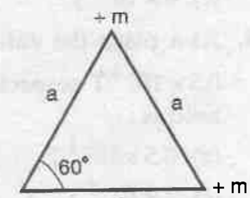
27. In a tangent galvanometer, a current of 0.1 A produces a deflection of 30°. The current required to produce a deflection of 60°, is :
(a) 0.2 A (b) 0.3 A
(c) 0.4 A (d) 0.5 A

Level-2

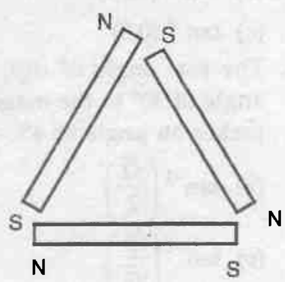
1. The force acting between two small magnets, placed in end on position 0.1 m apart from their centres is : [Given magnetic moment of each magnet is 5 Am^2]
(a) 0.6 N (b) 0.8 N
(c) 0.15 N (d) 0.2 N

2. Two similar equal magnetic poles when separated by a distance of 1 m, repel with a force of 10^{-3} N. The pole strength is :
(a) 10 Am (b) 20 Am
(c) 50 Am (d) 100 Am

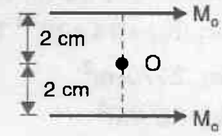
3. Three similar megnetic south poles each of strength 10 Am are placed at the corners of an equilateral triangle of side 20 cm. The magnetic force on one of the pole is :
   (a) 0.25×10^{-3} N (b) 10^{-3} N
   (c) 10×10^{-3} N (d) none of these
4. Six similar magnetic poles are placed on six corners of a regular hexagon of side 10 cm. A south pole of strength 10 Am is placed at the centre of hexagon. The magnetic force on the south pole is:
   (a) zero (b) $4\pi \times 10^{-4}$ N
   (c) 10 N (d) none of these
5. Two magnets of exactly equal lengths have magnetic moments M_1 and M_2 respectively. What is the effective magnetic moment, if they are placed one over the other such that same poles are in same direction ?
   (a) $M_1 + M_2$ (b) $M_1 - M_2$
   (c) $\frac{M_1 + M_2}{2}$ (d) $\frac{M_1 - M_2}{2}$
6. The magnetic moment of the system as shown in figure, will be :
   (a) $\sqrt{3}ma$
   (b) ma
   (c) $2ma$
   (d) none of the above



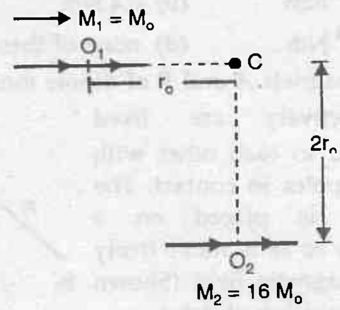
7. Three identical magnets are arranged as shown in the figure. The magnetic moment of each magnet is M. The effective magnetic moment of the given combination is :
   (a) 6 m
   (b) 3 m
   (c) zero
   (d) 2 m



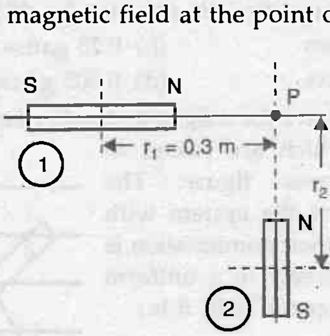
8. The flux of $\vec{B}$ through any closed surface is :
   (a) > 0 (b) < 0
   (c) $= 0$ (d) > 0
9. A magnetic wire of dipole moment 4π Am^2 is bent in the form of semicircle. The new magnetic moment is :
   (a) 4π Am^2 (b) 8π Am^2
   (c) 4 Am^2 (d) none of these
10. At a point on the right bisector of a magnetic dipole, the magnetic :
   (a) potential varies as $\frac{1}{r^2}$
   (b) potential is zero at all points on the right bisector
   (c) field varies as r^3
   (d) field is perpendicular to the axis of dipole
11. Two disimilar poles of strength x mWb and 2 mWb are separated by a distance 12 cm. If the null point is at a distance of 4 cm from 2 mWb, then the value of x is :
   (a) 5 (b) 6
   (c) 7 (d) 8
12. Two small magnets each of magnetic moment M_0 is placed parallel to each other (shown in figure). The magnetic field at point O is :



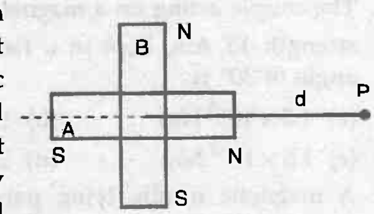
   (a) zero (b) 4×10^{-4} N
   (c) 2×10^{-4} N (d) none of these
13. The magnetic field at point C as shown in figure is :



   (a) $\frac{\mu_0 M_0}{2\pi r_0^3}$ (b) $\frac{\sqrt{2}\mu_0 M_0}{2\pi r_0^3}$
   (c) zero (d) $\frac{\sqrt{2}\,\mu_0 M_0}{4\pi r_0^3}$
14. Two short magnets of magnetic moment 2 Am^2 and 5 Am^2 are placed along two lines drawn at right angle to each other on the sheet of paper as shown in the figure. What is the magnetic field at the point of intersection of their axis :



   (a) 2.15×10^{-5} T (b) 215×10^{-5} T
   (c) 2.15×10^{-3} T (d) 21.5×10^{-5} T
15. The magnetic induction at P, for the arrangement shown in the figure, when two similar short magnets of magnetic moment M are joined at the middle so that they are mutually perpendicular, will be :



   (a) $\frac{\mu_0}{4\pi}\frac{M\sqrt{3}}{d^3}$ (b) $\frac{\mu_0}{4\pi}\frac{2M}{d^3}$
   (c) $\frac{\mu_0 M\sqrt{5}}{4\pi d^3}$ (d) $\frac{\mu_0 2M}{4\pi d^3}$

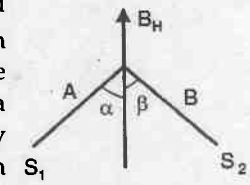
16. A small magnet of dipole moment M is kept on the arm of a deflection magnetometer set in $\tan A$ position at a distance of 0.2 m. If the deflection is 60°, the value of P is : ($B_H = 0.4 \times 10^{-4}$ T)

(a) 2.77 Am^2 (b) 8 Am^2
(c) 0.2 Am^2 (d) none of these

17. A magnet of dipole moment 2 Am^2 is deflected through 30° from magnetic meridian. The required deflecting torque is : ($B_H = 0.4 \times 10^{-4}$ T)

(a) 0.4×10^{-4} Nm (b) 0.4 Nm
(c) 0.2×10^{-4} Nm (d) none of these

18. Two small magnets A and B of dipole moments M_0 and $2M_0$ respectively are fixed perpendicular to each other with their North poles in contact. The combination is placed on a floating body so as to move freely in earth's magnetic field (Shown in figure), the value of α is :

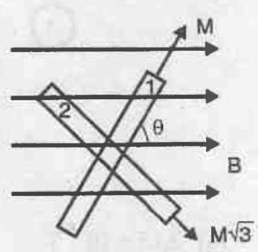


(a) $\tan^{-1}(2)$ (b) $\sin^{-1}\left(\frac{1}{2}\right)$
(c) $\cos^{-1}\left(\frac{1}{2}\right)$ (d) none of these

19. A uniform magnetic needle of strength of each pole is 98.1 amp. cm is suspended from its centre by a thread. When a mass of 50 mg is loaded to its upper end, the needle become horizontal, then the vertical component of earth's magnetic induction is : ($g = 981$ cm/sec^2)

(a) 0.50 gauss (b) 0.25 gauss
(c) 0.05 gauss (d) 0.005 gauss

20. M and $M/\sqrt{3}$ are the magnetic dipole moments of the two magnets, which are joined to form a cross figure. The inclination of the system with the field, if their combination is suspended freely in a uniform external magnetic field B is :



(a) $\theta = 30°$
(b) $\theta = 45°$
(c) $\theta = 60°$
(d) $\theta = 15°$

21. The couple acting on a magnet of length 10 cm and pole strength 15 Am, kept in a field of $B = 2 \times 10^{-5}$ T at an angle of 30° is :

(a) 1.5×10^{-5} Nm (b) 1.5×10^{-3} Nm
(c) 1.5×10^{-2} Nm (d) 1.5×10^{-6} Nm

22. 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 :

(a) 2 W (b) $\sqrt{3}$ W
(c) W (d) $\frac{\sqrt{3}}{2}$ W

23. A bar magnet of magnetic moment 2.5 J/T, is placed in magnetic field 0.2 T. What work is done in turning the magnet from parallel to antiparallel position relative to field direction ?

(a) 1 J (b) 2 J
(c) 3 J (d) 4 J

24. Two like poles of strength m_1 and m_2 are far distance apart. The energy required to bring them r_0 distance apart is :

(a) $\frac{\mu_0}{4\pi}\frac{m_1 m_2}{r_0}$ (b) $\frac{\mu_0}{8\pi}\frac{m_1 m_2}{r_0}$
(c) $\frac{\mu_0}{16\pi}\frac{m_1 m_2}{r_0}$ (d) none of these

25. The work done in deflecting a small magnet of magnetic moment 10 Am^2 through 180° from a uniform magnetic field of strength 0.4×10^{-4} T is :

(a) 8×10^{-4} J (b) zero
(c) 4×10^{-4} J (d) none of these

26. At a place the value of B_H and B_V are 0.4×10^{-4} T and 0.3×10^{-4} T respectively. The resultant earth's magnetic field is :

(a) 0.5×10^{-4} T (b) 10^{-4} T
(c) 2×10^{-4} T (d) none of these

27. In previous problem, the angle of dip is

(a) $\tan^{-1}(0.75)$ (b) $\tan^{-1}(0.5)$
(c) $\tan^{-1}(0.8)$ (d) none of these

28. The real angle of dip, if a magnet is suspended at an angle of 30° to the magnetic meridian and the dip needle makes an angle of 45° with horizontal, is :

(a) $\tan^{-1}\left(\frac{\sqrt{3}}{2}\right)$ (b) $\tan^{-1}(\sqrt{3})$
(c) $\tan^{-1}\left(\frac{\sqrt{3}}{\sqrt{2}}\right)$ (d) $\tan^{-1}\left(\frac{2}{\sqrt{3}}\right)$

29. A magnet is cut in three equal parts by cutting it perpendicular to its length. The time period of original magnet is T_0 in a uniform magnetic field B. Then the time period of each part in the same magnetic field is :

(a) $T_0/2$ (b) $T_0/3$
(c) $T_0/4$ (d) none of these

30. A magnet is cut in four equal parts by cutting it parallel to its length. What will be the time period of each part, if the time period of original magnet in the same field is T_0 ?

(a) $T_0/\sqrt{2}$ (b) $T_0/2$
(c) $T_0/4$ (d) $4T_0$

31. The angle of dip, if a dip needle oscillating in a vertical plane makes 40 oscillations per minute in a magnetic meridian and 30 oscillations per minute in a vertical plane at right angle to the magnetic meridian, is :

(a) $\theta = \sin^{-1}(0.5625)$ (b) $\theta = \sin^{-1}(0.325)$
(c) $\theta = \sin^{-1}(0.425)$ (d) $\theta = \sin^{-1}(0.235)$

32. A thin rectangular magnet suspended freely has a period of oscillation equal to T. Now, it is broken into two equal halves (each having half of the original length) and one piece is made to oscillate freely in the same field. If its period of oscillation is T', the ratio T'/T is :
(a) 1/4 (b) $1/2\sqrt{2}$
(c) 1/2 (d) 2

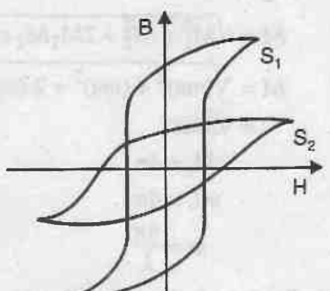
33. Curie temperature is the temperature above which :
(a) a paramagnetic material becomes ferromagnetic
(b) a ferromagnetic material becomes paramagnetic
(c) a paramagnetic material becomes diamagnetic
(d) a ferromagnetic material becomes diamagnetic

34. A tangent galvanometer has coil of 50 turns and a mean diameter of 22 cm. The current through it when the needle is deflected through 60° at a place where horizontal components of earth is $H = 30\,\mu_0$ A/m, is :
(a) 300 mA (b) 130 mA
(c) 228 mA (d) 158 mA

35. An atom is paramagnetic if it has :
(a) an electric dipole moment
(b) no magnetic moment
(c) a magnetic moment
(d) no electric dipole moment

36. The magnetic moment of a diamagnetic atom is :
(a) zero (b) infinity
(c) negative infinity (d) another value

37. The B-H curves S_1 and S_2 in the adjoining figure are associated with :

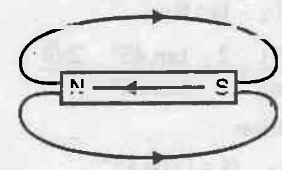


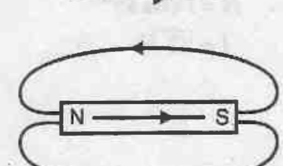
(a) a diamagnetic and paramagnetic substances respectively
(b) a paramagnetic and ferromagnetic substances respectively
(c) soft iron and steel respectively
(d) steel and soft iron respectively

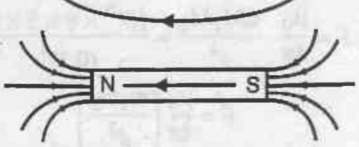
38. An iron rod is subjected to cycles of magnetisation at the rate of 50 Hz. Given the density of the rod is 8×10^3 kg/m^3 and specific heat is 0.11×10^{-3} cal/kg°C. The rise in temperature per minute, if the area inclosed by the B-H loop corresponds to energy of 10^{-2} J, is : [Assume there is no radiation losses]
(a) 78°C (b) 88°C
(c) 8.1°C (d) none of these

39. Inside a long solenoid wounded with 300 turns/metre, an iron rod is placed. An iron rod is 0.2 m long, 10 mm in diameter and of permeability 10^3. The magnetic moment of the rod, if 0.5 amp of current is passed through the rod, is :
(a) 2.356 SI unit (b) 1.335 SI unit
(c) 3.664 SI unit (d) 1.664 SI unit

40. Which of the following is correct representation of magnetic lines of force ?

(a)


(b)


(c)


(d) None of the above

41. The magnetic lines of force inside a bar magnet :
(a) are from south pole to north pole of the magnet
(b) are from north pole to south pole of the magnet
(c) do not exist
(d) depend upon the area of cross-section of the bar magnet

42. The value of $\frac{\delta B_x}{\delta_x} + \frac{\delta B_y}{\delta_y} + \frac{\delta B_z}{\delta_z}$ is :
(a) >0 (b) <0
(c) >0 (d) $=0$

Answers

Level-1

1. (a)	2. (a)	3. (c)	4. (a)	5. (a)	6. (c)	7. (d)	8. (b)	9. (a)	10. (b)
11. (d)	12. (c)	13. (a)	14. (c)	15. (d)	16. (a)	17. (b)	18. (c)	19. (d)	20. (b)
21. (d)	22. (b)	23. (c)	24. (b)	25. (b)	26. (d)	27. (b)			

Level-2

1. (c)	2. (d)	3. (a)	4. (a)	5. (a)	6. (a)	7. (c)	8. (c)	9. (c)	10. (a)
11. (d)	12. (a)	13. (c)	14. (a)	15. (c)	16. (a)	17. (a)	18. (a)	19. (b)	20. (c)
21. (a)	22. (b)	23. (a)	24. (a)	25. (a)	26. (a)	27. (a)	28. (a)	29. (b)	30. (a)
31. (a)	32. (c)	33. (b)	34. (c)	35. (a)	36. (a)	37. (c)	38. (c)	39. (a)	40. (a)
41. (a)	42. (d)								

29

Electromagnetic Induction

Syllabus: Induced emf, Faraday's law, Lenz's law, self and mutual induction.

Review of Concepts

It is well known that whenever an electric current flows through a conductor, a magnetic field is immediately brought into existence in the space surrounding the conductor. The converge of this is also true, *i.e.*, when a magnetic field embracing a conductor moves relative to the conductor, it produces a flow of electrons. This phenomenon whereby an emf and hence current (*i.e.* flow of electrons) is induced in any conductor that is cut across or is cut by magnetic lines of force (magnetic flux), is known as **electromagnetic induction.**

1. Magnetic Flux: As we know that the number of lines of induction passing through a unit area normal to the area, measures the magnitude of magnetic induction or magnetic flux density $\vec{B}$. Obviously in a region, smaller is the relative spacing of lines of induction, greater is the value of magnetic induction.

The tangent to the line of induction at any point gives the direction of magnetic induction at that point.

The magnetic flux 'ϕ_B' through a surface of area A is the total number of magnetic lines of induction passing through that area normally.

Mathematically, magnetic flux, $\phi_B = \Sigma \vec{B} \cdot \Delta \vec{A}$

$$\therefore \qquad \phi_B = \int_s \vec{B} \cdot \vec{dA} = BA\hat{n}$$

The unit of magnetic field induction in SI system is weber per metre^2 or tesla (T).

$$1 \text{ gauss} = 1\text{G} = 10^{-4} \text{ tesla}$$

$$\therefore \qquad 1 \text{ maxwell} = 10^{-8} \text{ weber}$$

2. Faraday's Laws of Electromagnetic Induction :

First law: *"Whenever the magnetic flux linked with a circuit changes, an emf is always induced in it."*

"Whenever a conductor cuts across magnetic lines of flux, an emf is induced in that conductor."

Second law: *"The magnitude of induced emf is directly proportional to the rate of change of flux linkages."*

The direction of induced emf (or induced current) is such that it opposes the cause which is produced by it. This statement is known as **Lenz's law.**

Mathematically, $\quad e = -\dfrac{Nd\phi}{dt}$

(where, N = number of conductors or number of turns in the coil.)

If R is the resistance of the circuit, then

$$I = \frac{e}{R} = -\frac{Nd\phi}{Rdt}$$

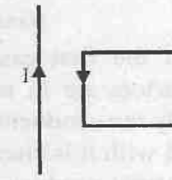
The charge induced in time dt is given by

$$dq = Idt = -\frac{Nd\phi}{Rdt}dt = -\frac{Nd\phi}{R} \Rightarrow \Delta q = \frac{N\Delta\phi}{R}$$

$$\therefore \qquad \boxed{\Delta q = \frac{\text{net change in flux}}{\text{resistance}}}$$

Obviously charge induced is independent of time

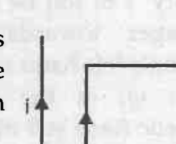
Illustrative Example: Let us place conducting loop near a long straight wire carrying a current I as shown in figure. Let us try to find the direction of induced current in the loop. Firstly assume that the current increases continuously with respect to time.



If I increases, ϕ increases and hence, $\dfrac{d\phi}{dt}$ increases.

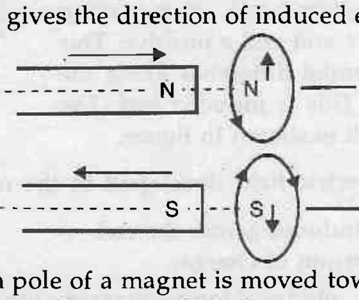
Therefore, $\dfrac{d\phi}{ut}$ is positive, and e is negative, *i.e.*, the current is negative. Hence, the induced current is in opposite direction on the straight wire carrying current in the nearest vertical side.

If the current I decreases continuously with respect to time, the direction of current will be as shown in figure.



In this case $\dfrac{d\phi}{dt}$ decreases and e becomes positive.

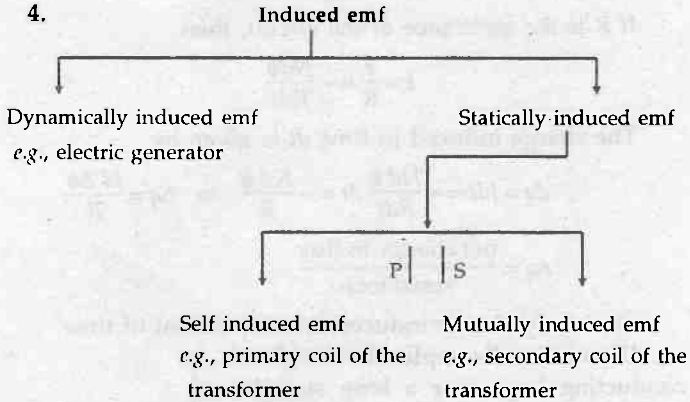
3. Lenz's Law: The Lenz's law is based on conservation of energy and it gives the direction of induced emf or current in the coil.



When north pole of a magnet is moved towards the coil, the induced current flows in a direction so, as to oppose the motion of the magnet towards the coil. This is possible only when nearer face of the coil acts as a magnetic north pole which necessitates an anticlockwise current in the coil. Then the repulsion between two similar poles opposes the motion of the magnet towards the coils.

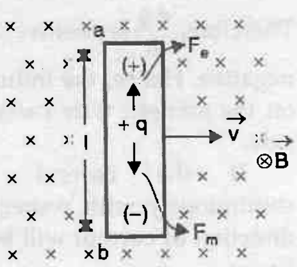
Similarly, when the magnet is moved away from the coil, the direction of induced current is such as to make the nearer face of the coil as a south-pole which necessitates a clockwise induced current in the coil. Then the attraction between two opposite poles opposes the motion of the magnet away from the coil. In either case, therefore work has to be done in moving the magnet. Thus, it is mechanical work which appears as electrical energy in the coil. Thus, the production of the induced emf or induced current in the coil is in accordance with the law of conservation of energy.

4.

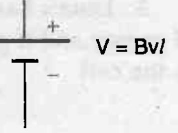


In the first case, usually the field is stationary and conductors are in motion. In second type of induced emf usually the conductor or the coil remains stationary and flux linked with it is changed by simply increasing or decreasing the current producing this flux.

Dynamically induced emf: Let a thin conducting rod ab of length l moves in a uniform magnetic $\vec{B}$ directed perpendicular to the plane of the paper, downwards. Let the velocity $\vec{v}$ of rod be in the plane of paper towards right. By Fleming's left hand rule a charge carrier (q) in the rod suffers magnetic force qvB directed from b to a along the rod.



While an electron will suffer a force evB from a to b, along the length of the rod. Due to this force the free electrons of rod moves from a to b, thus making end b negative and end a positive. This causes a potential difference along the ends of rod. This is induced emf. The equivalent cell is shown in figure.



If E is electric field developed in the rod, then $E = \frac{V}{l}$, V being emf induced across the rod.

In equilibrium of charges,

$$\text{electrical force} = \text{magnetic force}$$

$$eE = Bve$$

or $$E = vB$$

$\therefore$ Induced emf $V = El = Bvl$

If the rod moves across the magnetic field moving an angle θ with it, then induced emf

where, B_n is component of magnetic field normal to $\vec{v}$, here $B_n = B \sin \theta$.

$\therefore$ Induced emf $= (E) = V = Bvl \sin \theta$

The direction of induced current is given by Fleming's right hand rule, which states that if the fore-finger, middle finger and the thumb of right hand are arranged mutually perpendicular to such a way that fore-finger points along the magnetic field, the thumb along the direction of motion of conductor, then the middle finger will point along the direction of induced current.

Self induced emf: When the electric current flowing through a circuit changes, the magnetic flux linked with the circuit also changes. As a result an induced emf is set-up in the circuit. This phenomenon is called self induction and the induced emf is called the back emf or self induced emf.

If I is the current flowing in the circuit, the flux linked with the circuit, $\phi \propto I$

or $$\phi = LI$$

where, L is called the self-inductance of the coil and its unit is henry (H).

We know that, $$e = \frac{-d\phi}{dt}$$

$\therefore$ $$e = \frac{-dLI}{dt} = \frac{-LdI}{dt}$$

For N turns of the coil, we know that

$$e = -\frac{Nd\phi}{dt}$$

For the same coil, we can write

$$e = -\frac{Ld\phi}{dt}$$

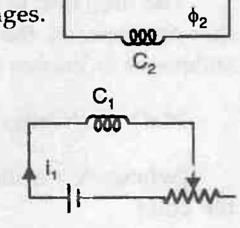
$\therefore$ $$-\frac{Nd\phi}{dt} = -\frac{LdI}{dt} \quad \text{or} \quad L = \frac{Nd\phi}{dI}$$

Simply we can write, $L = \frac{N\phi}{I}$

The role of self inductance in an electrical circuit is the same as that of inertia in mechanical motion. Thus, the self inductance of a coil is a measure of its ability to oppose the change in current through it.

Mutually induced emf: Consider coils C_1 and C_2 placed near each other such that if a current passes in coil C_1, the coil C_2 is in the magnetic field of coil C_1 and *vice-versa*.

Whenever the current flowing through a coil (C_1) changes, the magnetic flux linked with the neighbouring coil (C_2) also changes. This causes an induced emf and hence, an induced current in coil C_2. This phenomenon is called mutual induction. The induced emf in the second coil is known is mutually induced emf.



The circuit in which the current changes is called the primary circuit, while the neighbouring circuit in which emf is induced, is called the secondary circuit.

If I_1 is current flowing through primary coil at any instant, the flux linked with secondary coil is given by

$$\phi_2 \propto I_1 \text{ or } \phi_2 - MI_1$$

where M is called the mutual induction of the coil. Also the induced emf in the secondary coil

$$e = \frac{-d\phi_2}{dt} = \frac{-d}{dt}(MI_1) = -\frac{MdI_1}{dt}$$

In general, $e = -\frac{MdI_1}{dt}$ or $M = \frac{\phi_2}{I_1}$

Like self inductance, the unit of mutual inductance is henry (H). The direction of induced emf or induced current arising due to a change in magnetic flux in all case is given by Lenz's law.

5. Coefficient of Magnetic Coupling: Two coils are said to be magnetically coupled if full or a part of the flux produced by one links with the other. Let L_1 and L_2 be the self-inductances of the coils and M be their mutual inductance, then

$$k = \frac{M}{\sqrt{L_1 L_2}}$$

When all the flux produced by one coil links with the other, then mutual inductance between the two is maximum and is given by

$$M = \sqrt{L_1 L_2}$$

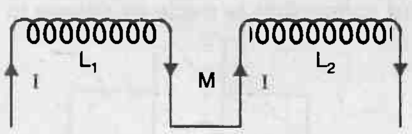
In that case, $k = 1$

When there is no common flux between the two wires, they are said to be magnetically isolated. In this case; $k = 0$ and $M = 0$

In practice k lies between 0 and 1

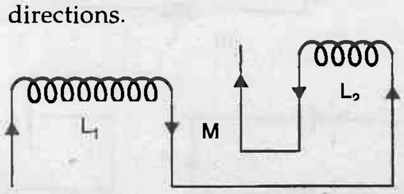
6. Combination of Inductances :

Case I: When the two coils are so joined in series such that their fluxes are additive *i.e.*, in the same direction. For the figure shown.



$$L_{eq} = L_1 + L_2 + 2M$$

Case II: When the coils are so joined that their fluxes are in opposite directions.



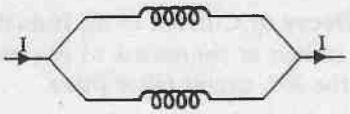
For the figure shown above.

$$L_{eq} = L_1 + L_2 - 2M$$

Note: When $M = 0$, then $L_{series} = L_1 + L_2$

Case III: When two coils of self inductances L_1 and L_2 are connected in parallel, assuming the inductors are so far apart that their mutual inductance is negligible then their equivalent inductance is

$$L_{parallel} = \frac{L_1 L_2}{L_1 + L_2}$$



7. Self-inductance of a Long Solenoid:

Let r = radius of solenoid cross-section

n = number of turns per unit length

l = length of the solenoid.

We know, that $L = \frac{(nl)\,\phi}{I} = \frac{(nl)}{I} B A$

$$\therefore \quad L = \frac{(nl)}{I} \times \mu_0 nI \times \pi r^2 = \mu_0 n^2 Al$$

8. Energy Density in Magnetic field: Consider again a long solenoid of radius r, length l and having n turns per unit length. If it carries a current I, the magnetic field within it is given by

$$B = \mu_0 nI$$

Now, we have, $L = \mu_0 n^2 Al$

The magnetic energy is therefore,

$$U = \frac{1}{2} LI^2 \qquad \text{(Proved later)}$$

$$= \frac{1}{2} \mu_0 n^2 AlI^2$$

$$U = \frac{1}{2\mu_0} (\mu_0 nI)^2 V$$

(where, V = volume enclosed by the solenoid)

$$\therefore \text{ Energy density} = \frac{U}{V} = \frac{B^2}{2\mu_0} \qquad \text{(For air cored solenoid)}$$

(Assuming that magnetic field is zero outside the solenoid)

9. Energy Stored in an Inductor: When an inductor carries a current, a magnetic field builds up in it and magnetic energy is stored in it.

Let I = instantaneous value of current.

e = induced emf at the instant $= \frac{LdI}{dt}$

Then, work done in time dt in overcoming this opposition is

$$dW = eIdt$$

$$dW = \frac{LdI}{dt} \times I \times dt \qquad \left(\because e = \frac{LdI}{dt}\right)$$

$$dW = LI\,dI$$

Total work done in establishing the maximum steady current of I is,

$$\int_0^I LI\,dI = \int_0^W dW = \frac{1}{2} LI^2$$

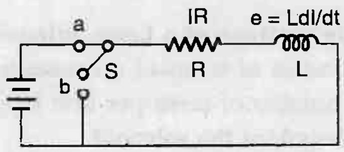
$$\therefore \qquad W = \frac{1}{2} L I^2$$

Hence, energy stored in inductor

$$U = \frac{1}{2} L I^2 \text{ joule}$$

10. Rise and Decay of Current in an Inductive Circuit:

(i) When the switch is connected to position *a*, rise of current in the *R-L* circuit takes place.



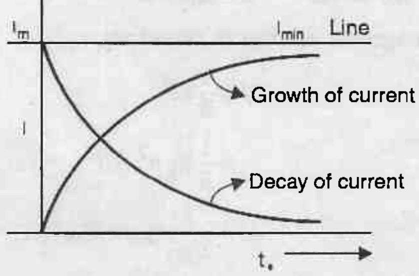
The growth of current, *i* through the circuit is given by

$$I = I_m (1 - e^{-t/\lambda})$$

where, $I_m = \frac{V}{R}$ and $\lambda = \frac{L}{R}$ = time constant of the circuit

(ii) When the switch *S* is connected to position *b*, decay of current in *R-L* circuit takes place. In this case current *I* is given by

$$I = I_m e^{-t/\lambda}$$



where, $I_m = V/R$ and $\lambda = L/R$

In the case of rise of current, when $t = \lambda$

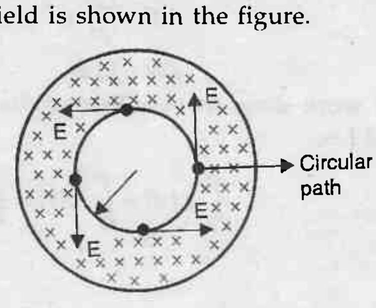
$I = 0.632\, I_m$ and in the case of decay of current, when $t = \lambda$, $I = 0.368\, I_m$

Note : The expressions of current may be obtained on the basis of charging and discharging of a capacitor.

11. Induced Electric Fields: A charging magnetic field produces an electric field. Hence, Faraday's law may be reformulated as

$$\oint \vec{E} \cdot \vec{dl} = -\frac{d\phi_B}{dt}$$

In the figure shown, let us consider the magnetic field-neglecting fringing-flux a cylindrical volume of radius *R*. Let us consider a hypothetical circular path of radius *R*. Assuming *dB/dt* increases in magnitude at a constant rate, induced electric field is shown in the figure.



Consider a test charge q_0 moving around the circular path as shown in figure. The work *W* done on it with one revolution by the electric field is Vq_0 where *V* is the induced emf.

Also, $$W = \oint \vec{F} \cdot \vec{dl} = (q_0 E)(2\pi r)$$

$$\therefore \qquad Vq_0 = (q_0 E) \times (2\pi r)$$

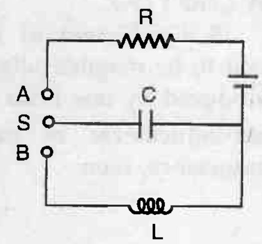
or $$V = E\,(2\pi r)$$

Electric potential has meaning only for electric fields that are produced by static charges, it is absurd for electric fields that are produced by induction.

In the case of induced electric fields, electric lines of force form a closed curves.

Also $$\oint \vec{E} \cdot \vec{dl} \neq 0$$

12. *L-C* Oscillation: As we know that capacitor stores energy in the electric field but inductor stores energy in magnetic field. An *L-C* circuit consists of a resistanceless inductor of inductance *L* connected to capacitance *C*. This circuit is also known by the name of the tank circuit.

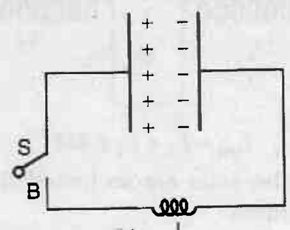


(a)

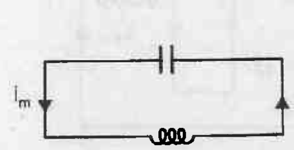
Let us consider a circuit consisting of a capacitor of capacitance *C*, a resistor of resistance *R*, an inductor of inductance *L* and a battery of emf *E* [shown in figure (a)]. When switch *S* is thrown over to *A*, the capacitor begins to charge. When capacitor is fully charged, then switch *S* is thrown over to *B* and *A* is disconnected from *S*. In the beginning when the capacitor is fully charged and the charge stored in the capacitor is q_0. The electric field is set-up between the plates. The energy stored in capacitor is

$$U_C = \frac{q_0^2}{2C}$$

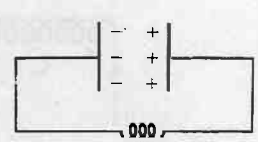
The capacitor starts to discharge through the inductor at the instant connection is made as shown in figure



(b)



(c)



(d)

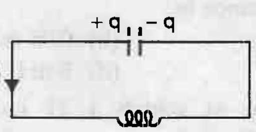
This is the cause of flowing current. As the current rises from zero, it builds up a magnetic field in the inductor as shown in figure (c). When capacitor is completely discharged and the potential difference between plates of capacitor is decreased to zero, the current becomes maximum I_0. At this instant energy stored in the inductor is $U_B = \frac{1}{2} L I_0^2$ and energy stored in the capacitor is zero so, at this time, total electrical energy is converted into magnetic field-energy linked with the inductor. The magnetic field now decreases as emf in the inductor in the same direction as the current. The current, therefore, persists although with diminishing magnitude, until the magnetic field has disappeared and the capacitor has been charged in the opposite sense of its initial polarity as shown in figure (d).

The process now repeats itself in the reversed direction. If there is no loss of energy in the circuit (only ideal concept), electric charges on the capacitor swell back, and forth indefinitely. This process is known as electrical oscillation.

From energy point of view, the oscillations of an electrical circuit consists of a transfer of energy back and forth from electric field of capacitor to the magnetic field of inductor remembering total energy remains constant.

Expression for Frequency of *L-C* Oscillation: Let us consider the situation when capacitor is fully charged and switch is connected to terminal *B* after disconnecting from *A*.

In this case, let at any instant *t* the charge on the capacitor is *q* and electric current in the circuit is *I* during discharging of capacitor.



$$\therefore \quad \frac{q}{C} - L\frac{dI}{dt} = 0 \quad \text{or} \quad \frac{dI}{dt} = +\frac{q}{LC}$$

$$\text{or} \quad \frac{dI}{dq} \cdot \frac{dq}{dt} = \frac{q}{LC} \quad \text{or} \quad -I\frac{dI}{dq} = \frac{q}{LC} \qquad \left[I = -\frac{dq}{dt}\right]$$

$$\text{i.e.} \quad \int_0^I I\,dI = \int_{q_0}^{q} -\frac{q}{LC}\,dq$$

$$\Rightarrow \quad \frac{I^2}{2} = -\frac{q^2}{2LC} + \frac{q_0^2}{2LC} = \frac{1}{2LC}(q_0^2 - q^2)$$

$$\Rightarrow \quad I^2 = \frac{1}{LC}(q_0^2 - q^2)$$

$$\Rightarrow \quad I = \frac{1}{\sqrt{LC}}\sqrt{(q_0^2 - q^2)}$$

$$\text{But,} \quad \frac{1}{\sqrt{LC}} = \omega \quad \text{(say)}$$

$$\Rightarrow \quad I = \omega\sqrt{(q_0^2 - q^2)}$$

$$\text{or} \quad \frac{dq}{dt} = \omega\sqrt{(q_0^2 - q^2)}$$

$$\int \frac{dq}{\sqrt{(q_0^2 - q^2)}} = \int \omega\,dt$$

$$\text{Put} \quad q = q_0 \sin\theta$$

$$dq = q_0 \cos\theta\,d\theta$$

$$\therefore \quad \int \frac{\cos\theta\,d\theta}{\cos\theta} = \int \omega\,dt$$

$$\text{or} \quad \theta = \omega t + \alpha$$

$$\text{or} \quad \sin^{-1}\left(\frac{q}{q_0}\right) = (\omega t + \alpha) \quad \text{or} \quad \sin(\omega t + \alpha) = \frac{q}{q_0}$$

$$\therefore \quad q = q_0 \sin(\omega t + \alpha)$$

when, $t = 0$, $q = q_0$, then

$$\sin(\omega \times 0 + \alpha) = \frac{q_0}{q_0} = 1 = \sin\frac{\pi}{2}$$

$$\therefore \quad q = q_0 \sin\left(\omega t + \frac{\pi}{2}\right) = q_0 \cos\omega t$$

$$\therefore \quad q = q_0 \cos\omega t$$

But this is periodic function.
Let fundamental period be *T*.

$$\therefore \quad q_0 \cos[\omega(t + T)] = q_0 \cos\omega t$$

$$\text{or} \quad \cos[\omega(t + T)] = \cos\omega t$$

$$\Rightarrow \quad \omega(t + T) = 2\pi n \pm \omega t$$

$$\Rightarrow \quad \omega t + \omega T = 2\pi n \pm \omega t$$

when $n = 1$, then

$$\omega t + \omega T = 2\pi \pm \omega t$$

$$\text{or} \quad \omega t + \omega T = 2\pi + \omega t$$

$$\therefore \quad \omega T = 2\pi$$

$$\Rightarrow \quad T = \frac{2\pi}{\omega} = 2\pi\sqrt{CL}$$

$$\therefore \quad \text{frequency} = f = \frac{1}{T} = \frac{1}{2\pi\sqrt{LC}}$$

General expression for I, U_E and U_B:

Now, we know that $q = q_0 \cos\omega t$,

$$\text{where} \quad \omega = \frac{1}{\sqrt{LC}}$$

$$\Rightarrow \quad I = \frac{dq}{dt} = -\omega q_0 \sin\omega t$$

$$\therefore \quad I = -\omega q_0 \sin\omega t$$

$$\text{Now,} \quad U_E = \frac{q^2}{2C} = \frac{q_0^2 \cos^2\omega t}{2C}$$

$$\text{and} \quad U_B = \frac{1}{2}LI^2 = \frac{1}{2}L(-\omega q_0 \sin\omega t)^2$$

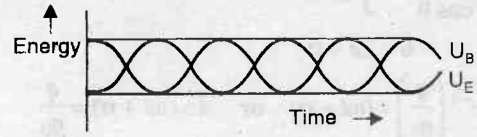
$$U_B = \frac{1}{2}Lq_0^2 \times \frac{1}{LC}\sin^2\omega t$$

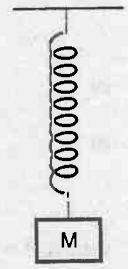
$$U_B = \frac{q_0^2}{2C}\sin^2\omega t$$

Energy-time graph in *L-C* oscillation:

$$U_B + U_E = \frac{q_0^2}{2C}$$

Comparison between electrical and mechanical oscillations: *L-C* oscillation is analogous to the oscillation of a body suspended through a spring





Mechanical Oscillation (Mass Spring System)	*L-C* Oscillation
Kinetic energy $= \frac{1}{2}mv^2$	Magnetic energy $= \frac{1}{2}LI^2$
Potential energy $= \frac{1}{2}kx^2$	Electrical energy $= \frac{q^2}{2C} = \frac{1}{2}CV^2$
$\frac{1}{2}mv^2 + \frac{1}{2}kx^2 = \frac{1}{2}kA^2$	$\frac{1}{2}LI^2 + \frac{1}{2}\frac{q^2}{C} = \frac{q_0^2}{2C}$
$v = \frac{dx}{dt}$	$I = \frac{dq}{dt}$
$e = A\cos\sqrt{\left(\frac{k}{m}\right)}\,t$	$q = q_0\cos\sqrt{\left(\frac{1}{LC}\right)}\,t$

Conceptual Points : In an actual *L-C* circuit, the oscillations will not continue indefinitely because there is always some resistance present in the circuit which produces heating effect.

Electric current is out of phase with charge.

Objective Questions

Level-1

1. The normal drawn to the surface of a conductor makes an angle θ with the direction of field $\vec{B}$, the flux ϕ passing through the area $\vec{A}$ is given by :
(a) $\phi = \vec{A} \times \vec{B}$ (b) $\phi = \frac{\vec{B}}{\vec{A}}$
(c) $\phi = \vec{B} \times \vec{A}$ (d) $\phi = \vec{B} \cdot \vec{A}$

2. A coil of area $10\,cm^2$ has 200 turns. Magnetic field of $0.1\,Wb/m^2$ is perpendicular to the coil. The field is reduced to zero in 0.1 sec, the induced emf in the coil is :
(a) 1 V (b) 0.2 V
(c) 2 V (d) zero

3. When current changes from 13 A to 7 A in 0.5 sec through a coil, the emf induced is 3×10^{-4} V. The coefficient of self induction is :
(a) 25×10^{-3} H (b) 25×10^{-4} H
(c) 25×10^{-5} H (d) 25×10^{-6} H

4. In *LR* circuit, the time constant is given by :
(a) LR (b) R/L
(c) $\frac{L}{R}$ (d) $\frac{1}{LR}$

5. In a step up transformer the number of turns in :
(a) primary are less
(b) primary are more
(c) primary and secondary are equal
(d) primary are infinite

6. Two pure inductor coils of self inductance *L* each are connected in series, the net inductance is :
(a) L (b) $2L$
(c) $L/2$ (d) $L/4$

7. The self induced emf in a 0.2 henry coil when the current in it is changing at the rate of 400 amp/s, is :
(a) 125 V (b) 80 V
(c) 8×10^{-4} V (d) 8×10^{-5} V

8. If a current of 3 amp flowing in the primary coil is reduced to zero in 0.01 second then the induced emf in the secondary coil is 1500 volts, the mutual inductance between the two coils is :
(a) 0.5 H (b) 5 H
(c) 1.5 H (d) 10 H

9. For two coils with number of turns 500 and 200 each of length 1 m and cross-sectional area $4 \times 10^{-4}\,m^2$, the mutual inductance is :
(a) 0.5 H (b) 0.05 mH
(c) 0.5 μH (d) 5 μH

10. The frequency at which 1 H inductor will have a reactance of 2500 Ω is :
(a) 418 Hz (b) 378 Hz
(c) 398 Hz (d) 406 Hz

11. A copper disc of radius 0.1 m is rotated about its centre with 20 revolutions per second in a uniform magnetic field of 0.2. tesla with its plane perpendicular to the field. The emf induced across the radius of disc is :
(a) $\frac{\pi}{10}$ volt (b) $\frac{2\pi}{10}$ volt
(c) $4\pi \times 10^{-2}$ volt (d) $2\pi \times 10^{-2}$ volt

12. The transformer is used to light a 500 W and 220 V lamp from 220 V mains. If the main current is 0.5 amp, the efficiency of the transformer is :
(a) 11% (b) 550%
(c) 455% (d) 390%

13. A conducting circular loop of radius *r* carries constant current *i*. It is placed in a uniform magnetic field B_0 such that B_0 is magnitude of magnetic field to a plane of the loop, the magnetic force acting on the loop is :
(a) irB_0 (b) $2\pi irB_0$
(c) πirB_0 (d) zero

14. If a current increases from zero to 1 ampere in 0.1 sec in coil of 5 mH, then the magnitude of the induced emf will be :
(a) 0.005 V (b) 0.5 V
(c) 0.05 V (d) 5 V

15. The mutual inductance between a pair of coils each of turns N is n, if a current i in the first coil is brought to zero in a time t, then average emf induced in the second coil is :
(a) $N\frac{ni}{t}$ (b) $Nn\frac{t}{i}$
(c) $\frac{nt}{iN}$ (d) $\frac{it}{Nn}$

16. A coil of wire of radius R has 200 turns and a self inductance of 108 mH. The self inductance of a similar coil of 500 turns will be :
(a) 375 mH (b) 527 mH
(c) 675 mH (d) none of these

17. A 50 Hz AC current of crest value 1 amp flows through the primary of a transformer. If the mutual inductance between the primary and secondary be 0.5 H, the crest voltage induced in the secondary is :
(a) 75 V (b) 150 V
(c) 100 V (d) none of these

18. A 50 mH coil carries a current of 2 amp, the energy stored in joule is :
(a) 1 (b) 0.05
(c) 0.1 (d) 0.5

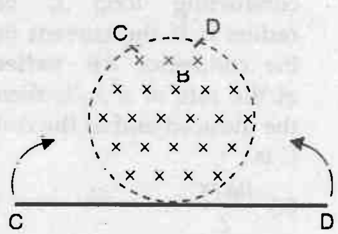
Level-2

1. The magnetic flux ϕ (in weber) in a closed circuit of resistance 10 ohm varies with time t (in second) according to equation $\phi = 6t^2 - 5t + 1$. The magnitude of induced current at $t = 0.25$ s is :
(a) 1.2 A (b) 0.8 A
(c) 0.6 A (d) 0.2 A

2. The perfect formula used for calculating induced emf in a rod moving in a uniform magnetic field is :
(a) $e = \vec{B}\cdot(\vec{l}\times\vec{v})$ (b) $e = \vec{B}\cdot(\vec{l}\cdot\vec{v})$
(c) $e = \vec{B}\times(\vec{l}\cdot\vec{v})$ (d) $e = \vec{B}\times(\vec{l}\times\vec{v})$

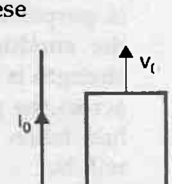
3. A metallic circular loop of radius r is placed in uniform magnetic field B acting perpendicular to the plane of the loop. A naughty boy pulls diametrically opposite corner so that after sometime the loop changes into an ellipse of major and minor radius a and b. If total resistance of loop is R and it remains constant during the pulling, the average charge flowing through loop during pulling is :
(a) $\frac{B(\pi ab)}{R}$ (b) $\frac{B(\pi ab - \pi r^2)}{R}$
(c) $\frac{B\pi r^2}{R}$ (d) $\frac{B\pi br}{R}$

4. The figure shows a straight wire lying in the plane of the paper and a uniform magnetic field perpendicular to the plane of the paper. The ends C and D are slowly turned to form a ring of radius R so that the entire magnetic field is confined in it. The emf induced in the ring is given by :



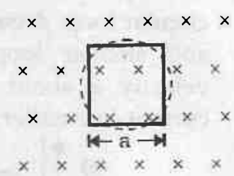
(a) $\frac{\pi R^2 B}{2}$ (b) $\pi R^2 B$
(c) zero (d) none of these

5. A constant current I_0 is passing through a long straight wire (shown in figure). A rectangular loop of total resistance R is moving parallel to the wire. Then :



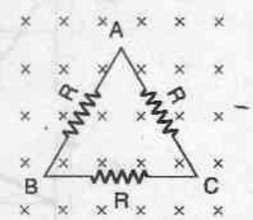
(a) the heat generated in the loop is with constant rate.
(b) current in the loop is zero
(c) velocity of loop will decreases according to Lenz's law
(d) none of the above

6. A square loop lying in a perpendicular magnetic field is changed in circle. If side of square is a and change occurs in t seconds in magnetic field B tesla, the induced emf is :



(a) $\frac{4}{\pi}\frac{Ba^2}{t}$ (b) $\frac{Ba^2}{t}$
(c) $\frac{Ba^2}{t}\left(\frac{4}{\pi}-1\right)$ (d) zero

7. Three resistances of magnitude R each are connected in the form of an equilateral triangle of side a. The combination is placed in a magnetic field $B = B_0 e^{-\lambda t}$ perpendicular to the plane. The induced current in the circuit is given by :



(a) $\left(\frac{a^2\lambda}{2\sqrt{3}R}B_0\right)e^{-\lambda t}$ (b) $\left(\frac{a^2\lambda}{4(\sqrt{3})R}B_0\right)e^{-\lambda t}$
(c) $\left(\frac{a^2 B_0}{\lambda 4\sqrt{3}R}\right)e^{-\lambda t}$ (d) $\left(\frac{a^2 B_0 R}{\lambda 4\sqrt{3}}\right)e^{-\lambda t}$

8. When a magnet with its magnetic moment along the axis of a circular coil and directed towards the coil is withdrawn away from the coil, parallel to itself, the current in the coil as seen by the withdrawing magnet is:
(a) zero
(b) clockwise
(c) anticlockwise
(d) independent of the resistance of the coil

9. Three long parallel wires carrying steady currents 20 A, 10 A, 10 A are cut by a perpendicular plane in the vertices A and B and C of a triangle in which angles B and C are equal. The current of 20 A through A is in opposite direction of through B and C, then :
(a) on the line through A perpendicular to BC, the only point at which the magnetic induction vanishes lies on the circumcircle of the triangle ABC

(b) on the line through A perpendicular to BC, the only point at which magnetic induction does not vanish lies on the circumcircle of the triangle ABC

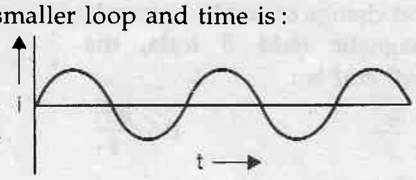
(c) if the triangle ABC is equilateral, each side being of length 10 cm, the magnitude of the mechanical force per unit length on the wire through A is zero

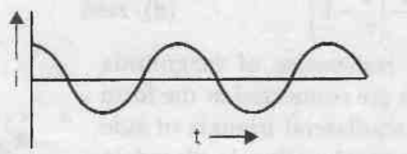
(d) if the triangle ABC is equilateral, each side being of length 10 cm, the magnitude of the mechanical force per unit length on the wire through A is 1732 dyne.

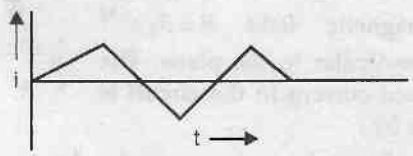
10. An Indian ship with a vertical conducting mass navigates the Indian ocean in the latitude of magnetic equator. To induce the greatest emf in the mast, the ship should proceed :

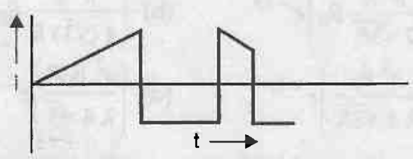
(a) northward (b) southward
(c) eastward (d) none of these

11. A very small circular loop of negligible inductance is initially coplanar and concentric with much larger fixed circular loop. A constant current is passed in bigger loop and smaller loop is rotated with constant angular velocity ω about the diameter. The graph of induced current in smaller loop and time is :

(a)


(b)


(c)


(d)


12. A magnet is allowed to fall through a copper circular wire. Then during fall :

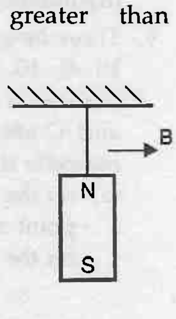
(a) the electric current flows through the wire

(b) the acceleration of magnet is less than gravitational acceleration

(c) the acceleration of magnet is equal to gravitational acceleration

(d) the acceleration of magnet is greater than gravitational acceleration.

13. A bar magnet hangs by a thread attached to the ceiling of a room. When a horizontal magnetic field directed to the right is established :



(a) both the string and the magnet will deviate from the vertical

(b) the string will deviate from the vertical and the magnet will remain vertical

(c) the string will remain vertical and the magnet will deviate from the vertical

(d) both will remain vertical

14. A small bar magnet is placed on the axis of a small conducting ring of radius r. The ring is pushed towards the dipole at a speed v that is kept constant. When the dipole-ring separation is x :

(a) the induced current in the loop varies as x^{-8}

(b) the magnetic flux through the loop varies as x^{-8}

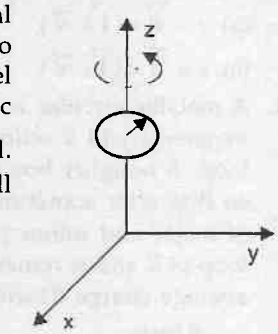
(c) the force on the ring due to the magnetic dipole varies as x^{-8}

(d) the magnetic moment of the ring due to the magnetic dipole varies as x^{-4}

15. A fan blade of length $2a$ rotates with frequency f cycle per second perpendicular to magnetic field B. Then potential difference between centre and end of blade is :

(a) $\pi Ba^2 f$ (b) $4\pi Baf$
(c) $4\pi a^2 Bf$ (d) $2\pi aBf$

*** 16.** A circular loop of wire radius R rotates about z-axis with angular velocity ω. The normal to the loop is perpendicular to z-axis. At $t = 0$ normal is parallel to y-axis. An external magnetic field $\vec{B} = B_y \hat{j} + B_z \hat{k}$ is applied. The emf induced in the coil will be :



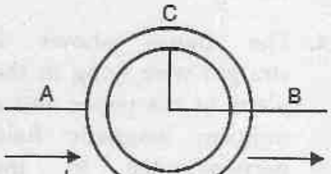
(a) $\pi r^2 \omega B_y \sin \omega t$

(b) $\pi r^2 \omega B_z \sin \omega t$

(c) $\pi r^2 \omega B_z \cos \omega t$

(d) $\pi r^2 \omega B_y \cos \omega t$

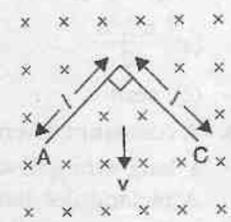
17. A conductor AB lies along the axis of a circular conducting loop C of radius r. If the current in the conductor AB varies at the rate of x A/s, then the induced emf in the coil C is :



(a) $\frac{\mu_0 rx}{2}$ (b) $\frac{1}{4} mxr$

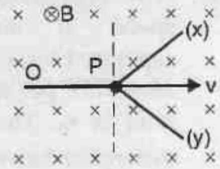
(c) $\frac{\mu_0 \pi xr}{2}$ (d) zero

18. A rigid conducting wire bent as shaped is released to fall freely in a horizontal magnetic field which is perpendicular to the plane of the conductor. If magnetic field strength is B then the emf induced across the points A and C when it has fallen through a distance h will be :



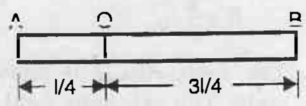
(a) $Bl\sqrt{2gh}$ (b) $Bl\sqrt{gh}$
(c) $2Bl\sqrt{gh}$ (d) $2Bl\sqrt{2gh}$

19. A conducting wire in the shape Y with each side of length l is moving in a uniform magnetic field B, with a uniform speed v as shown in figure. The induced emf at the two ends x and y of the wire will be :



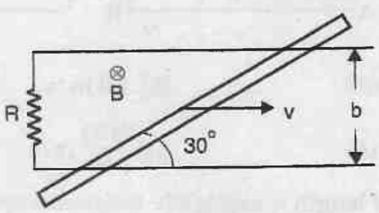
(a) zero (b) $2Blv$
(c) $2Blv \sin(\theta/2)$ (d) $2Blv \cos(\theta/2)$

20. A metal rod AB of length l is rotated with a constant angular velocity ω about an axis passing through 'O' and normal to its length. Potential difference between ends of rod in absence of external magnetic field is : (where e = electric charge)



(a) zero (b) $\frac{m\omega^2 l^2}{4e}$
(c) $\frac{m\omega^2 l^2}{2e}$ (d) $\frac{m\omega^2 l^2}{8e}$

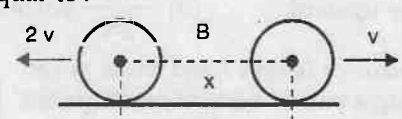
21. A wire is sliding as shown in the figure. The angle between the acceleration and velocity of the wire is



(a) 30° (b) 40°
(c) 120° (d) 90°

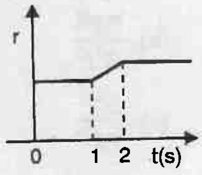
22. A fan blade of length $1/\sqrt{\pi}$ meter rotates with frequency 5 cycle per second perpendicular to a magnetic field 10 tesla. What is potential difference between the centre and the end of blade ?
(a) -50 V (b) $+50$V
(c) -2.0V (d) $+0.02$V

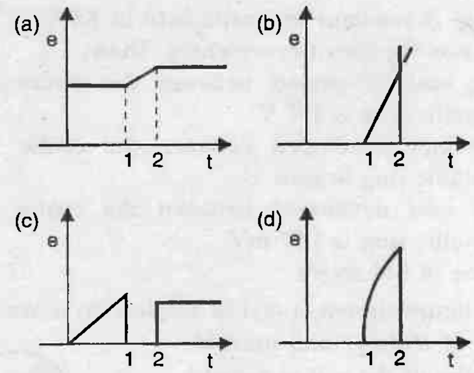
***23.** Two conducting rings of radii r and $2r$ move in opposite directions with velocities $2v$ and v respectively on a conducting surface S. There is a uniform magnetic field of magnitude B perpendicular to the plane of the two rings is equal to :



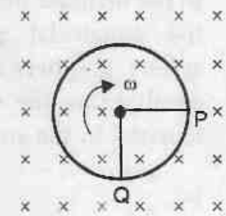
(a) zero (b) $2rvB$
(c) $4rvB$ (d) $8rvB$

***24.** A circular coil is placed in uniform magnetic field such that its plane is perpendicular to field. The radius of coil changes with time as shown in the figure. Which of the following graphs represents the induced emf in the coil with time ?



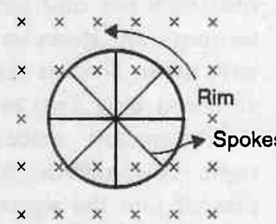


25. A conducting ring of radius r is rolling without slipping with a constant angular velocity ω. If the magnetic field strength is B and is directed into the page then emf induced across PQ is :



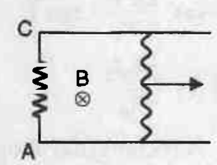
(a) $B\omega r^2$ (b) $\frac{B\omega r^2}{2}$
(c) $4B\omega r^2$ (d) $\frac{\pi^2 r^2 B\omega}{8}$

26. A bicycle wheel of radius 0.5 m has 32 spokes. It is rotating at the rate of 120 revolutions per minute, perpendicular to the horizontal component of earth's magnetic field $B_H = 4 \times 10^{-5}$ T. The emf induced between the rim and the centre of the wheel will be :



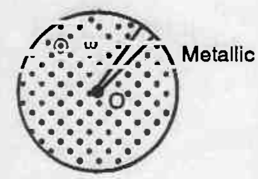
(a) 6.28×10^{-5} V (b) 4.8×10^{-5} V
(c) 6.0×10^{-5} V (d) 1.6×10^{-5} V

27. Two long parallel conducting horizontal frictionless and resistanceless rails are connected by a resistor of resistance R (shown in the figure). The distance AC is equal to l. A uniform magnetic field B acts vertically downwards in the region. An irregular shape of wire is placed over the rails. The force required to maintain a uniform velocity v_0 of the irregular wire is :



(a) zero
(b) $\frac{B^2 l^2 v_0}{R}$
(c) no sufficient information
(d) none of the above

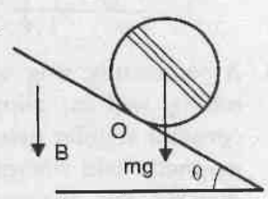
28. A conducting rod of 1 m length moves with a frequency of 50 rev/s, with one end at the centre and the other end at the circumference of a circular metal ring of radius 1 m, about an axis passing through the centre of the ring and perpendicular to the plane of



the ring. A constant magnetic field of 1 Wb/m^2 parallel to the axis is present everywhere. Then :

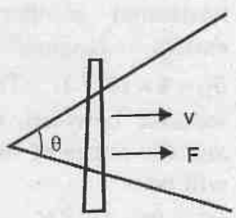
(a) the emf developed between the centre and the metallic ring is 157 V
(b) the emf developed between the centre and the metallic ring is zero
(c) the emf developed between the centre and the metallic ring is 1.57 mV
(d) none of the above

29. In the figure shown, a coil of single turn is wound on a sphere of radius r and mass m. The plane of the coil is parallel to the inclined plane and lies in the equatorial plane of the sphere. If sphere is in rotational equilibrium, the value of B is : (current in the coil is I)



(a) $\dfrac{mg}{\pi I r}$ (b) $\dfrac{mg\sin\theta}{\pi I}$
(c) $\dfrac{mgr\sin\theta}{\pi I}$ (d) none of these

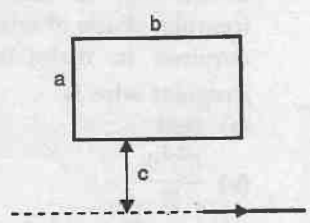
$*$ 30. Two straight super-conducting rails form an angle θ where their ends are joined a conducting bar having R_0 resistance per unit length in contact with the rails and forming an isosceles triangle with them. The bar starts at the vertex at time $t = 0$ and moves with constant velocity v to right. A magnetic field B is present into the region (shown in figure). Find the force exerted by external agent to maintain constant velocity to the rod :



(a) $\dfrac{2B^2v^2t}{R_0}\tan\dfrac{\theta}{2}$ (b) $\dfrac{B^2v^2t}{R_0}\tan\dfrac{\theta}{2}$
(c) $\dfrac{B^2v^2t}{R_0}$ (d) none of these

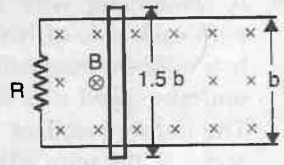
$*$ 31. A rectangular loop of sides a and b has a resistance R and lies at a distance c from an infinite straight wire carrying current I_0. The current decreases to zero in time t_0.

$I(t) = I_0\left(\dfrac{t_0 - t}{t_0}\right)$, $0 < t < t_0$. The charge flowing through the rectangular loop is :



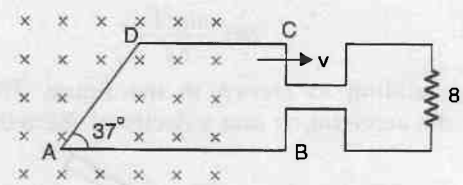
(a) $\mu_0 I_0 t_0$ (b) $\mu_0 I_0 \dfrac{ab}{c^2} t_0$
(c) $\dfrac{\mu_0 b I_0}{2\pi R}\ln\left|\dfrac{a+c}{c}\right|$ (d) $\dfrac{\mu_0 I t_0}{R}\left(\dfrac{ab}{c^2}\right)$

32. A wire of length 1.5b slides at speed 'v' along the rails separated by a distance 'b'. The resistance per unit length of the wire is r_0. Then the potential difference between ends of the rod is :



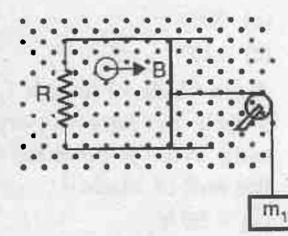
(a) Bbv (b) $\dfrac{Bbv}{R + \frac{2}{3}r_0}$
(c) $\dfrac{BbvR}{R + \frac{2}{3}r_0}$ (d) none of these

33. The loop $ABCD$ is moving with velocity 'v' towards right. The magnetic field is 4 T. The loop is connected to a resistance of 8 ohm. If steady current of 2 A flows in the loop then value of v if loop has a resistance of 4 ohm, is : (Given $AB = 30$ cm, $AD = 30$ cm)



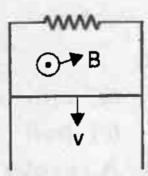
(a) $\dfrac{50}{3}$ m/s (b) 20 m/s
(c) 10 m/s (d) $\dfrac{100}{3}$ m/s

$*$ 34. A rod of length l, negligible resistance and mass m slides on two horizontal frictionless rails of negligible resistance by hanging a block of mass m_1 by the help of insulating massless string passing through fixed massless pulley (as shown). If a constant magnetic field B acts upwards perpendicular to the plane of the figure, the steady state velocity of hanging mass is :



(a) $\dfrac{m_1 gR}{B^2l^2}$ upward (b) $\dfrac{m_1 gR}{B^2l^2}$ downward
(c) $\dfrac{m_1 gR}{B^2l^2}$ upward (d) $\dfrac{m_1 gR}{B^2 l}$ downward

35. A conductor of length l and mass m can slide along a pair of vertical metal guides connected by a resistor R. A uniform magnetic field of strength B normal to the plane of page is directed outwards. The steady speed of fall of rod is :



(a) $\dfrac{mgR}{B^2l^2}$ (b) $\dfrac{mg}{B^2l^2R}$
(c) $\dfrac{B^2l^2}{mgR}$ (d) $\dfrac{mgB}{l^2R}$

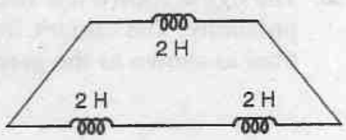
36. The self inductance of the air cored solenoid of length 80 cm and has 500 turns and its circular cross-section has diameter of 2 cm is :
(a) 150.6 μH (b) 162.2 μH
(c) 123.3 μH (d) 102.5 μH

37. What is the mutual inductance of coil and solenoid if a solenoid of length 0.50 m and with 5000 turns of wire has a radius 4 cm and a coil of 700 turns is wound on the middle part of the solenoid ?
(a) 44.17 mH (b) 48.98 mH
(c) 34.34 mH (d) 36.73 mH

38. When the current changes from + 2 A to − 2 A in 0.05 s, an emf of 8 V is induced in a coil. The coefficient of self-induction of the coil is :
(a) 0.1 H (b) 0.2 H
(c) 0.4 H (d) 0.8 H

39. A closed circuit consists of a source of emf E and an inductor coil of inductance L, connected in series. The active resistance of whole circuit is R. At the moment $t = 0$, inductance of coil abruptly decreased to L/n. Then current in the circuit immediately after, is :
(a) zero (b) E/R
(c) $\frac{nE}{R}$ (d) $\frac{E}{nR}$

40. Three pure inductors each of 2 H are connected as shown in the figure. The equivalent inductance of the circuit is :

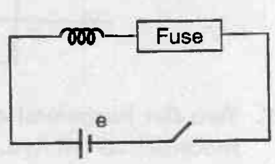


(a) $\frac{8}{6}$ H (b) 6 H
(c) 2 H (d) none of these

41. The sum and the difference of self inductances of two coils are 13 H and 5 H respectively. The maximum mutual inductances of two coil is
(a) 6 H (b) 5 H
(c) $\sqrt{65}$ H (d) 18 H

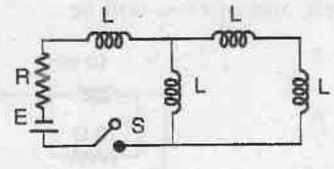
42. A coil of inductance $L = 300$ mH and resistance $R = 140$ mΩ is connected to a constant voltage source. Current in the coil will reach to 50% of its steady value after time t equals to :
(a) 155 s (b) 0.755 s
(c) 0.155 s (d) 1.48 s

43. A coil has an inductance 3 H and a fuse wire of negligible resistance is connected in series with a cell of emf 6 V with no internal resistance. The fuse wire will blow when the current through it reaches 8 A. If the switch is closed at $t = 0$, the fuse will blow :



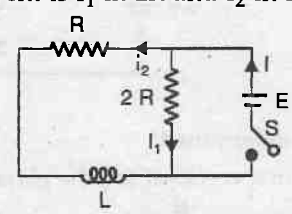
(a) just after the switch is closed
(b) at $t = \infty$
(c) at $t = 4$ s
(d) at $t = 8$ s

44. Study the diagram. As soon as the switch S is closed, the current through the cell is I_1. After a long time the current through the cell is found to be I_2, then :

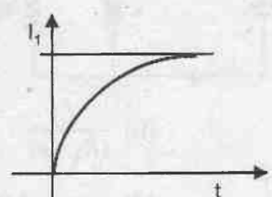


(a) $I_1 = \frac{E_0}{R}, I_2 = \frac{E_0}{2R}$ (b) $I_1 = 0, I_2 = \frac{E_0}{R}$
(c) $I_1 = \frac{E_0}{R}, I_2 = 0$ (d) none of these

45. In the figure, S is shorted at $t = 0$. The current at a time t after this event is I_1 in $2R$ and I_2 in R, then :



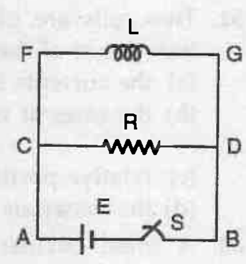
(a) $I_1(t)$ graph is a straight line parallel to i_1 axis
(b) $I_1(t)$ graph is as shown follows



(c) $I_1 = E/2R$ for all t and $I_2 = \frac{E}{R}(1 - e^{-Rt/L})$ at time t
(d) none of the above

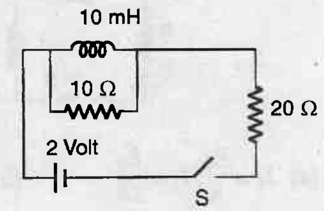
46. A non-conducting ring of radius r has charge per unit length λ. A magnetic field perpendicular to plane of the ring changes at rate dB/dt. Torque experienced by the ring is :
(a) $\lambda \pi r^3 \frac{dB}{dt}$ (b) $\lambda 2\pi r^3 \frac{dB}{dt}$
(c) $\lambda^2 (2\pi r)^2 r \frac{dB}{dt}$ (d) zero

47. A solenoid of inductance L and resistance r is connected in parallel to a resistance R and a battery of emf E. Initially if the switch is closed for a long time and at $t = 0$, then the :



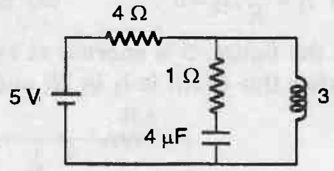
(a) current through solenoid at any time t, after opening the switch is $\frac{E}{r} e^{-(R+r)t/L}$
(b) induced emf across solenoid at time $t = 0$ is $\frac{E(R+r)}{r}$
(c) amount of heat generated in solenoid is $\frac{E^2 L}{2r(r+R)}$
(d) potential difference across solenoid at $t = 0$ is E

48. The switch S is closed at time $t = 0$, the current through battery at $t = 0$, and at $t = \infty$ will be :



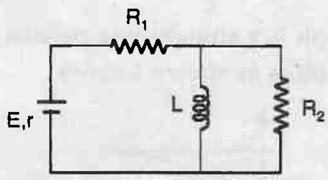
(a) $\frac{1}{15}$ A, $\frac{1}{10}$ A
(b) $\frac{1}{10}$ A, $\frac{1}{15}$ A
(c) $\frac{2}{15}$ A, $\frac{1}{10}$ A
(d) $\frac{1}{15}$ A, $\frac{2}{25}$ A

49. In the figure, the steady state current through the inductor will be :



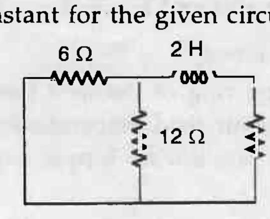
(a) zero
(b) 1 A
(c) 1.25 A
(d) cannot be determined

50. The value of time constant for the given circuit is :



(a) $\frac{L}{R_1 + r + R_2}$ (b) $\frac{L}{(R_1 + r)}$
(c) $\frac{L(R_1 + R_2 + r)}{(R_1 + r) R_2}$ (d) none of these

51. The time constant for the given circuit is :

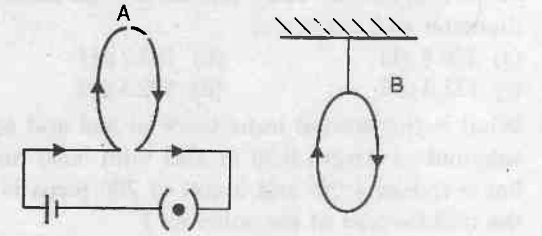


(a) 4 s (b) $\frac{1}{4}$ s
(c) 2 s (d) $\frac{1}{2}$ s

52. Two coils are placed close to each other. The mutual inductance of the pair of coils depend upon :
(a) the currents in the two coils
(b) the rates at which currents are changing in the two coils
(c) relative position and orientation of the two coils
(d) the materials of the wires of the coils

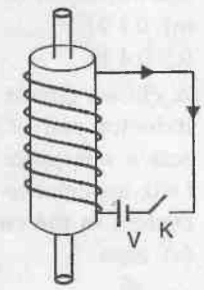
53. A small circular loop of radius r is placed inside a circular loop of radius R ($R >> r$). The loops are coplanar and their centres coincide. The mutual inductance of the system is proportional to :
(a) r/R (b) r^2/R
(c) r/R^2 (d) r^2/R^2

54. A system S consists of two coils A and B. The coil A have a steady current I while the coils B is suspended near by as shown in figure. Now the system is heated so as to raise the temperature of two coils steadily, then :



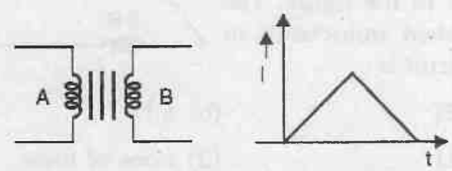
(a) the two coils show attraction
(b) the two coils show repulsion
(c) there is no change in the position of the two coils
(d) induced currents are not possible in coil B

55. A conducting ring is placed around the core of an electromagnet as shown in figure. When key K is pressed, the ring :

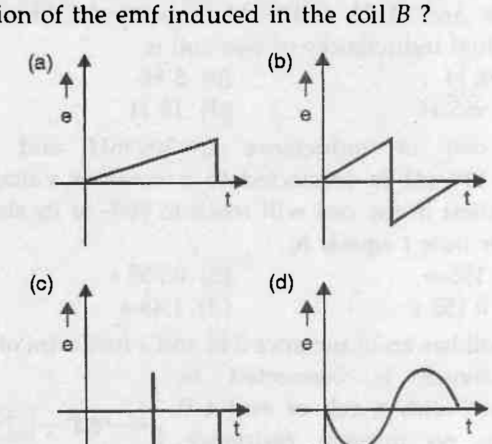


(a) remains stationary
(b) is attracted towards the electromagnet
(c) jumps out the core
(d) none of the above

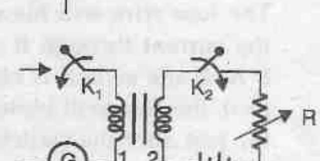
56. The figure shown has two coils of wires placed in close proximity. The current in coil A is made to vary with time as shown in the graph.



Which of the graphs given below best represents the variation of the emf induced in the coil B ?



57. Two flat horizontal coils are mounted as shown. Which one of the following actions will not cause the sensitive galvanometer G to deflect ?

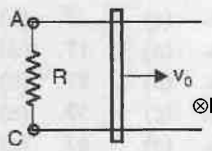


(a) Coils stationary and coil 1 moves upwards with K_1 and K_2 closed
(b) Both coils stationary, K_2 closed and K_1 switched on or off

(c) With K_1 and K_2 closed, a variable resistance R is increased and decreased rapidly

(d) Both coils stationary, K_1 closed and K_2 switched on or off

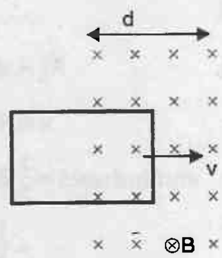
58. A superconducting rod of mass m is placed on two resistanceless parallel smooth rails connected by a resistor of resistance R. Uniform magnetic field B is acting perpendicular to the plane of loop. At $t = 0$ velocity v_0 is given to the rod. The total heat generated in rod before coming to rest is :

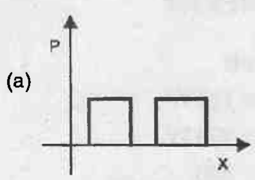


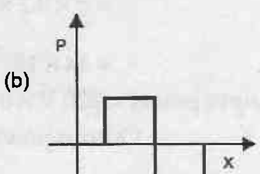
(a) $\frac{1}{2}mv_0^2$ (b) zero

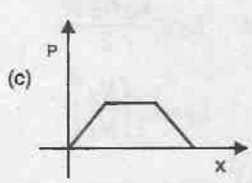
(c) $(Bvl)^2/R$ (d) none of these

* 59. A closed conducting loop of resistance R, width b and length l is being pulled at constant speed v through a region of thickness $d\,(d > l)$ in which a uniform magnetic field B is present (shown in figure). As function of the position y of the right hand edge of the loop, plot the rate of production of internal energy (P) in the loop :









(d) none of these

60. With usual notations, the energy dissipation in an ideal inductor is given by :

(a) LI (b) $\frac{1}{2}LI$

(c) $\frac{1}{2}LI^2$ (d) none of these

61. The inductance of a coil in which a current of 0.1 A increasing at the rate of 0.5 A/s represents a power flow of $\frac{1}{2}$ watt, is :

(a) 2 H (b) 8 H

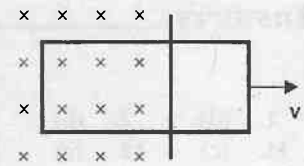
(c) 20 H (d) 10 H

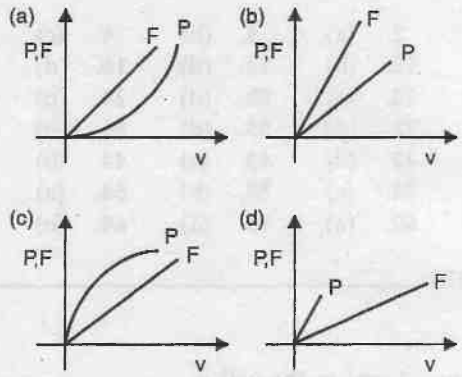
62. The energy stored in the magnetic field if current of 5A produces a magnetic flux of 2×10^{-3} Wb through a coil of 500 turns is :

(a) 2.5 J (b) 0.25 J

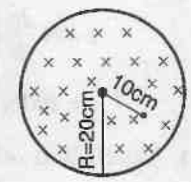
(c) 250 J (d) 1.5 J

63. Figure shows a rectangular loop being pulled out in magnetic field $\vec{B}$ with constant speed v, then force and power by external agent vary with speed v as :





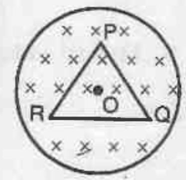
64. Figure shows a uniform magnetic field B confined to a cylindrical volume of radius R. If B is increasing at constant rate of 0.01 T/s, instantaneous acceleration experienced by electron at $r = 10$ cm ($< R$) as shown in the figure :



(a) $8.79 \times 10^{-12}\ \text{m/s}^2$ (b) $8.79 \times 10^{7}\ \text{m/s}^2$

(c) $8.79 \times 10^{-10}\ \text{m/s}^2$ (d) $8.79 \times 10^{9}\ \text{m/s}^2$

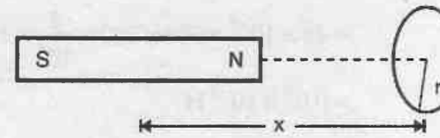
65. In a cylindrical region, $\vec{B}$ is static and uniform and points along the axis of the cylinder. Consider an equilateral triangle PQR with its plane perpendicular to $\vec{B}$. If B increases at a constant rate of 1 T/s and $PQ = 1$ m, the work done by induced electric force on a unit positive charge (+1C) taken from P to Q is :



(a) positive (b) zero

(c) $1/\sqrt{3}$ J (d) $-1/2\sqrt{3}$ J

66. A magnet of magnetic moment $\overline{M}$ moves with velocity $\bar{v}$ towards a magnet. Consider a small circular loop whose plane is normal to $\bar{v}$. Its radius r is so small that magnetic induction is almost constant over it. Then :



(a) the magnetic flux through the area of the loop is constant

(b) the electric field intensity along the tangent to the loop and in the plane of the loop is of magnitude $3\mu_0 \frac{Mvr}{4\pi x^4}$ and direction $\overline{E} \perp \bar{v}$

(c) the electric field intensity is in the direction along $\bar{v}$

(d) the electric field intensity is not induced anywhere

Answers

Level-1

1. (d)	2. (b)	3. (d)	4. (c)	5. (a)	6. (b)	7. (b)	8. (b)	9. (b)	10. (c)
11. (c)	12. (c)	13. (c)	14. (c)	15. (a)	16. (c)	17. (c)	18. (c)		

Level-2

1. (d)	2. (a)	3. (b)	4. (c)	5. (b)	6. (c)	7. (b)	8. (b)	9. (a)	10. (c)
11. (d)	12. (b)	13. (d)	14. (d)	15. (a)	16. (a)	17. (d)	18. (c)	19. (c)	20. (b)
21. (c)	22. (a)	23. (d)	24. (b)	25. (d)	26. (a)	27. (b)	28. (a)	29. (a)	30. (a)
31. (c)	32. (d)	33. (d)	34. (b)	35. (a)	36. (c)	37. (a)	38. (a)	39. (c)	40. (a)
41. (a)	42. (d)	43. (a)	44. (b)	45. (c)	46. (a)	47. (a)	48. (a)	49. (c)	50. (c)
51. (b)	52. (c)	53. (b)	54. (a)	55. (c)	56. (c)	57. (b)	58. (a)	59. (a)	60. (d)
61. (d)	62. (a)	63. (a)	64. (b)	65. (d)	66. (b)				

Solutions

Level-1

2. The induced emf in the coil is

$$e = N\frac{d\phi}{at} = N\frac{d(BA)}{dt} = NA\left(\frac{dB}{dt}\right)$$

$$e = 200 \times (10 \times 10^{-4}) \times \frac{0.1-0}{0.1} = 0.2 \text{ V}$$

3. Coefficient of self induction is given by

$$e = -L\frac{di}{dt}$$

$$\therefore \quad L = -\frac{e}{\frac{di}{dt}} = -\frac{300 \times 10^{-6} \times 0.5}{(7-13)} = 25 \times 10^{-6} \text{ H}$$

7. Self induced emf is given by

$$|e| = L\frac{di}{dt} = 0.2 \times 400 = 80 \text{ V}$$

8. Mutual inductance is

$$e = -M\frac{di}{dt}$$

$$1500 = -M\left(\frac{0-3}{0.01}\right)$$

$$\therefore \quad M = \frac{1500 \times 0.01}{3} = 5 \text{ H}$$

9. From the formula

$$M = \mu_0 n_2 n_1 Al$$

$$= 4\pi \times 10^{-7} \times 500 \times 200 \times \frac{1}{10^4} \times 1 = 160\pi \times 10^{-7}$$

$$= 0.05 \times 10^{-3} \text{ H}$$

10. $$X_L = \omega L = 2\pi nL = 2 \times \frac{22}{7} \times n \times 1 = 2500$$

$$n = 397.7 \approx 398 \text{ Hz}$$

11. emf induced $= \frac{1}{2}BR^2\omega$

$$= \frac{1}{2}BR^2(2\pi n) = \frac{1}{2} \times 0.2 \times (0.1)^2 (2\pi \times 20)$$

$$= \frac{1}{2} \times 0.2 \times 0.01 \times 40\pi$$

$$= 4\pi \times 10^{-2} \text{ volt}$$

12. Input power $= 220 \text{ V} \times 0.5 = 110 \text{ W}$

Output power $= 500 \text{ W}$

$\therefore$ efficiency $\eta = \frac{500}{110} = 45.5\%$

16. $$L_1 = \frac{\mu_0 N_1^2 \pi r}{2} \quad \text{and} \quad L_2 = \frac{\mu_0 N_2^2 \pi r}{2}$$

$$\frac{L_2}{L_1} = \left(\frac{N_2}{N_1}\right)^2 \quad \text{or} \quad L_2 = L_1\left(\frac{N_2}{N_1}\right)^2$$

$$L_2 = 108 \times \left(\frac{500}{200}\right)^2 = 108 \times 6.25 = 675 \text{ mH}$$

17. $$di = 1-(-1) = 2 \text{ amp}$$

$$dt = \left(\frac{1}{100}\right), \quad M = 0.5 \text{ H}$$

$$e = M\frac{di}{dt} = 0.5\left(\frac{2}{1/100}\right) = 0.5 \times 2 \times 100 = 100 \text{ V}$$

Level-2

1. $$e = \frac{d\phi}{dt} = 12t - 5$$

$$\therefore \quad I = \frac{e}{R} = \left|\frac{12t-5}{10}\right| = |1.2t - 0.5|$$

$$= |1.2 \times 0.25 - 0.5| = 0.2 \text{ A}$$

3. $$\Delta Q = \frac{\Delta\phi}{R} = \frac{\phi_f - \phi_i}{R} = \frac{B(\pi ab - \pi r^2)}{R}$$

5. The magnetic flux in the loop remains constant. So, induced emf in the loop is zero.

Hence, induced current in the loop is zero.

7. $$\phi = BA = B_0 e^{-\lambda t}\frac{\sqrt{3}}{4}a^2$$

$$e = -\frac{d\phi}{dt} = -\frac{\sqrt{3}}{4}a^2 B_0 \frac{d}{dt}(e^{-\lambda t})$$

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Alternating Current and Electromagnetic Wave

Syllabus : Alternating currents, impedance and reactance, power in A.C. circuits with L, C and R series combination, resonant circuits, transformers and A.C. generators.

Review of Concepts

1. Alternating Current :

(a) $V = V_0 \sin \omega t$

and $I = i_0 \sin (\omega t + \phi)$

where V_0 and I_0 are peak voltage and peak current respectively.

(b) Average value for half cycle,

$$I_{av} = \frac{2I_0}{\pi} = 0.637 I_0 \quad \text{(positive half)}$$

and $$I_{av} = -\frac{2I_0}{\pi} = -0.637\, I_0 \quad \text{(negative half)}$$

(c) Average value for long time or one time period,

$$I_{av} = 0$$

(d) Electric charge transferred,

$$\Delta q = I_{av} \times \text{time}$$

(e) $I_{rms} = \dfrac{I_0}{\sqrt{2}}$ and $V_{rms} = \dfrac{V_0}{\sqrt{2}}$

(f) $\Delta H = I^2_{rms} Rt$

(g) A.C. can be converted into D.C. by rectifier.

(h) D.C. can be converted into A.C. by inverter.

(i) Electrolysis does not take place by A.C.

(j) A.C. is measured by hot wire instrument.

(k) Transformer works for A.C. only

(l) Form factor $= \dfrac{I_{rms}}{I_{av}} = \dfrac{\pi}{2\sqrt{2}}$

(m) RMS value is also known as virtual value or effective value.

(n) The angular frequency of D.C. voltage is taken as zero.

2. Current and Potential Relations :

(a) Resistor in an A.C. circuit :

(i) A.C. current and voltage equations are

$$i = i_0 \sin \omega t \quad \text{and} \quad V_R = V_0 \sin \omega t$$

(ii) A resistance opposes the current but does not oppose a change in current. Hence, current is in phase with emf.

(b) Capacitor in an A.C. circuit :

(i) A.C. current and voltage equations are

$$i = i_0 \sin \left(\omega t + \frac{\pi}{2}\right)$$

and $$V_C = V_0 \sin \omega t$$

(ii) Capacitive reactance

$$X_C = 1/\omega C$$

(iii) The current leads the voltage by $\pi/2$.

(c) Inductor in an A.C. circuit :

(i) A.C. current and voltage equations are

$$i = i_0 \sin \omega t$$

and $$V_L = V_0 \sin (\omega t + \pi/2)$$

(ii) Inductive reactance

$$X_L = 1/\omega L$$

(iii) The current lags behind the voltage by $\pi/2$.

(d) Series *L-R* circuit :

(i) Impedance $Z = \sqrt{R^2 + (\omega L)^2}$

(ii) The voltage leads the current by an angle

$$\phi = \tan^{-1}(\omega L/R)$$

(e) Series *C-R* circuit :

(i) Impedance $Z = \sqrt{R^2 + \left(\dfrac{1}{\omega C}\right)^2}$

(ii) The voltage lags behind the current by an angle

$$\phi = \tan^{-1}(1/\omega CR)$$

(f) Series *L-C-R* circuit :

(i) Modulus of impedance is

$$|Z| = \sqrt{R^2 - \left(\omega L - \frac{1}{\omega C}\right)^2}$$

(ii) Phase angle $\phi = \tan^{-1}\left(\dfrac{\omega L - 1/\omega C}{R}\right)$

(iii) Resonant frequency of series *L-C-R* circuit

$$f = \frac{1}{2\pi\sqrt{LC}}$$

3. Power : $P = V_{rms} I_{rms} \cos \phi$

Here, $\cos \phi$ is power factor equal to $\dfrac{R}{|Z|}$.

(a) For pure resistive circuit, $\cos \phi = 1$

(b) For *L-R* circuit,

$$\cos \phi = \frac{R}{|Z|} = \frac{R}{\sqrt{R^2 + \omega^2 L^2}}$$

(c) For *R-C* circuit, $\cos \phi = \dfrac{R}{\sqrt{R^2 + \left(\dfrac{1}{\omega C}\right)^2}}$

4. **Transformer :**

(a) Turn ratio, $n = \frac{n_s}{n_p}$

(b) $\frac{V_s}{V_p} = \frac{I_p}{I_s} = \frac{n_s}{n_p}$

(c) Efficiency,

$$\eta = \frac{\text{output power}}{\text{input power}} = \frac{E_s I_s}{E_p I_p}$$

5. **Electromagnetic Wave :**

$$E = E_0 \sin(\omega t - kx)$$

and $$B = B_0 \sin(\omega t - kx)$$

6. **Maxwell's Equations :**

(a) $\int_C \vec{E} \cdot \vec{ds} = \frac{q}{\varepsilon_0}$ (b) $\int_C \vec{B} \cdot \vec{ds} = 0$

(c) $\int_C \vec{E} \cdot d\vec{L} = -\frac{d\phi_B}{dt}$

(d) $\int_C \vec{B} \cdot \vec{dI} = \mu_0 \left(I + \varepsilon_0 \frac{d\phi_E}{dt} \right)$

Some Important Relations :

(a) $c = \frac{1}{\sqrt{\mu\varepsilon}}$

(b) $c_0 = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$

(c) Refractive index $= \sqrt{\mu_r \varepsilon_r}$

(d) $\frac{\omega}{k} = \frac{E}{B} = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = c_0$

(e) Energy carried by electromagnetic wave

$$U_E = \frac{1}{2} \varepsilon_0 E^2 \times \text{volume}, \quad U_B = \frac{B^2}{2\mu_0} \times \text{volume}$$

Total energy, $U = U_E + U_B = \left(\frac{1}{2} \varepsilon_0 E^2 + \frac{B^2}{2\mu_0} \right) \times \text{volume}$

(f) Momentum, $p = \frac{h}{\lambda}$ (For one photon)

(g) Energy $= \frac{hc}{\lambda}$ (For one photon)

Objective Questions

Level-1

1. The A.C. current is given by $I = 20 \sin \omega t$ when the current is expressed in amperes, the rms value of current will be :
(a) 20 (b) $20\sqrt{2}$
(c) $20/\sqrt{2}$ (d) 10

2. The rms value of current in an A.C. of 50 Hz is 10 amp. The time taken by the alternating current in reaching from zero to maximum value and the peak value will be respectively :
(a) 2×10^{-2} s and 14.14 amp
(b) 1×10^{-2} s and 7.07 amp
(c) 5×10^{-3} s and 7.07 amp
(d) 5×10^{-3} s and 14.14 amp

3. A group of electric lamps having a total power rating of 1000 watt is supplied by an A.C. voltage $E = 200 \sin(310t + 60°)$ then the rms value of the circuit current is :
(a) 10 amp (b) $10\sqrt{2}$ amp
(c) 20 amp (d) $20\sqrt{2}$ amp

4. The phase difference between the current and voltage at resonance is :
(a) 0 (b) $\frac{\pi}{2}$
(c) π (d) $-\pi$

5. The phase angle between emf and current in *LCR* series A.C. circuit is :
(a) 0 to $\frac{\pi}{2}$ (b) $\frac{\pi}{4}$
(c) $\frac{\pi}{2}$ (d) π

6. A choke coil is preferred to a rheostat in A.C. circuit, then :
(a) it consumes almost zero power
(b) it increases current
(c) it increases power
(d) it increases voltage

7. A 12 Ω resistor and a 0.21 henry inductor are connected in series to A.C. source operating at 20 volt 50 cycles. The phase angle between the current and source voltage is :
(a) 30° (b) 40°
(c) 80° (d) 90°

8. The reactance of a 25 μF capacitor at the A.C. frequency of 4000 Hz is :
(a) $\frac{5}{\pi}$ Ω (b) $\sqrt{\frac{5}{\pi}}$ Ω
(c) 10 Ω (d) $\sqrt{10}$ Ω

9. The current in a *LR* circuit builds up to 3/4 th of its steady state value in 4 s. The time constant of this circuit is :
(a) $\frac{1}{\ln 2}$ s (b) $\frac{2}{\ln 2}$ s
(c) $\frac{3}{\ln 2}$ s (d) $\frac{4}{\ln 2}$ s

10. The power in A.C. circuit is given by $P = E_{rms} i_{rms} \cos \phi$. The value of power factor $\cos \phi$ in series *LCR* circuit at resonance is :
(a) zero (b) 1
(c) $\frac{1}{2}$ (d) $\frac{1}{\sqrt{2}}$

11. A.40 Ω electric heater is connected to a 200 V, 50 Hz main supply. The peak value of electric current flowing in the circuit is approximately :
(a) 2.5 A (b) 5.0 A
(c) 7 A (d) 10 A

12. The voltage of domestic A.C. is 200 V. What does this represent ?
(a) Mean voltage (b) Peak voltage
(c) Root mean voltage (d) Root mean square voltage

13. The time constant of *C-R* circuit is :
(a) $\frac{1}{CR}$ (b) $\frac{C}{R}$
(c) CR (d) $\frac{R}{C}$

14. In a series circuit $R = 300\ \Omega$, $L = 0.9$ H. $C = 2.0\ \mu F$ $\omega = 1000$ rad/s, the impedance of the circuit is :
(a) 1300 Ω (b) 900 Ω
(c) 500 Ω (d) 400 Ω

15. The average power of A.C. lost per cycle is given by :
(a) $\frac{1}{2} E_0 i_0 \sin \phi$ (b) $\frac{1}{2} E_0 i_0 \cos \phi$
(c) $\frac{1}{2} E_0 i_0 \tan \phi$ (d) $\frac{1}{2} E_0 i_0 \phi$

16. A coil of inductance 8.4 mH and resistance 6 Ω is connected to a 12 V battery. The current in the coil is 1.0 A at the time approximately :
(a) 500 s (b) 20 s
(c) 35 s (d) 1 ms

17. In order to obtain time constant of 10 second in an *R-C* circuit containing a resistance of $10^3\ \Omega$, the capacity of the condenser should be :
(a) 10 μF (b) 100 μF
(c) 1000 μF (d) 10000 μF

18. An A.C. series circuit contains 40 Ω of resistance, 30 Ω of inductive resistance then the impedance of circuit is :
(a) 70 Ω (b) 10 Ω
(c) 50 Ω (d) 70 Ω

19. One 10 V, 60 W bulb is to be connected to 100 V line. The required self inductance of induction coil will be : ($f = 50$ Hz)
(a) 0.052 H (b) 2.42 H
(c) 16.2 H (d) 16.2 mH

20. An 8 μF capacitor is connected to the terminals of an A.C. source whose V_{rms} is 150 volt and the frequency is 60 Hz, the capacitive reactance is :
(a) $0.332 \times 10^3\ \Omega$ (b) $2.08 \times 10^3\ \Omega$
(c) $4.16 \times 10^3\ \Omega$ (d) $12.5 \times 10^3\ \Omega$

21. In step-up transformer the turn ratio is 1 : 2. A leclanche cell (emf = 1.5 V) is connected across the primary, the voltage developed in the secondary would be :
(a) 3.0 V
(b) 0.75 V
(c) 1.5 V
(d) zero

Level-2

1. An A.C. source of voltage $V = 100 \sin 100\pi t$ is connected to a resistor of resistance 20 Ω. The rms value of current through resistor is :
(a) 10 A (b) $\frac{10}{\sqrt{2}}$ A
(c) $\frac{5}{\sqrt{2}}$ A (d) none of these

2. In previous problem, average value of current for long time is :
(a) zero (b) $\frac{5}{\sqrt{2}}$ A
(c) 10 A (d) none of these

3. In previous problem, the average value for half cycle is :
(a) $\frac{10}{\pi}$ A (b) $\frac{5}{\pi}$ A
(c) zero (d) none of these

4. In previous problem, total charge transferred through resistor in long time is :
(a) zero (b) $\frac{2I_0}{\pi}$
(c) $\frac{I_0}{25\pi}$ (d) none of these

5. In previous problem, total charge transferred in 1/100 second is :
(a) 1/10π C (b) 1/5π C
(c) zero (d) none of these

6. In previous problem, total heat generated in one cycle is :
(a) $\sqrt{2}$ J (b) 5 J
(c) $4\sqrt{2}$ J (d) zero

7. In previous problem, power factor is :
(a) 1 (b) 0
(c) 1/2 (d) none of these

8. The peak and rms value of current in A.C. circuit. The current is represented by the equation $i = 5 \sin\left(300t - \frac{\pi}{4}\right)$ where t is in seconds, and 'i' in ampere :
(a) 5 A, 3.535 A (b) 5 A, 5.53 A
(c) 3 A, 3.53 A (d) 6.25 A, 5.33 A

9. An A.C. voltage is represented by
$$e = 220\sqrt{2} \cos (50\pi)\, t$$
How many times will the current become zero in one sec ?
(a) 50 times (b) 100 times
(c) 30 times (d) 25 times

10. The average value for half cycle in a 200 V A.C. source is :
(a) 180 V (b) 200 V
(c) 220 V (d) none of these

11. Two alternating currents are given by

$$I_1 = I_0 \sin \omega t$$

and $\quad I_2 = I_0 \cos (\omega t + \phi)$

The ratio of rms values is :

(a) 1 : 1 (b) 1 : ϕ

(c) 1 : 2 (d) none of these

12. A current $I = 3 + 8 \sin 100t$ is passing through a resistor of resistance 10 Ω. The effective value of current is :

(a) 5 A (b) 10 A

(c) $4\sqrt{2}$ A (d) $3/\sqrt{2}$ A

13. An alternating voltage $V = 30 \sin 50t + 40 \cos 50t$ is applied to a resistor of resistance 10 Ω. The rms value of current through resistor is :

(a) $\frac{5}{\sqrt{2}}$ A (b) $\frac{10}{\sqrt{2}}$ A

(c) $\frac{7}{\sqrt{2}}$ A (d) 7 A

14. The electric field in an electromagnetic wave is given by

$$E = (100 \text{ N/C}) \sin \omega \left(t - \frac{x}{c}\right)$$

If the energy contained in a cylinder of cross-section 10 cm^2 and length 50 cm along the x-axis is 4.4×10^{-8} J/m^3, then the intensity of the wave is :

(a) 12.4 W/m^2 (b) 13.2 W/m^2

(c) 15.7 W/m^2 (d) 11.9 W/m^2

15. The root mean square value of voltage, if an alternating voltage is given by $e = e_1 \sin \omega t + e_2 \cos \omega t$ is :

(a) $\frac{\sqrt{e_1^2 + e_2^2}}{2}$ (b) $\frac{\sqrt{e_1^2 - e_2^2}}{2}$

(c) $\sqrt{e_1 e_2}$ (d) none of these

16. An alternating voltage $V = 140 \sin 50t$ is applied to a resistor of resistance 10 Ω. This voltage produces ΔH heat in the resistor in time Δt. To produce the same heat in the same time, required D.C. current is :

(a) 14 A (b) about 20 A

(c) about 10 A (d) none of these

17. An A.C. is represented by $e = 220 \sin (100\pi)\, t$ volt and is applied over a resistance of 110 ohm. The heat produced in 7 minutes is :

(a) 11×10^3 cal (b) 22×10^3 cal

(c) 33×10^3 cal (d) 25×10^3 cal

18. The reactance of a capacitor connected with D.C. voltage is :

(a) zero (b) infinity

(c) 1 Ω (d) none of these

19. The reactance of an inductor connected with a D.C. voltage is :

(a) zero (b) ∞

(c) 1 Ω (d) none of these

20. An A.C. voltage $e = e_0 \sin 50t - e_0 \cos 100\pi t$ is connected in series with a resistor and capacitor. The steady state current through circuit is found to be

$$I = I_0 \sin (50\pi t + \phi_1) + I_0' \cos (100\pi t + \phi_2)$$

Then the ratio of $\frac{I_0'}{I_0}$ is :

(a) greater than 1 (b) equal to 1

(c) less than 1 (d) none of these

21. In a region of uniform magnetic field $B = 10^{-2}$ T, a circular coil is rotating at 'ω' rpm about an axis which is perpendicular to the direction of 'B' and which forms a diameter of the coil. The radius of the coil is 30 cm and resistance π^2 ohm. If the amplitude of the alternating current induced in the coil is 6 mA, then value of 'ω' is :

(a) 15 rpm (b) 300 rpm

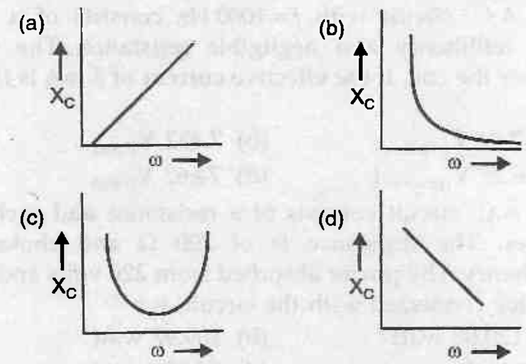
(c) 21 rpm (d) 400 rpm

22. An alternating voltage $V = V_0 \sin \omega t$ is connected to a capacitor of capacity C_0 through an A.C. ammeter of zero resistance. The reading of ammeter is :

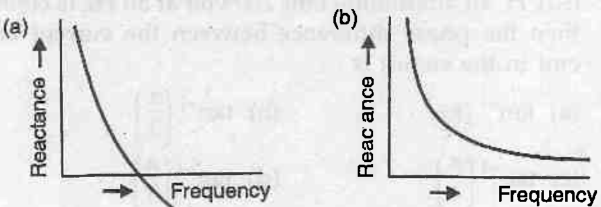
(a) $\frac{V_0}{\sqrt{2}}$ (b) $\frac{V_0}{\omega C \sqrt{2}}$

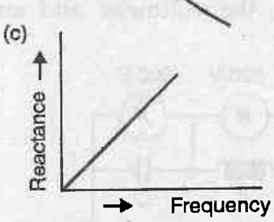
(c) $\frac{V_0 \omega C}{\sqrt{2}}$ (d) none of these

23. Which one of the following represents capacitive reactance versus angular frequency graph ?



24. Which of the following plots may represent the reactance of a series L-C combination ?





(d) none of these

25. The maximum current in the circuit, if a capacitor of capacitance 1 μF is charged to a potential of 2 V and is connected in parallel to an inductor of inductance 10^{-3} H, is :

(a) $\sqrt{4000}$ mA (b) $\sqrt{2000}$ mA
(c) $\sqrt{1000}$ mA (d) $\sqrt{5000}$ mA

26. In a circuit consisting of inductor (L), capacitor (C) and resistor (R) are in series, if $\omega L < \frac{1}{\omega C}$, then the emf :
(a) leads the current
(b) lags behind the current
(c) is in phase with current
(d) is zero

27. In a circuit, a resistance of 20000 ohm is connected to a capacitor of capacity of 0.1 µF in parallel. A voltage of 20 volt and $f = 50$ Hz is connected across the arrangement. The main current is :
(a) 117 mA (b) 1.18 mA
(c) 11.7 mA (d) 0.117 mA

28. The resonant frequency of a series circuit consisting of an inductance 200 µH, a capacitance of 0.0005 µF and a resistance of 10 Ω is :
(a) 480 kHz (b) 503 kHz
(c) 406 kHz (d) 607 kHz

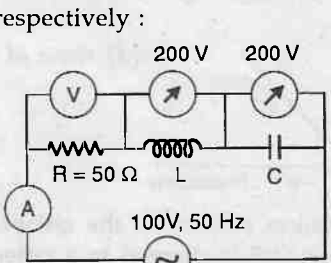
29. The frequency of voltage for an A.C. circuit, the equation of alternating voltage is $V = 200 \sin 314t$ is :
(a) 50 Hz (b) 60 Hz
(c) 55 Hz (d) 65 Hz

30. An A.C. circuit with $f = 1000$ Hz consists of a coil of 200 millihenry and negligible resistance. The voltage across the coil, if the effective current of 5 mA is flowing, is :
(a) 7.64 $V_{(rms)}$ (b) 7.452 $V_{(rms)}$
(c) 6.28 $V_{(rms)}$ (d) 74.62 $V_{(rms)}$

31. An A.C. circuit consists of a resistance and a choke in series. The resistance is of 220 Ω and choke is of 0.7 henry. The power absorbed from 220 volts and 50 Hz, source connected with the circuit, is :
(a) 120.08 watt (b) 109.97 watt
(c) 100.08 watt (d) 98.08 watt

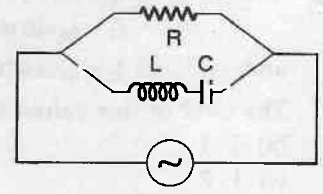
32. If a circuit made up of a resistance 1 Ω and inductance 0.01 H, an alternating emf 200 volt at 50 Hz is connected, then the phase difference between the current and the emf in the circuit is :
(a) $\tan^{-1}(\pi)$ (b) $\tan^{-1}\left(\frac{\pi}{2}\right)$
(c) $\tan^{-1}\left(\frac{\pi}{4}\right)$ (d) $\tan^{-1}\left(\frac{\pi}{3}\right)$

33. In the series LCR circuit, the voltmeter and ammeter readings are respectively :



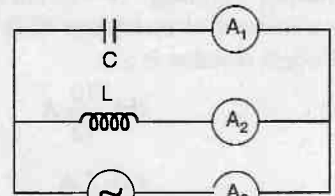
(a) $V = 250$ V, $I = 4$ A (b) $V = 150$ V, $I = 2$ A
(c) $V = 1000$ V, $I = 5$ A (d) $V = 100$ V, $I = 2$ A

34. The current in resistance R at resonance is
(a) zero
(b) minimum but finite
(c) maximum but finite
(d) infinite



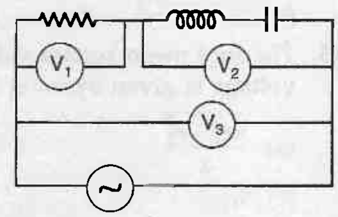
$V = V_0 \sin \omega t$

35. An inductor L, a capacitor C and ammeters A_1, A_2 and A_3 are connected to an oscillator in the circuit as shown in the adjoining figure



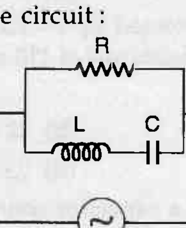
When frequency of the oscillator is increased, then at resonant frequency, the ammeter reading is zero in the case of :
(a) ammeter A_1 (b) ammeter A_2
(c) ammeter A_3 (d) all the three

36. A resistor R, an inductor L, a capacitor C and voltmeters V_1, V_2 and V_3 are connected to an oscillator in the circuit as shown in the following diagram. When the frequency of the oscillator is increased, then at resonance frequency, the voltmeter reading is zero in the case of :



(a) voltmeter V_1
(b) voltmeter V_2
(c) voltmeter V_3
(d) all the three voltmeters

37. At resonance, in the circuit :



(a) the power factor is zero
(b) the current through the A.C. source is zero
(c) the current through the A.C. source is maximum
(d) currents through L and R are equal

38. A condenser of capacitance of 2.4 µF is used in a transmitter to transmit at λ wavelength. If the inductor of 10^{-8} H is used for resonant circuit, then value of λ is :
(a) 292 m (b) 400 m
(c) 334 m (d) 446 m

39. If 20 V battery is connected to primary coil of a transformer, then output voltage is :
(a) zero (b) 20 V
(c) 10 V (d) none of these

40. If a dry cell of emf $= 1.5$ V is connected across the primary of a step-up transformer of turn ratio 3 : 5, then the voltage developed across the secondary is :
(a) 30 V (b) 5 V
(c) zero (d) 2.5 V

41. An A.C. source has an internal resistance of 10^4 ohm. The turn ratio of a transformer so as to match the source to a load of resistance 10 ohm, is :
(a) 4.62×10^{-2} (b) 2.03×10^{-2}
(c) 3.16×10^{-2} (d) 5.62×10^{-2}

42. An output voltage of $E = 170 \sin 377t$ is produced by an A.C. generator, where t is in sec, then the frequency of alternating voltage will be :
(a) 50 Hz (b) 110 Hz
(c) 60 Hz (d) 230 Hz

43. The electric field 'E' and magnetic field 'B' in electromagnetic waves are :
(a) parallel to each other
(b) inclined at an angle of 45°
(c) perpendicular to each other
(d) opposite to each other

44. The energy of photon of electromagnetic radiation of wavelength = 2000 Å is :
(a) 1.76×10^{-18} J (b) 0.99×10^{-18} J
(c) 0.54×10^{-18} J (d) 0.63×10^{-18} J

45. The speed of light in air, if an electromagnetic wave is travelling in air whose dielectric constant is $k = 1.006$, will be :
(a) 3×10^8 m/s (b) 3.88×10^8 m/s
(c) 2.5×10^8 m/s (d) 4.6×10^8 m/s

46. An object is placed at some distance from a radio station. If the interval between transmission and reception of pulses is 2.66×10^{-2} sec, then the distance is :
(a) 4000 km (b) 2000 km
(c) 3000 km (d) 2500 km

47. The wavelength of a radio wave of frequency of 1 MHz is :
(a) 400 m (b) 300 m
(c) 350 m (d) 200 m

48. Some radio waves of frequency of about 1.5×10^9 Hz was received by a radio-telescope from distant star. If the speed of the waves is 3×10^5 km/s, then the wave- length of the wave will be :
(a) 0.1 m (b) 0.6 m
(c) 0.2 m (d) 0.46 m

49. A radio wave of intensity I is reflected by a surface. The intensity (I), if pressure exerted on the surface is 2×10^{-8} N/m^2, will be :
(a) 3 N/m^2 (b) 4 N/m^2
(c) 6 N/m^2 (d) 7 N/m^2

50. A TV tower has a height of 100 m. The area covered by the TV broadcast, if radius of the earth is 6400 km, will be :
(a) 380×10^7 m^2 (b) 402×10^7 m^2
(c) 595×10^7 m^2 (d) 440×10^7 m^2

51. An electromagnetic wave with pointing vector 5 W/m^2 is absorbed by a surface of some area. If the force on the surface is 10^{-7} N, then area is :
(a) 6 m^2 (b) 3 m^2
(c) 60 m^2 (d) 4 m^2

52. The average power per unit area at distance of 2 m from a small bulb, if the bulb emits 20 W of electromagnetic radiation uniformly in all directions, will be :
(a) 0.69 W/m^2 (b) 0.56 W/m^2
(c) 0.78 W/m^2 (d) 0.39 W/m^2

53. The correct option, if speed of gamma rays, X-rays and microwaves are v_g, v_x and v_m respectively will be :
(a) $v_g > v_x > v_m$ (b) $v_g < v_x < v_m$
(c) $v_g > v_x < v_m$ (d) $v_g = v_x = v_m$

54. If at a certain instant, the magnetic induction of the electromagnetic wave in vacuum is 6.7×10^{-12} T, then the magnitude of electric field intensity will be :
(a) 2×10^{-3} N/C (b) 3×10^{-3} N/C
(c) 4×10^{-3} N/C (d) 1×10^{-3} N/C

Answers

Level-1

1. (c)	2. (d)	3. (b)	4. (a)	5. (a)	6. (a)	7. (c)	8. (a)	9. (b)	10. (b)
11. (c)	12. (d)	13. (c)	14. (c)	15. (b)	16. (d)	17. (d)	18. (c)	19. (a)	20. (a)
21. (d)									

Level-2

1. (c)	2. (a)	3. (a)	4. (a)	5. (a)	6. (b)	7. (a)	8. (a)	9. (a)	10. (a)
11. (a)	12. (a)	13. (a)	14. (b)	15. (a)	16. (c)	17. (b)	18. (b)	19. (a)	20. (c)
21. (c)	22. (c)	23. (b)	24. (a)	25. (a)	26. (b)	27. (b)	28. (b)	29. (a)	30. (c)
31. (b)	32. (a)	33. (d)	34. (c)	35. (c)	36. (b)	37. (c)	38. (a)	39. (a)	40. (c)
41. (c)	42. (c)	43. (c)	44. (b)	45. (a)	46. (a)	47. (b)	48. (c)	49. (a)	50. (b)
51. (a)	52. (d)	53. (d)	54. (a)						

31

Cathode Rays, Photoelectric Effect of Light and X-rays

Syllabus: Discovery of electrons, cathode rays, $\frac{e}{m}$ of electron, photoelectric effect and Einstein's equation for photoelectric effect.

Review of Concepts

1. Cathode Rays : It consists of fast moving electrons. If discharge tube is operating at voltage V, then

$$E_k = eV = \frac{1}{2} mv^2$$

More about cathode Rays :

(a) Cathode rays were discovered by Sir William Crookes.

(b) Cathode rays are a stream of fast moving electrons almost in vacuum.

(c) Mass of electrons is (1/1837) times that of hydrogen atom.

(d) **Methods of producing electrons :**
- (i) discharge of electricity through gases,
- (ii) thermionic emission,
- (iii) photoelectric emission,
- (iv) β-ray emission,
- (v) cold-cathode emission or field emission.

(e) The acceleration produced on electron in parallel electric field.

$$a = \frac{F}{m} = \frac{eE}{m}$$

(f) The deflection of electron at right angles to its direction of motion (x-axis) after travelling distance t in perpendicular electric field is

$$y = \frac{1}{2} at^2 = \frac{1}{2}\left(\frac{eE}{m}\right)\left(\frac{t}{v_x}\right)^2$$

2. de-Broglie Wavelength of Matter Waves :

$$\lambda = \frac{h}{mv} = \frac{h}{p}$$

where h = Planck's constant $= 6.63 \times 10^{-34}$ J-s

For charged particle, its value is

$$\lambda = \frac{h}{\sqrt{2mqV}}$$

Hence, for electron λ (in Å) $= \sqrt{\frac{150}{V \text{ (in volt)}}}$

3. Einstein's Photoelectric Equation :

$$h\nu = h\nu_0 + \frac{1}{2} mv_{max}^2$$

where, ν = frequency of incident radiation,
ν_0 = threshold frequency,
m = rest mass of electron

(a) If $\nu > \nu_0$, photoelectrons are emitted.

(b) If $\nu < \nu_0$, photoelectrons are not emitted.

(c) The maximum speed of emitted photoelectrons is proportional to frequency of incident radiation.

(d) The maximum speed of electrons does not depend upon intensity of radiation.

(e) The number of photoelectrons depends upon intensity of light.

(f) When emission of electrons takes place from the metal surface, the metal gets positively charged.

(g) Photo-electric current is proportional to intensity of incident light.

(h) If V_0 is stopping potential, then

$$eV_0 = \frac{1}{2} mv_{max}^2$$

(i) Work function, $\phi = h\nu_0 = \frac{hc}{\lambda_0}$

(j) The rest mass of photon is zero.

(k) Photon is neither accelerated nor decelerated.

(l) $E = pc$ formula is only applicable for photon.

(m) $E = h\nu = \frac{hc}{\lambda}$. (For a photon.)

(n) Total energy of radiation $= nh\nu$, where n = number of photons.

(o) The velocity of photon is always equal to velocity of light.

(p) Power $= \frac{nh\nu}{t}$

Here, $\frac{n}{t}$ = number of photons per second.

(q) Photon never be charged.

(r) e/m of positive rays $= \frac{2B}{l^2E^2} \cdot \frac{z}{y}$

where E = electric field,
B = magnetic field along Y-axis,
l = length of field along X-axis

(s) $\frac{e}{m}$ of electron $\frac{e}{m} = \frac{v}{rB} = 1.76 \times 10^{11}$ C/kg

4. X-rays : X-rays are electromagnetic wave.

(a) $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$ in vacuum.

(b) X-rays are diffracted by crystals.

(c) X-rays affect photographic plate.

(d) X-rays have no charge.

(e) For continuous X-rays, $\lambda_{min} = \frac{hc}{eV}$

where, V = potential difference between target and the filament.

(f) For characteristics X-ray,

$$\lambda = \frac{hc}{E_K - E_L} \quad \text{for } K_\alpha$$

$$\lambda = \frac{hc}{E_K - E_M} \quad \text{for } K_\beta$$

$$\lambda = \frac{hc}{E_L - E_M} \quad \text{for } L_\alpha$$

Here, E_K = energy of electron in K shell,

E_L = energy of electron in L shell,

E_M = energy of electron in M shell

5. Moseley's Law : Frequency ν of characteristic X-ray spectrum

$$\sqrt{\nu} = a(z - \sigma)$$

where a and σ are constant and screening constant. For K_α line, $\sigma = 1$ and screening constant for L_α line, $\sigma = 7.4$.

6. Bragg's Law : Direction of maxima of X-ray diffracted from crystal

$$2d \sin\theta = n\lambda \qquad (n - 1, 2, 3, \ldots)$$

Intensity of X-rays transmitted through a thickness x of meterial

$$I = I_0 e^{-kx} \qquad (k \text{ is constant})$$

Objective Questions

Level-1

1. Matter waves are :
(a) electromagnetic waves
(b) mechanical waves
(c) either mechanical or electromagnetic waves
(d) neither mechanical nor electromagnetic waves

2. Cathode rays are made to pass between the plates of a charged capacitor. It attracts :
(a) towards positive plate
(b) towards negative plate
(c) (a) and (b) are correct
(d) (a) and (b) are wrong

3. The X-ray tube is operated at 50 kV, the minimum wavelength produced is :
(a) 0.5 Å (b) 0.75 Å
(c) 0.25 Å (d) 1.0 Å

4. A beam of electrons is moving with constant velocity in a region having electric and magnetic field 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 ?
(a) 20 m/s (b) 40 m/s
(c) 8 m/s (d) 5.5 m/s

5. If the kinetic energy of the moving particle is E, then de Broglie wavelength is :
(a) $\lambda = h\sqrt{2mE}$ (b) $\sqrt{\frac{2mE}{h}}$
(c) $\lambda = \frac{h}{\sqrt{2mE}}$ (d) $\lambda = \frac{hE}{\sqrt{2mE}}$

6. When a beam of accelerated electrons hits a target, a continuous X-ray spectrum is emitted from the target, which one of the following wavelengths is absent in the X-ray spectrum if the X-ray tube is operating at 40,000 volt ?
(a) 1.5 Å (b) 0.5 Å
(c) 0.35 Å (d) 1.0 Å

7. The minimum wavelength of X-ray produced by electron accelerated through a potential difference of V volt is directly proportional to :
(a) $\sqrt{V}$ (b) $\sqrt{2V}$
(c) $\frac{1}{\sqrt{V}}$ (d) $\frac{1}{V}$

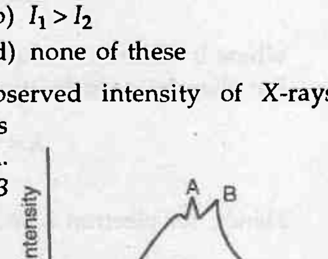
8. In a discharge tube at 0.02 mm there is formation of :
(a) Faraday's dark space
(b) Crooke's dark space
(c) Both spaces partly
(d) Crooke's dark space with glow near the electrons

9. Therm-ions are :
(a) photons (b) protons
(c) electrons (d) nuclei

10. X-ray is used to :
(a) investigate the structure of solid
(b) to charge a body
(c) to activate the radioactivity
(d) to change the structure of solid

11. The cathode of a photoelectric cell is changed such that work function changes from ϕ_1 to ϕ_2 ($\phi_1 > \phi_2$). If the current before and after change are I_1 and I_2, all other conditions remaining unchanged then :
(a) $I_1 = I_2$ (b) $I_1 > I_2$
(c) $I_1 < I_2$ (d) none of these

12. The figure shows the observed intensity of X-rays emitted by an X-ray tube as a function of wavelength. The sharp peaks A and B denote :



(a) band spectrum
(b) continuous spectrum
(c) characteristic ratio
(d) white radiation

13. The speed of photon :
(a) may be less than speed of light
(b) may be greater than speed of light
(c) must be equal to speed of light
(d) must be less than speed of light

14. The energy of a photon of frequency f is :
(a) hf (b) $\frac{h}{f}$
(c) h^2f (d) h/f^2

15. Planck's constant :
(a) is universal constant
(b) depends upon frequency of light
(c) depends upon wavelength of light
(d) depends upon medium

16. If we consider photon and electron of the same wavelength, then they will have the same :
(a) velocity (b) angular momentum
(c) energy (d) momentum

17. Hundred photons each of energy 2.5 eV are incident on a metal plate whose work function is 4 eV, then the number of electrons emitted from metal surface will be :
(a) 100 (b) 200
(c) zero (d) infinity

18. The frequency of the incident light falling on a metal plate is doubled, the maximum kinetic energy of the emitted photoelectrons is :
(a) unchanged (b) doubled
(c) more than double (d) less than double

19. The number of ejected photoelectrons increases with increase :
(a) in frequency of light
(b) in wavelength of light
(c) in intensity of light
(d) none of these

20. When a monochromatic point source of light is at a distance of 0.2 metre from a photocell, the cut off voltage and the saturation current are 0.6 V and 18 mA rexpectively. If the same source is placed 0.6 m away from the photoelectric cell, then :
(a) the stopping potential will be 0.2 V
(b) the stopping potential will be 0.6 V
(c) the saturation potential will be 6 mA
(d) none of the above

21. When one centimetre thick surface is illuminated with light of wavelength λ, the stopping potential is V. When the same surface is illuminated by light of wavelength 2λ, stopping potential is $\frac{V}{3}$, threshold wavelength for metallic surface is :
(a) $\frac{4\lambda}{3}$ (b) 4λ
(c) 6λ (d) $\frac{8\lambda}{3}$

22. An image of the sun is formed by a lens of focal length of 30 cm on the metal surface of a photoelectric cell and a photoelectric current I is produced. The lens forming the image is then replaced by another of same diameter but of focal length 15 cm, the photoelectric current in this case is :
(a) $\frac{I}{2}$ (b) I
(c) $2I$ (d) $4I$

23. Kinetic energy of emitted ray is dependent on :
(a) voltage only
(b) work function only
(c) both (a) and (b)
(d) it does not depend upon any physical quantity

24. For the same speed, de Broglie wavelength :
(a) of electron is larger than proton
(b) of proton is larger than α-particle
(c) of electron is larger than α-particle
(d) all of the above

Level-2

1. Which one of the following is incorrect statement ?
(a) Cathode rays are emitted out from the surface of cathode
(b) Cathode ray travel in straight line
(c) Cathode rays have constant e/m ratio
(d) Cathode rays are electromagnetic radiations

2. Which one of the following is incorrect statement ?
(a) Anode rays are heavier than cathode rays
(b) Anode rays are emitted out from the surface of anode
(c) Anode rays are made up of positively charged ions
(d) Anode rays travel in straight line

3. Cathode rays are made up of electrons. Anode rays are made up of :
(a) protons only
(b) protons and positrons only
(c) positive residue of atoms
(d) all positive particles of atoms

4. e/m ratio of anode rays produced in a discharge tube, depends on the :
(a) nature of gas filled in the tube
(b) nature of the material of anode
(c) nature of the material of cathode
(d) all of the above

5. In an oil drop experiment, the following charges (in arbitrary units) were found on a series of oil droplets : 2.30×10^{-15}, 6.90×10^{-15}, 1.38×10^{-14}, 5.75×10^{-15}, 1.955×10^{-14}. The charge on electron (in the same unit) should be :
(a) 2.30×10^{-15}
(b) 1.15×10^{-15}
(c) 1.38×10^{-14}
(d) 1.955×10^{-14}

6. In Wilson cloud chamber experiment, two particles were found to show equal deviation but in opposite directions. The names positron and negatron were given to these particles by Anderson. Negatron should be :
(a) neutron (b) neutrino
(c) electron (d) proton

7. An α-particle when accelerated through a potential difference of V volt has a wavelength λ associated with it. In order to have same λ, by what potential difference a proton must be accelerated ?
(a) 8 V (b) 6 V
(c) 4 V (d) 12 V

8. The cathode ray particles originate in a discharge tube from the :
(a) cathode (b) anode
(c) source of high voltage (d) residual gas

9. Three particles having charges in the ratio of 2 : 3 : 5, produce the same point on the photographic film in Thomson experiment. Their masses are in the ratio of :
(a) 2 : 3 : 5 (b) 5 : 3 : 2
(c) 15 : 10 : 6 (d) 3 : 5 : 2

10. It the velocity of an electron is doubled its de Broglie frequency will :
(a) be halved (b) remain same
(c) be doubled (d) become four times

11. An electron is at rest. Its wavelength is
(a) 1 (b) infinity
(c) $\frac{h}{m_v}$ (d) it has not wave character

12. If the de Broglie wavelength of a proton is 10^{-13} m, the electric potential through which it must have been accelerated is :
(a) 4.07×10^4 V (b) 8.2×10^4 V
(c) 8.2×10^3 V (d) 4.07×10^5 V

13. Which of the following statements is false ?
(a) Material wave (de Broglie wave) can travel in vacuum
(b) Electromagnetic wave can travel through vacuum
(c) The velocity of photon is not the same whether light passes through any medium
(d) Wavelength of de Broglie wave depends upon velocity

14. A moving electron has numerical relation $\lambda = h$. Then :
(a) $m_e = \frac{1}{v_e}$ (b) $v_e = \frac{1}{m_e}$
(c) both (a) and (b) (d) none of these

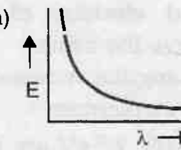
15. The de Broglie wavelength of a bus moving with speed v is λ. Some passengers left the bus at a stopage. Now when the bus moves with twice its initial speed, its kinetic energy is found to be twice its initial value. What will be the de Broglie wavelength, now?
(a) λ (b) 2λ (c) $\lambda/2$ (d) $\lambda/4$

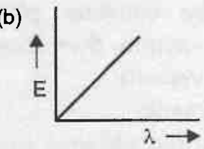
16. Proton and α-particle both are accelerated through the same potential, the ratio of wavelengths is :
(a) 2 (b) $\sqrt{2}$
(c) 4 (d) $1/2\sqrt{2}$

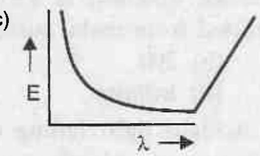
17. The magnitude of the de Broglie wavelength (λ) of an electron (e), proton (p), neutron (n) and α-particle (α) all having the same energy of MeV, in the increasing order will follow the sequence :
(a) $\lambda_e, \lambda_p, \lambda_n, \lambda_\alpha$ (b) $\lambda_\alpha, \lambda_n, \lambda_p, \lambda_e$
(c) $\lambda_e, \lambda_n, \lambda_p, \lambda_\alpha$ (d) $\lambda_p, \lambda_e, \lambda_\alpha, \lambda_n$

18. Two photons of same frequencies moving in same medium have :
(a) same linear momenta and wavelengths
(b) same linear momenta and same speeds
(c) same energies and same linear momenta
(d) none of the above

19. Which one of the following is the correct graph between energy and wavelength for a given photon ?

(a)


(b)


(c)


(d) None of these

20. An electron is accelerated through voltage. Its frequency will be (e = charge on electron, h = Planck's constant)
(a) eV (b) eVh
(c) $\frac{eV}{h}$ (d) $\frac{h}{eV}$

21. A certain molecule has an energy level diagram for its vibrational energy in which two levels are 0.014 eV apart. The wavelength of the emitted line for the molecule as it falls from one of these levels to the other, is :
(a) 8.9×10^{-5} m (b) 1.2×10^{-6} m
(c) 173.6 m (d) 4.6×10^{-7} m

22. How many photons are emitted by a laser source of 5×10^{-3} W operating at 632.2 nm in 2 second ? ($h = 6.63 \times 10^{-34}$ Js)
(a) 3.2×10^{16} (b) 1.6×10^{16}
(c) 4×10^{16} (d) None of these

23. Only a fraction of the electrical energy supplied to a tungsten light bulb is converted into visible light. If a 100 W light bulb converts 20% of the electrical energy into visible light ($\lambda = 662.6$ nm), then the number of photons emitted by the bulb per second is :
(a) 6.67×10^{19} (b) 2×10^{28}
(c) 6×10^{36} (d) 6.30×10^{19}

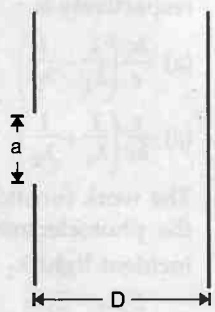
24. The number of photons emitted by a 60 W bulb per second, if 10% of the electrical energy supplied to an incandescent light bulb is radiated as visible light, is :
(a) 1.8×10^{19} (b) 1.8×10^{16}
(c) 1.8×10^{11} (d) 1.8×10^{21}

25. The momentum of a photon having energy equal to the rest energy of an electron is :
(a) zero (b) 2.73×10^{-22} kg ms^{-1}
(c) 1.99×10^{-24} kg ms^{-1} (d) infinite

26. A perfectly reflecting solid hemisphere of radius R is placed in the path of a parallel beam of light of large aperture. If the beam carries an intensity I, the force exerted by the beam on the hemisphere is :
(a) $\frac{2\pi R^2 I}{c}$ (b) $\frac{\pi R^2 I}{c}$
(c) $\frac{4\pi R^2 I}{c}$ (d) none of these

27. A parallel beam of monochromatic light with power of 3 W incident normally on a perfectly absorbing surface. The force exerted by the light beam on the surface is :
(a) 5×10^{-9} N (b) 10^{-8} N
(c) 5×10^{-7} N (d) 2×10^{-8} N

28. Consider the shown arrangement to obtain diffraction pattern when a monochromatic radiation of wavelength λ is incident on the narrow aperture. If $a = 3\lambda$, in the diffraction pattern obtained on screen , the number of intensity minima would be :
(a) 3 (b) 4
(c) 5 (d) 6



29. Photodissociation of water

$$H_2O\,(l) + h\nu \longrightarrow H_2\,(g) + \frac{1}{2}O_2\,(g)$$

has been suggested as a source of hydrogen. The heat absorbed in this reaction is 285.8 kJ/mol of water decomposed. The maximum wavelength, that would provide the necessary energy assuming that one photon causes the dissociation of one water molecule is :
(a) 6.95×10^{-28} m (b) 4.19×10^{-7} m
(c) 6.95×10^{-31} m (d) 1.72×10^{-6} m

30. Photoelectric effect supports quantum nature of light because :
(a) there is a minimum frequency of light below which no photoelectrons are emitted
(b) the maximum kinetic energy of photoelectrons depends only on the frequency of light and not on its intensity
(c) even when the metal surface is faintly illuminated, the photoelectrons leave the surface immediately
(d) all of the above

31. The maximum kinetic energy of the photoelectrons emitted from a surface is dependent on the :
(a) intensity of incident radiation
(b) potential of the collector electrode
(c) frequency of incident radiation
(d) angle of incident of radiation of the surface

32. If the work function of the metal is ϕ and the frequency of incident light is ν, there is no emission of photoelectrons when :
(a) $\nu < \frac{\phi}{h}$ (b) $\nu = \frac{\phi}{h}$
(c) $\nu > \frac{\phi}{h}$ (d) $\nu \geq \frac{\phi}{h}$

33. Einstein's photoelectric equation states that $E_k = h\nu - \phi$. In this equation E_k refers to :
(a) kinetic energy of all the emitted electrons
(b) mean kinetic energy of the emitted electrons
(c) maximum kinetic energy of the emitted electrons
(d) minimum kinetic energy of the emitted electrons

34. 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:
(a) 2.48 eV, 0.18 eV (b) 0.18 eV, zero
(c) 2.30 eV, 0.18 eV (d) 0.18 eV, 0.18 eV

35. 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 :
(a) 2×10^{15} Hz (b) 1×10^{15} Hz
(c) 3×10^{15} Hz (d) 1.67×10^{15} Hz

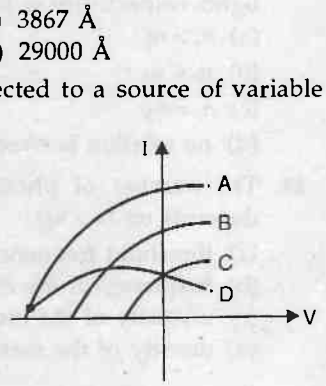
36. A surface is irradiated with ultra violet radiation of wavelength 0.2 μm. If the maximum velocity of electron liberated from the surface is 8.8×10^5 m/s, then the work function of the surface is :
(a) 3 eV (b) 4 eV
(c) 5 eV (d) 6 eV

37. Choose the correct option for the graph between the frequency of incident light and the stopping potential :
(a) It is a parabola (b) It is a straight line
(c) It is a hyperbola (d) It is a circle

38. A metallic surface ejects n-electrons per second, when exposed to green colour light of certain intensity I. The long wavelength limit for the surface being 560 nm. If the surface is exposed to same intensity I of green, yellow and red light simultaneously, then the number of electrons emitted will be :
(a) n (b) $2n$
(c) $3n$ (d) $9n$

39. The work function of a substance is 1.6 eV. The longest wavelength of light that can produce photo-emission from the substance is :
(a) 7734 Å (b) 3867 Å
(c) 5800 Å (d) 29000 Å

40. A photoelectric cell is connected to a source of variable potential difference connected across it and the photoelectric current is plotted against the applied potential difference. The graph in the broken line represents one for a given frequency and intensity of the incident radiation. If



the frequency is increased and the intensity is reduced, the curve which now represents the situation is :

(a) A (b) B
(c) C (d) D

41. A photoelectron has a frequency ν_e. It was ejected by a photon having frequency υ_p from a metal of work function ϕ. Then which of the following is correct assuming all of the energy of photon is utilised ?

(a) $\phi = \nu_p - \nu_e$ (b) $\nu_p > \nu_e$
(c) $\nu_p = \nu_e$ (d) $\nu_p = h\phi + \nu_e$

42. Work function of a metal is 10 eV. Photons of 20 eV are bombarded on it. The frequency of photoelectrons will be :

(a) $= \frac{10}{h}$ (b) $> \frac{10}{h}$
(c) $< \frac{10}{h}$ (d) $\geq \frac{10}{h}$

43. A radiation is incident on a metal surface of work function 2.3 eV. The wavelength of incident radiation is 600 nm. If the total energy of incident radiation is 23 J, then the number of photoelectrons is :

(a) zero (b) $> 10^4$
(c) $= 10^4$ (d) none of these

44. Two sources A and B have same power. The wavelength of radiation of A is λ_a and that of B is λ_b. The number of photons emitted per second by A and B are n_a and n_b respectively, then :

(a) $\lambda_a > \lambda_b$ (b) if $\lambda_a > \lambda_b$, $n_a < n_b$
(c) if $\lambda_a < \lambda_b$, $n_a < n_b$ (d) if $\lambda_a > \lambda_b$, $n_a = n_b$

45. Ultraviolet beam of wavelength 280 nm is incident on lithium surface of work function 2.5 eV. The maximum velocity of electron emitted from metal surface is .

(a) 8.2×10^5 m/s (b) 10^6 m/s
(c) 7×10^5 m/s (d) none of these

46. In previous problem, the stopping potential is :

(a) 1.9 V (b) 10 V
(c) 3 V (d) none of these

47. Threshold frequency for photoelectric effect from a metal surface of work function 4.5 eV is :

(a) 1.1×10^9 Hz (b) 540 Hz
(c) 1.1×10^{15} Hz (d) none of these

48. If n_r and n_b are the number of photons of red and blue lights respectively with same energy, then :

(a) $n_r > n_b$
(b) $n_r < n_b$
(c) $n_r = n_b$
(d) no relation between n_r and n_b

49. The number of photoelectrons emitted per unit time depends on ($\nu > \nu_0$) :

(a) threshold frequency
(b) frequency of the incident radiation
(c) intensity of the incident radiation
(d) density of the metal irradiated

50. Photoelectrons comes out when a metal is radiated by indigo light but not by green light. Would photoelectrons come out when the metal is radiated by orange light ?

(a) Yes
(b) No
(c) Yes, if intensity of radiation is increased
(d) Yes, if metal is radiated for a long time

51. Ultraviolet light of wavelength 66.26 nm and intensity 2 W/m^2 falls on potassium surface by which photoelectrons are ejected out. If only 0.1% of the incident photons produce photoelectrons, and surface area of metal surface is 4 m^2, how many electrons are emitted per second ?

(a) 2.67×10^{15} (b) 3×10^{15}
(c) 3.33×10^{17} (d) 4.17×10^{16}

52. The stopping potentials are V_1 and V_2. The value of $(V_1 - V_2)$, if λ_1 and λ_2 are wavelengths of incident lights, respectively is :

(a) $\frac{hc}{e}\left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right)$ (b) $\frac{hc}{e}\left(\frac{1}{\lambda_1} + \frac{1}{\lambda_2}\right)$
(c) $\frac{e}{hc}\left(\frac{1}{\lambda_1} + \frac{1}{\lambda_2}\right)$ (d) $\frac{e}{hc}\left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right)$

53. The work function of the metal, if the kinetic energies of the photoelectrons are E_1 and E_2, with wavelengths of incident light λ_1 and λ_2, is :

(a) $\frac{E_1\lambda_1 - E_2\lambda_2}{\lambda_2 - \lambda_1}$ (b) $\frac{E_1 E_2}{\lambda_1 - \lambda_2}$
(c) $\frac{(E_1 - E_2)\,\lambda_1\lambda_2}{(\lambda_1 - \lambda_2)}$ (d) $\frac{\lambda_1\lambda_2 E_1}{(\lambda_1 - \lambda_2)\,E_2}$

54. A radiation of wavelength 2000 Å incident on the metal surface, with work function 5.01 eV. What is the potential difference must be applied to stop the fastest photoelectron emitted by metal surface ?

(a) 1.19 eV (b) 6.19 eV
(c) 3.19 eV (d) 4.19 eV

55. For a certain metal ν is five times of ν_0 and the maximum velocity of coming out photons is 8×10^6 m/s. If $\nu = 2\nu_0$, the maximum velocity of photoelectrons will be :

(a) 4×10^6 m/s (b) 6×10^6 m/s
(c) 2×10^6 m/s (d) 1×10^6 m/s

56. A red bulb and violet bulb of equal power emits n_R and n_V number of photons in a given time, then :

(a) $n_R = n_V$ (b) $n_R > n_V$
(c) $n_R < n_V$ (d) $n_R > n_V$

57. When a surface 1 cm thick is illuminated with light of wavelength λ, the stopping potential is V_0, but when the same surface is illuminated by light of wavelength 3λ, the stopping potential is $\frac{V_0}{6}$. The threshold wavelength for metallic surface is :

(a) 4λ (b) 5λ
(c) 3λ (d) 2λ

58. Photoelectric effect shows:
(a) wave-like behaviour of light
(b) particle-like behaviour of light
(c) both wave-like and particle-like behaviour of light
(d) neither wave-like nor particle-like behaviour of light

59. What is the energy of photon of wavelength 24800 Å?
(a) 0.5 eV (b) 0.9 eV
(c) 1.1 eV (d) 0.75 eV

60. Choose the correct statement:
(a) The continuous X-rays are produced because of transition of electrons from outer shell to inner shell whereas the characteristic X-rays are produced by deceleration of incident electrons
(b) The characteristic as well as the continuous X-rays are produced due to deceleration of incident electrons
(c) The continuous X-rays are produced due to deceleration of incident electrons but the characteristic X-rays are produced due to transition of outer shell electrons to inner shell
(d) The continuous as well as characteristic X-rays are emitted due to transition of electrons from outer to inner shell

61. If X-ray tube is operating at 15 kV, the lower limit of the wavelength of X-rays produced is:
(a) 0.82×10^{-7} m (b) 0.82×10^{-8} m
(c) 0.83×10^{-10} m (d) 0.82×10^{-13} m

62. The X-rays beam coming from an X-ray tube will be:
(a) monochromatic
(b) having all wavelengths smaller than a certain minimum wavelength
(c) having all wavelengths larger than a certain minimum wavelength
(d) having all wavelength lying between a minimum and a maximum wavelength

63. At its closest approach, the distance between the mars and the earth is found to be 60 million km. When the planets are at this closest distance, how long would it take to send a radio-message from a space probe of mars to earth?
(a) 5 s (b) 200 s
(c) 0.2 s (d) 500 s

64. At one time, the metre was defined as 1650763.73 wavelengths of the orange light emitted by a light source containing Kr^{86} atoms. What is the corresponding photon energy of this radiation?
(a) 3.28×10^{-19} J/quanta (b) 1.204×10^{-31} J/quanta
(c) 1.09×10^{-27} J/quanta (d) 4.01×10^{-40} J/quanta

65. A ruby laser produces radiations of wavelengths, 662.6 nm in pulses whose duration are 10^{-9} s. If the laser produces 0.39 J of energy per pulse, how many photons are produced in each pulse?
(a) 1.3×10^{9} (b) 1.3×10^{18}
(c) 1.3×10^{27} (d) 3.9×10^{18}

66. Specific heat of water is 4.2 J/g °C. If light of frequency 3×10^{9} Hz is used to heat 400 g of water from 20°C to 40°C, the number of moles of photons needed will be:
(a) 1.69×10^{29} (b) 1.69×10^{28}
(c) 2.80×10^{4} (d) 2.80×10^{5}

Answers

Level-1

1. (d)	2. (a)	3. (c)	4. (b)	5. (c)	6. (c)	7. (a)	8. (b)	9. (c)	10. (a)
11. (a)	12. (c)	13. (c)	14. (a)	15. (a)	16. (d)	17. (c)	18. (d)	19. (c)	20. (b)
21. (b)	22. (b)	23. (c)	24. (d)						

Level-2

1. (d)	2. (b)	3. (c)	4. (a)	5. (b)	6. (c)	7. (a)	8. (a)	9. (a)	10. (c)
11. (d)	12. (b)	13. (c)	14. (c)	15. (a)	16. (a)	17. (c)	18. (d)	19. (a)	20. (c)
21. (a)	22. (a)	23. (a)	24. (a)	25. (b)	26. (b)	27. (b)	28. (b)	29. (b)	30. (d)
31. (c)	32. (a)	33. (c)	34. (b)	35. (c)	36. (d)	37. (b)	38. (a)	39. (a)	40. (d)
41. (b)	42. (a)	43. (a)	44. (c)	45. (a)	46. (a)	47. (c)	48. (a)	49. (c)	50. (b)
51. (a)	52. (a)	53. (a)	54. (a)	55. (a)	56. (b)	57. (b)	58. (b)	59. (a)	60. (c)
61. (c)	62. (c)	63. (b)	64. (a)	65. (b)	66. (c)				

Solutions

Level-1

17. $\therefore p = \frac{h}{\lambda}$

19. From Einstein's photoelectric equation $h\nu = \phi + (KE)_{max}$

or $(KE)_{max} = h\nu - \phi$

20. The number of photoelectrons is directly proportional to intensity of light.

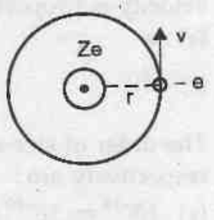
24. de Broglie wavelength is given by $\lambda = \frac{h}{mv}$

32
Atomic Structure

Syllabus: Rutherford's model of the atom, Bohr's model, energy of quantization, hydrogen spectrum.

Review of Concepts

1. Bohr's model :



(a) $\dfrac{Ze^2}{4\pi\varepsilon_0 r^2} = \dfrac{mv^2}{r}$

Here, $\varepsilon_0 = 8.85 \times 10^{-12}$ C²/Nm²,

$$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \text{ Nm}^2/\text{C}^2$$

Here, v = velocity of electron in nth orbit

r = radius of nth orbit

m = mass of electron

(b) $mvr = \dfrac{nh}{2\pi}$

n = principal quantum number, $n = 1, 2, \ldots$

h = Planck's constant $= 6.63 \times 10^{-34}$ Js

(c) (i) $r = \dfrac{\varepsilon_0 n^2 h^2}{\pi m Z e^2}$ (ii) $r_n = \left(\dfrac{n^2}{Z}\right) \times 0.53$ Å

Here, Z = atomic number, (for H-atom $Z = 1$)

(d) Speed of electron :

(i) $v = \dfrac{Ze^2}{2\varepsilon_0 nh}$ (ii) $v = \left(\dfrac{c}{137}\right)\left(\dfrac{Z}{n}\right)$

Here, $c = 3 \times 10^8$ m/s

(e) Kinetic energy of electron :

$$K = \frac{1}{2} mv^2 = \frac{mZ^2e^4}{8\varepsilon_0^2 n^2 h^2}$$

(f) Potential energy :

$$U = \frac{-mZ^2e^4}{4\varepsilon_0^2 n^2 h^2}$$

(g) Total energy :

(i) $E = K + U = -\dfrac{mZ^2e^4}{8\varepsilon_0^2 n^2 h^2}$

(ii) $E_n = -\dfrac{Z^2Rhc}{n^2} = -13.6\left(\dfrac{Z}{n}\right)^2$ eV

where, $R = \dfrac{me^4}{8\varepsilon_0^2 ch^3}$ (Rydberg constant)

(h) Orbital frequency of electron :

$$f = \frac{v}{2\pi r} = \frac{mZ^2e^4}{4\varepsilon_0^2 n^3 h^3}$$

(i) Time period of revolution of electron :

(i) $T = \dfrac{1}{f}$

(ii) $T = (1.52 \times 10^{-16})\left(\dfrac{n^3}{Z^2}\right)$ sec

(j) $\Delta E = 13.6\left(\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}\right)$ eV where $n_1 < n_2$

(k) $\dfrac{1}{\lambda} = R\left(\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}\right)$

Here, R = Rydberg constant $= 1.0973 \times 10^7$ per metre.

(l) Frequency of radiation :

$$\nu = \frac{\Delta E}{h} = \frac{c}{\lambda}$$

2. Rutherford's model : Rutherford scattering formula

$$N_\phi = \frac{N_0 nt\,(2Ze^2)^2}{4\,(4\pi\varepsilon_0)^2\, r^2\, (mv_0^2)^2} \times \frac{1}{\sin^4 \frac{\phi}{2}}$$

where N_0 = total number of α-particles that strikes the unit area of the scatterer; n = number of target atoms per m³; t = thickness of target; Ze = charge on the target nucleus; $2e$ = charge on α-particle; r = distance of screen from the target and v_0 = velocity of α-particle at nearest distance of approach.

Distance of closest approach:

$r_0 = \dfrac{1}{4\pi\varepsilon_0} \cdot \dfrac{2Ze^2}{E_k}$ (where E_k is KE of incident particle)

3. Spectral series :

(a) Lyman : $\dfrac{1}{\lambda} = R\left(1 - \dfrac{1}{n^2}\right)$

(ultraviolet region) where $n > 1$

(b) Balmer : $\dfrac{1}{\lambda} = R\left(\dfrac{1}{4} - \dfrac{1}{n^2}\right)$

(visible region) where $n > 2$

(c) Paschen : $\dfrac{1}{\lambda} = R\left(\dfrac{1}{9} - \dfrac{1}{n^2}\right)$

(infrared region) where $n > 3$

(d) Brackett : $\dfrac{1}{\lambda} = R\left(\dfrac{1}{16} - \dfrac{1}{n^2}\right)$

(infrared region) where $n > 4$

(e) Pfund : $\frac{1}{\lambda}=R\left(\frac{1}{25}-\frac{1}{n^2}\right)$ (infrared region) where $n>5$

(f) Humphery : $\frac{1}{\lambda}=R\left(\frac{1}{36}-\frac{1}{n^2}\right)$ where $n>6$

Objective Questions

Level-1

1. The mass of an electron in motion depends upon :
(a) direction of motion (b) its velocity
(c) initial mass of e^- (d) its shell number

2. The mass and energy equivalent to 1 a.m.u. respectively are :
(a) 1.67×10^{-27} g, 9.30 MeV
(b) 1.67×10^{-27} kg, 930 MeV
(c) 1.67×10^{-27} kg, 1 MeV
(d) 1.67×10^{-34} kg, 1 MeV

3. It is given for the azimuthal quantum number $l=3$, the total number of different possible values of the magnetic azimuthal quantum number, m_l is :
(a) 3 (b) 4
(c) 5 (d) 7

4. The acceleration of electron in the first orbit of hydrogen atom is :
(a) $\frac{4\pi^2 m}{h^3}$ (b) $\frac{h^2}{4\pi^2 mr}$
(c) $\frac{h^2}{4\pi^2 m^2 r^3}$ (d) $\frac{m^2h^2}{4\pi^2 r^3}$

5. If the electron in a hydrogen atom jumps from an orbit level $n_1=3$ to an orbit level $n_2=2$, the emitted radiation has a wavelength given by :
(a) $\lambda=\frac{36}{5R}$ (b) $\lambda=\frac{5R}{36}$
(c) $\lambda-\frac{6}{R}$ (d) $\lambda=\frac{R}{6}$

6. Number of electrons that constitute one ampere of current is :
(a, 265×10^{16} (b) 625×10^{12}
(c) 4.8×10^{10} (d) 625×10^{16}

7. The angular momentum of electron in hydrogen atom is proportional to :
(a) $\sqrt{r}$ (b) $\frac{1}{r}$
(c) r^2 (d) $\frac{1}{\sqrt{r}}$

8. The radius of hydrogen atom, when it is in its second excited state, becomes :
(a) half (b) double
(c) four times (d) nine times

9. If Bohr's radius is R_0 then radius of 3rd orbit of hydrogen atom will be :
(a) $3R_0$ (b) $6R_0$ (c) $9R_0$ (d) $12R_0$

10. In terms of Rydberg constant R, the wave number of the first Balmer line is :
(a) R (b) $3R$
(c) $\frac{5R}{36}$ (d) $\frac{8R}{9}$

11. For electron moving in nth orbit of the atom, the angular velocity is proportional to :
(a) n (b) $1/n$
(c) n^3 (d) $\frac{1}{n^3}$

12. The order of size of nucleus and Bohr radius of an atom respectively are :
(a) 10^{-14} m, 10^{-10} m (b) 10^{-10} m, 10^{-8} m
(c) 10^{-20} m, 10^{-16} m (d) 10^{-8} m, 10^{-6} m

13. In the lowest energy level of hydrogen atom, electron has the angular momentum :
(a) $\frac{\pi}{h}$ (b) $\frac{h}{\pi}$
(c) $\frac{h}{2\pi}$ (d) $\frac{2\pi}{h}$

14. The velocity of an electron in its fifth orbit, if the velocity of an electron in the second orbit of sodium atom (atomic number = 11) is v, will be :
(a) v (b) $\frac{22}{5}v$
(c) $\frac{5}{2}v$ (d) $\frac{2}{5}v$

15. Atomic hydrogen is excited to the nth energy level. The maximum number of spectral lines which it can emit while returning to the ground state, is :
(a) $\frac{1}{2}n(n-1)$ (b) $\frac{1}{2}n(n+1)$
(c) $n(n+1)$ (d) $n(n+1)$

16. The KE of the electron in an orbit of radius r in hydrogen atom is : (e = electronic charge)
(a) $\frac{e^2}{r^2}$ (b) $\frac{e^2}{2r}$
(c) $\frac{e^2}{r}$ (d) $\frac{e^2}{2r^2}$

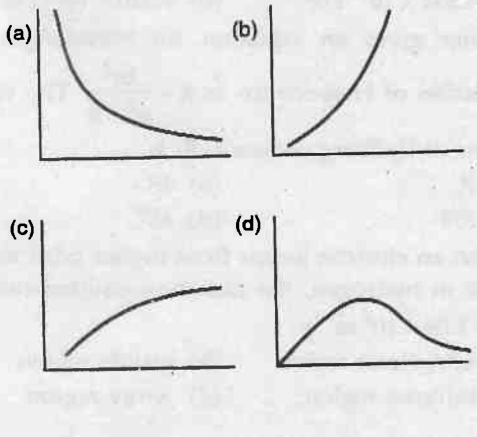
17. In the lowest orbit, the binding energy of an electron in hydrogen atom is 13.6 eV. The energy required to take out the electron from the lower three orbits in (eV) will be :
(a) 13.6, 6.8, 8.4 (b) 13.6, 10.2, 3.4
(c) 13.6, 27.2, 40.8 (d) 13.6, 3.4, 1.5

18. Minimum excitation potential of Bohr's first orbit in hydrogen atom is :
(a) 13.6 V (b) 3.4 V
(c) 10.2 V (d) 3.6 V

19. A proton and an alpha particle having same momentum enter a magnetic field at right angles to it. If r_1 and r_2 be their radii respectively then value of r_1/r_2 is :
(a) 1 (b) 2
(c) 1/2 (d) 1/4

Level-2

1. α-particles are projected towards the nuclei of the following metals, with the same kinetic energy. Towards, which metal, the distance of closest approach is minimum ?
(a) Cu (Z = 29) (b) Ag (Z = 47)
(c) Au (Z = 79) (d) Pd (Z = 46)
2. An α-particle accelerated through V volt is fired towards a nucleus. Its distance of closest approach is r. If a proton accelerated through the same potential is fired towards the same nucleus, the distance of closest approach of proton will be :
(a) r (b) $2r$
(c) $r/2$ (d) $r/4$
3. The distance of closest approach of an α-particle fired towards a nucleus with momentum p, is r. What will be the distance of closest approach when the momentum of α-particle is $2p$?
(a) $2r$ (b) $4r$
(c) $r/2$ (d) $r/4$
4. Which of the following is incorrect regarding Rutherford's atomic model ?
(a) Atom contains nucleus
(b) Size of nucleus is very small in comparison to that of atom
(c) Nucleus contains about 90% mass of the atom
(d) Electrons revolve round the nucleus with uniform speed
5. In Rutherford experiment the number of α-particles scattered through an angle 60° is 112 per minute, then the number of α particles scattered through an angle of 90° per minute by the same nucleus is :
(a) 28 per min
(b) 112 per min
(c) 12.5 per min
(d) 7 per min
6. Which of the following curves may represent radius of orbit in H-atom as a function of principal quantum number ?



7. The equivalent current due to motion of electron in first orbit of H-atom is :
(a) 0.7×10^{-3} A (b) 9×10^{-3} A
(c) 10^{-3} A (d) none of these
8. As the orbit number increases, the distance between two consecutive orbits in an atom or ion having single electron :
(a) increases
(b) decreases
(c) remains the same
(d) first increases and then becomes constant
9. If the radius of first Bohr's orbit is x, then de Broglie wavelength of electron in 3rd orbit is nearly :
(a) $2\pi x$ (b) $6\pi x$
(c) $9x$ (d) $x/3$
10. Rydberg atoms are the hydrogen atoms in higher excited states. Such atoms are observed in space. The orbit number for such an atom with radius about 0.01 mm should be :
(a) 1 (b) 435
(c) 13749 (d) 117
11. How many times larger is the spacing between the energy levels with $n = 3$ and $n = 4$ then the spacing between the energy levels with $n = 8$ and $n = 9$ for a hydrogen like atom or ion ?
(a) 0.71 (b) 0.41
(c) 2.43 (d) 14.82
12. In one revolution round the hydrogen nucleus, an electron makes five crests. The electron should belong from :
(a) 1st orbit (b) 4th orbit
(c) 5th orbit (d) 6th orbit
13. The circumference of the second orbit of an atom or ion having single electron, is 4×10^{-9} m. The de Broglie wavelength of electron revolving in this orbit should be :
(a) 2×10^{-9} m (b) 4×10^{-9} m
(c) 8×10^{-9} m (d) 1×10^{-9} m
14. In each of the following atoms or ions, electronic transition from $n = 4$ to $n = 1$ takes place. The frequency of the radiation emitted out will be minimum for :
(a) hydrogen atom (b) deuterium atom
(c) He^+ ion (d) Li^{2+} ion
15. If an electron is revolving round the hydrogen nucleus at a distance of 0.1 nm, what should be its speed?
(a) 2.188×10^6 m/s (b) 1.094×10^6 m/s
(c) 4.376×10^6 m/s (d) 1.59×10^6 m/s
16. The angular speed of an electron revolving round the H-nucleus is proportional to :
(a) $1/r$ (b) $1/r^{3/2}$
(c) $1/r^2$ (d) $r^{3/2}$

17. The angular momentum of the electron in third orbit of hydrogen atom, if the angular momentum in the second orbit of hydrogen atom is L is :
(a) L (b) $3L$
(c) $\frac{3}{2}L$ (d) $\frac{2}{3}L$

18. If an electron is moving around a nucleus of charge $2e$ in a circular orbit of radius 10^{-10} m, then the initial frequency of light emitted by the electron is :
(a) 4.2×10^{15} Hz (b) 0.36×10^{15} Hz
(c) 3.6×10^{15} Hz (d) 4.2×10^{15} Hz

19. An electron of hydrogen atom is revolving in third Bohr's orbit ($n=3$). How many revolutions will it undergo before making a transition to the second orbit ($n=2$). Assume the average life time of an excited state of the hydrogen atom is of the order of 10^{-8} s (Given : Bohr radius $=5.3\times10^{-12}$ m) :
(a) 2.5×10^{6} rev (b) 3.5×10^{6} rev
(c) 4.5×10^{6} rev (d) 1.5×10^{6} rev

20. In Bohr's orbit of hydrogen atom m kg is mass of an electron and e coulomb is the charge on it. The ratio (in SI units) of magnetic dipole moment to that of the angular momentum of electron is :
(a) $\frac{e}{2m}$ (b) $\frac{e}{m}$
(c) $\frac{2e}{m}$ (d) none of these

21. If $\left(\frac{0.51\times10^{-10}}{4}\right)$ metre is the radius of smallest electron orbit in hydrogen like atom, then this atom is :
(a) hydrogen atom (b) He^{+}
(c) Li^{2+} (d) Be^{3+}

22. How many different wavelengths may be observed in the spectrum from a hydrogen sample if the atoms are excited to third excited state ?
(a) 3 (b) 4
(c) 5 (d) 6

23. The maximum number of photons emitted by an H-atom, if atom is excited to states with principal quantum number four is :
(a) 4 (b) 3
(c) 2 (d) 1

24. In previous problem minimum number of photons emitted by the H-atom is :
(a) 1 (b) 2
(c) 3 (d) 4

25. For hydrogen atom the difference between any two consecutive energy levels (where n is the principal quantum number) :
(a) is always the same
(b) decreases inversely with n
(c) decreases inversely with n^2
(d) decreases inversely with n^3

26. An energy of 24.6 eV is required to remove one of the electrons from a neutral helium atom. The energy (in eV) required to remove both the electrons from a neutral helium atom is :
(a) 38.2 (b) 49.2
(c) 51.8 (d) 79.0

27. The energy of an atom or ion in the ground state is -54.4 eV. It may be :
(a) He^{+} (b) Li^{2+}
(c) Hydrogen (d) Deuterium

28. The ratio of the frequencies of the long wavelength limits of the Balmer and Lyman series of hydrogen is :
(a) 27 : 5 (b) 5 : 27
(c) 4 : 1 (d) 1 : 4

29. For a certain atom, there are energy levels A, B, C corresponding to energy values $E_A < E_B < E_C$. Choose the correct option if $\lambda_1, \lambda_2, \lambda_3$ are the wavelength of radiations corresponding to the transition from C to B, B to A and C to A respectively :
(a) $\lambda_3=\lambda_1+\lambda_2$ (b) $\lambda_3=\frac{\lambda_1\lambda_2}{\lambda_1+\lambda_2}$
(c) $\lambda_1+\lambda_2+\lambda_3=0$ (d) $3\lambda_2=\lambda_3+2\lambda_2$

30. The energy required to excite an electron in hydrogen atom from the ground state to the next higher state, if the ionisation energy for the hydrogen atom is 13.6 eV is :
(a) 3.4 eV (b) 10.2 eV
(c) 12.1 eV (d) 1.3 eV

31. The wavelength of the emitted radiation, if electron in hydrogen atom jumps from the third orbit to second orbit is :
(a) $\lambda=\frac{36}{5R}$ (b) $\lambda=\frac{5R}{36}$
(c) $\lambda=\frac{5}{R}$ (d) $\lambda=\frac{R}{6}$

32. Any radiation in the ultraviolet region of hydrogen spectrum is able to eject photoelectrons from a metal. What should be the maximum value of threshold frequency for the metal?
(a) 3.288×10^{15} Hz (b) 2.460×10^{15} Hz
(c) 4.594×10^{14} Hz (d) 8.220×10^{14} Hz

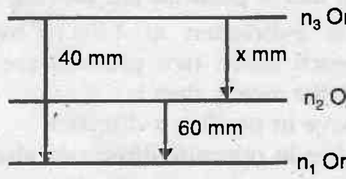
33. Balmer gives an equation for wavelength of visible radiation of H-spectrum as $\lambda=\frac{kn^2}{n^2-4}$. The value of k in terms of Rydberg constant, R, is :
(a) R (b) $4R$
(c) $R/4$ (d) $4/R$

34. When an electron jumps from higher orbit to the second orbit in hydrogen, the radiation emitted out will be in ($R=1.09\times10^{7}\ m^{-1}$) :
(a) ultraviolet region (b) visible region
(c) infrared region (d) X-ray region

35. Deuterium atoms in the ground state, are radiated by photons of energy 12.8 eV. What will be the energy of induced radiation of longest wavelength? Ionisation energy of deuterium is 14.4 eV :
(a) 12.8 eV (b) 10.8 eV
(c) 1.6 eV (d) 2.00 eV

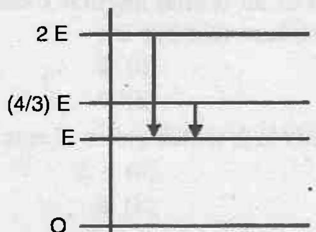
36. There are only three hydrogen atoms in the discharge tube. The analysis of spectrum shows that in all the hydrogen atoms, electrons are de-exciting from fourth orbit. What should be the maximum number of spectral lines?
(a) 6 (b) 1
(c) 4 (d) 5

37. For an atom of ion having single electron, the following wavelengths are observed. What is the value of missing wavelength, x ?



(a) 20 (b) 40
(c) 60 (d) 120

38. The figure shows energy levels of a certain atom, when the system moves from level $2E$ to E, a photon of wavelength λ is emitted. The wavelength of photon produced during its transition from level $\frac{4}{3}E$ to E level is



(a) 3λ (b) $3/4\,\lambda$
(c) $\lambda/4$ (d) 2λ

39. The ionisation energy of Li^{2+} atom in ground state is :
(a) 13.6×9 eV (b) 13.6 J
(c) 13.6 erg (d) 13.6×10^{-19} J

40. The first excitation potential of a given atom is 10.2 volt, then the ionisation potential is :
(a) 10.2 volt (b) 13.6 volt
(c) 30.6 volt (d) 20.4 volt

41. For a single ionised helium atom, the longest wavelength in ground state will absorb :
(a) 912 Å (b) 304 Å
(c) 606 Å (d) 1216 Å

42. If an electron drops from 4th orbit to 2nd orbit in an H-atom, then
(a) it gains 2.55 eV of potential energy
(b) it gains 2.55 eV of total energy
(c) it emits a 2.55 eV electron
(d) it emits a 2.55 eV photon

43. 29 electrons are removed from Zn-atom ($Z = 30$) by certain means. The minimum energy needed to remove the 30th electron, will be
(a) 12.24 keV (b) 408 eV
(c) 0.45 eV (d) 765 eV

44. An electron of kinetic energy E_0 is scattered by an atomic hydrogen sample in ground state. The minimum value of E_0 so that a photon of wavelength 656.3 nm may be emitted by H-atom is :
(a) 12.09 eV
(b) 13.6 eV
(c) 14.6 eV
(d) none of these

45. A H-atom moving with speed v makes a head on collision with a H-atom in rest. Both atoms are in ground state. The minimum value of velocity v for which one of atom may excite is :
(a) 6.25×10^4 m/s (b) 8×10^4 m/s
(c) 7.25×10^4 m/s (d) 13.6×10^4 m/s

46. A photon of energy 15 eV collides with H-atom. Due to this collision, H-atom gets ionized. The maximum kinetic energy of emitted electron is :
(a) 1.4 eV (b) 5 eV
(c) 15 eV (d) 13.6 eV

47. The minimum frequency of light which can ionize a hydrogen atom is :
(a) 3.28×10^{15} Hz (b) 5×10^{15} Hz
(c) 91.1 Hz (d) none of these

48. Which of the following is wrong about spin of electron according to quantum mechanics ?
(a) It is related to intrinsic angular momen- tum
(b) Spin is rotation of electron about its own axis
(c) Value of spin quantum number must not be 1
(d) $+\frac{1}{2}$ value of spin quantum number represents up spin

49. For which of the following set of quantum numbers, an electron will have the lowest energy?
(a) $3, 2, 1, \frac{1}{2}$ (b) $4, 2, -1, \frac{1}{2}$
(c) $4, 1, 0, -\frac{1}{2}$ (d) $5, 0, 0, \frac{1}{2}$

50. The angular momentum of the α-particles which are scattered through large angles by the heavier nuclei, is conserved because of the
(a) nature of repulsive forces
(b) conservation of kinetic energy
(c) conservation of potential energy
(d) conservation of total energy

51. p_x, p_y and p_z all the three have the same energy in :
(a) isolated H-atom
(b) He atom
(c) He^+ in magnetic field
(d) Li^{2+} in electric field

52. Which of the following statements about orbital angular momentum of an orbital is wrong?

(a) It is measured by $\sqrt{l(l+1)}\,\dfrac{h}{2\pi}$

(b) Its direction is fixed in space

(c) Its direction always make the same angle with 'z' axis

(d) Its x, y components change with time

53. In the case of Compton effect, which of the following is applicable?

(a) Energy conservation

(b) Momentum conservation

(c) Charge conservation

(d) All of the above

54. If only three quantum numbers of two electrons are the same, then which of the following is not correct?

(a) They have same energy in the absence of magnetic field

(b) They have same energy in the presence of electric field

(c) They have not same energy at all

(d) Both are present in the same orbital

55. Which is the common node for all orbitals :

(a) x, y and z-axis

(b) xy, yz and xz planes

(c) nodal spheres between two orbits

(d) nucleus

56. The number of nodal sphere of 3s-orbital are

(a) 1 (b) 2

(c) 3 (d) 0

57. Stability of half filled sub-shell is caused by :

(a) exchange energy (b) greater spin multiplicity

(c) both (a) and (b) (d) none of the above

58. In $2p^3$ electronic configuration only two electrons have the same spin quantum number. Which of the following statements is wrong about it?

(a) This is against the Hund's rule

(b) This is excited state

(c) This can be represented by $\boxed{\uparrow \mid \downarrow \mid \uparrow}$

(d) This is not possible

59. The number of orbitals in 3rd orbit are :

(a) 3 (b) 10

(c) 18 (d) none of these

60. How many quantum numbers are explained by Schrödinger's model?

(a) 1 (b) 2

(c) 3 (d) 4

61. Number of lobes of 2p-orbital as in yz- plane is :

(a) 2 (b) 4 (c) 6 (d) 8

62. In an isolated (free from any electric or magnetic field) Fe atom, all 'd' orbitals are not the same in energy due to :

(a) they all are in different orbits

(b) they all are not of same shape

(c) presence of magnetic field of other electrons

(d) P_z^2 have different shape than others

63. Pauli's principle is not applicable to :

(a) proton (b) neutron

(c) photon (d) π^-

64. In nitrogen atom outer p-orbital is as p_x^1, p_y^1, p_z^1 but not p_x^2, p_y^1, p_z^0 because :

(a) repulsion between electrons is minimum in first case

(b) p^1 is stable than p^2

(c) latter is opposite to Pauli's exclusion principle

(d) latter has only one unpaired electron

65. The change in frequency of a photon of red light whose original frequency is 7.3×10^{14} Hz when it falls through 22.5 m, is :

(a) 1.8 Hz (b) 100 Hz

(c) 7.3×10^{14} Hz (d) none of these

66. An electron and a positron are moving side by side in the positive x-direction at 1.5×10^8 m/s. When they annihilate each other, two photons are produced that move along the x-axis, then :

(a) both move in positive x-direction

(b) both move in opposite directions along x-axis

(c) both may move in same direction

(d) both (a) and (c) are correct

67. x and y components of an orbital angular momentum is zero for any instant and z component is h/π. The azimuthal quantum number of this orbital is :

(a) 1 (b) 0

(c) 2 (d) 3

68. z component of an orbital angular momentum is h/π, its magnetic quantum number is :

(a) 1 (b) 2

(c) – 1 (d) 0

69. If the value of l is 3, which value of m is not permissible ?

(a) 3 (b) – 3

(c) 2.5 (d) 0

70. Considering $3d$-orbitals, how many lobes are present in the xy-plane ?

(a) 2 (b) 4

(c) 6 (d) 8

71. Which of the following sets of quantum numbers is not possible?

(a) $n = 4, l = 1, m = 0, s = +\dfrac{1}{2}$

(b) $n = 4, l = 3, m = -3, s = -\dfrac{1}{2}$

(c) $n = 4, l = 1, m = +2, s = -\dfrac{1}{2}$

(d) $n = 4, l = 0, m = 0, s = -\dfrac{1}{2}$

72. Energy of an electron of isolated hydrogen atom does not depend upon

(a) principal quantum number

(b) azimuthal quantum number

(c) magnetic quantum number

(d) temperature of atomic gas

73. The wavelength of K_α line of zinc (atomic number 30) if K_α line from molybdenum (atomic number = 42) has a wavelength of 0.7078 Å is :
(a) 4.414 Å (b) 1.4148 Å
(c) 2.375 Å (d) 1.792 Å

74. The wavelength of the K_α line for an element of atomic number 57 is λ. What is the wavelength of the K_α line for the element of atomic number 29?
(a) λ (b) 2λ
(c) 4λ (d) λ/4

75. In Moseley's equation, $\sqrt{v} = a(Z - b)$, which was derived from the observations made during the bombardment of metal target with X-rays :
(a) a is independent but b depends on metal
(b) both a and b are independent to the metal
(c) both a and b depend on the metal
(d) b is independent but a depends on the metal

76. If the uncertainty in the position of a particle is equal to its de Broglie wavelength, the minimum uncertainty in its velocity should be :
(a) $\frac{1}{4\pi}$ (b) $\frac{v}{4\pi}$
(c) $\frac{v}{4\pi m}$ (d) $\frac{mv}{4\pi}$

77. Particles having spin $\frac{1}{2}, 1\frac{1}{2}, 2\frac{1}{2}$ etc., are called :
(a) Fermions (b) Bosons
(c) Kaons (d) Leptons

78. Particles having spin 1, 2, 3 ... are called :
(a) Fermions (b) Bosons
(c) Leptons (d) Mesons

Answers

Level-1

1. (b)	2. (b)	3. (d)	4. (c)	5. (a)	6. (d)	7. (a)	8. (d)	9. (c)	10. (c)
11. (d)	12. (a)	13. (c)	14. (d)	15. (a)	16. (b)	17. (d)	18. (c)	19. (b)	

Level-2

1. (a)	2. (a)	3. (d)	4. (c)	5. (a)	6. (b)	7. (c)	8. (a)	9. (b)	10. (b)
11. (b)	12. (c)	13. (a)	14. (a)	15. (d)	16. (b)	17. (c)	18. (c)	19. (a)	20. (a)
21. (d)	22. (d)	23. (b)	24. (a)	25. (d)	26. (d)	27. (a)	28. (a)	29. (b)	30. (b)
31. (a)	32. (b)	33. (d)	34. (b)	35. (d)	36. (a)	37. (d)	38. (a)	39. (a)	40. (b)
41. (b)	42. (d)	43. (a)	44. (a)	45. (a)	46. (a)	47. (a)	48. (b)	49. (c)	50. (d)
51. (a)	52. (b)	53. (b)	54. (b)	55. (d)	56. (b)	57. (c)	58. (d)	59. (d)	60. (c)
61. (b)	62. (c)	63. (c)	64. (a)	65. (a)	66. (b)	67. (c)	68. (b)	69. (c)	70. (d)
71. (c)	72. (d)	73. (b)	74. (c)	75. (b)	76. (b)	77. (b)	78. (b)		

Solutions

Level-1

6. $$i = ne = 1$$
$$n = \frac{1}{1.6 \times 10^{-19}} = 625 \times 10^{16}$$

8. $$r \propto n^2$$
$$r \propto (3)^2 \Rightarrow r \propto 9$$

10. Wave number, $$\bar{v} = \frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$
Here $$n_1 = 2, n_2 = 3$$
∴ $$\bar{v} = \frac{5R}{36}$$

13. $$mvr = \frac{nh}{2\pi}$$
For $n = 1$, $$mvr = \frac{h}{2\pi}$$

14. $$v \propto \frac{1}{n},$$
Here, $$\frac{v_5}{v_2} = \frac{2}{5} \Rightarrow v_5 = \frac{2v}{5}$$

16. $$\frac{mv_n^2}{r_n} = \frac{1}{4\pi\varepsilon_0}\left(\frac{Ze^2}{r_n^2}\right) = \frac{kZe^2}{r_n^2}$$
or $$mv_n^2 = \frac{kZe^2}{r_n}$$
∴ Kinetic energy of electron in nth orbit
$$KE = \frac{1}{2}mv_n^2 = \frac{kZe^2}{2r_n}$$
⇒ $$KE = \frac{e^2}{2r} \quad (\because r_n = r)$$

33

Nucleus

***Syllabus:** Atomic masses, size of the nucleus, radioactivity, rays and their properties-alpha, beta and gamma decay, half life, mean life, binding energy, mass-energy relationship, nuclear fission and nuclear fusion.*

Review of Concepts

1. Nucleus : It is most dense space of the universe.

(a) Radius : $R = R_0 A^{1/3}$

where, $R_0 = 1.1 \times 10^{-15}$ m, A = mass number

(b) Volume :

$$V = \frac{4}{3}\pi R^3 = \frac{4}{3}\pi R_0^3 A$$

(c) Density :

$$\text{Density} = \frac{\text{Mass of nucleus}}{\text{Volume of the nucleus}}$$

$$= \frac{Am_n}{\frac{4}{3}\pi (R_0 A^{1/3})^3}$$

$$= \frac{m_p}{\frac{4}{3}\pi R_0^3} \approx 10^{17} \text{ kg/m}^3$$

where $m_p = 1.67 \times 10^{-27}$ kg, $R_0 = 1.3$ fm.

(d) Atomic mass unit:

$$1 \text{ amu} = \frac{1}{6.02 \times 10^{26}} \text{ kg mass}$$

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

$$= 931 \text{ MeV/C}^2$$

(e) Atomic number (Z) = number of protons.

(f) Mass number (A) = number of protons + number of neutrons.

2. Decay Processes :

(a) α-decay: It consists of He^{2+} ion.

(i) **Cause :** Large size of nucleus $(A > 210)$.

(ii) **Effect :** Mass number decreases by 4 and atomic number decreases by 2.

(iii) **Decay equation :**

$$_Z^A X \longrightarrow {}_{Z-2}^{A-4}Y + {}_2^4\text{He}$$

e.g., $$^{238}_{92}\text{U} \longrightarrow {}^{234}_{90}\text{Th} + {}^4_2\text{He}$$

(iv) $Q = [m(^AX_Z) - m(Y) - m(\text{He})]\, c^2$

(v) This process provides kinetic energies to daughter nucleus and α-particle.

(vi) $Q = \frac{1}{2} m_y v_y^2 + \frac{1}{2} m_\alpha v_\alpha^2$

(vii) $m_\alpha v_\alpha = m_y v_y$ (In one dimension)

(viii) In general, $\vec{p}_\alpha + \vec{p}_y = 0$

Here, $\vec{p}_\alpha$ = momentum of α-particle,

$\vec{p}_y$ = momentum of daughter nucleus

(b) β-decay: It is stream of fast moving electrons. In this process, a neutron is converted into proton and electron. The basic equation is

$$n \rightarrow p + e + \bar{\nu} \text{ (anti-neutrino)}$$

(i) $\bar{\nu}$ is chargeless, massless particle. It is just like photon. Its spin is $\pm 1/2$.

(ii) **Cause :** Nucleus has too many neutrons relative to number of protons.

(iii) **Effect :** Due to emission of β-particle, the mass number remains constant, but atomic number increases by 1.

(iv) **Decay equation :**

$$_Z^A X \longrightarrow {}_{Z+1}^{A}Y + e + \bar{\nu}$$

e.g., $$^{14}_6\text{C} \longrightarrow {}^{14}_7\text{N} + e^- + \bar{\nu}$$

(v) Q-value: $Q = (m_x - m_y)\, c^2$

Here, m_x and m_y are atomic masses.

(vi) Q-value energy is shared by emitted electron and anti-neutrino. For maximum kinetic energy of electron, antineutrino energy is negligible.

$\therefore$ $Q = (\text{KE})_{\max}$ of electron

(c) Positron emission or β^+ decay : Positron is anti-particle of electron. Its rest mass is equal to that of electron and charge is $+e$.

(i) **Cause :** Nucleus has too many protons relative to number of neutrons.

(ii) **Effect :** Mass number remains constant but atomic number decreases by 1.

(iii) **Basic equation :** $p \longrightarrow n + e + \nu$ (neutrino)

(iv) Neutrino is anti-particle of anti-neutrino.

(v) **Decay equation :**

$$_Z^A X \longrightarrow {}_{Z-1}^{A}Y + e^+ + \nu$$

e.g., $$^{64}_{29}\text{Cu} \longrightarrow {}^{64}_{28}\text{Ni} + e^+ + \nu$$

(vi) **Q-value :** $Q = (m_x - m_y - 2m_e)\, c^2$

Here m_x and m_y are atomic masses.

(d) **Electron capture** : This is similar to positron emission. In this process, inner most atomic electron is captured by nucleus.

(e) γ-**decay** : γ-rays are electromagnetic waves of short wavelengths. The main reason for instability of nucleus is excess energy of nucleus. Due to γ-decay, neither the mass number nor the atomic number changes but energy of nucleus reduces.

3. Law of Radioactive Decay:

(a) $N = N_0 e^{-\lambda t}$

Here, N = present number of radioactive nuclei

N_0 = initial number of nuclei

$$\lambda = \text{decay constant} = \frac{0.693}{\text{half life period}}$$

(b) $A = A_0 e^{-\lambda t}$

Here, A = activity at an instant $t = \lambda N$

A_0 = activity at $t = 0$

(c) The number of decay nuclei in time t is

$$N_1 = N_0 - N = N_0 (1 - e^{-\lambda t})$$

(d) **Unit of activity :**

1 curie $= 3.7 \times 10^{10}$ disintegrations per second or becquerel

(e) Mean life $= 1/\lambda$

4. Radioactive Decay in Different Situations :

(a) Disintegration and formation of radioactive substance simultaneously :

$$\xrightarrow[q\text{ (constant)}]{\text{Formation}} A \xrightarrow[\lambda]{\text{decays}} B$$

The useful equation is $\frac{dN}{dt} = q - \lambda N$, where q = rate of formation of A.

(b) Decays chain :

$$\underset{\text{unstable}}{\overset{N_1}{A}} \xrightarrow[\lambda_1]{\text{decays}} \underset{\text{unstable}}{\overset{N_2}{B}} \xrightarrow[\lambda_2]{\text{decays}} \underset{\text{stable}}{\overset{N_3}{C}}$$

Here, $\frac{dN_1}{dt} = -\lambda_1 N_1$

$$\frac{dN_2}{dt} = \lambda_1 N_1 - \lambda_2 N_2 \quad \text{and} \quad \frac{dN_3}{dt} = \lambda_2 N_2$$

But $N_1 + N_2 + N_3$ = constant

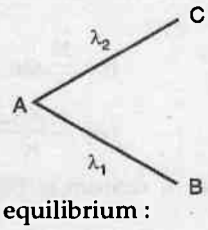
Also, $N_1 = N_0 e^{-\lambda_1 t}$

$$N_2 = \left(\frac{N_0 \lambda_1}{\lambda_2 - \lambda_1}\right)[e^{-\lambda_1 t} - e^{-\lambda_2 t}]$$

and $$N_3 = N_0 \left[\frac{\lambda_1 e^{-\lambda_2 t} - \lambda_2 e^{-\lambda_1 t}}{\lambda_2 - \lambda_1} + 1\right]$$

(c) Decays of nuclei by two processes simultaneously : In this case,

$$\lambda_{eff} = \lambda_1 + \lambda_2$$



(d) Radioactive equilibrium :

$$\lambda_1 N_1 = \lambda_2 N_2$$

5. Binding Energy : The binding energy of a nuclide $_ZX^A$ is given by

$$E_B = [Zm_p + (A - Z) m_n - m_X]c^2$$

where m_p = mass of proton, m = mass of neutron and m_X = mass of nucleus.

Here factor $[Zm_p + (A - Z)m_n - m_X]$ is called the mass defect.

Binding energy is utilised to bind the nucleons in the nucleus or to break the nucleus into its constituent particles.

6. Nuclear Fission : Breaking of heavy nucleus in two nuclei

$$_{92}U^{235} + {_0n^1} \longrightarrow x + y + p\,({_0n^1}) + 200 \text{ MeV}$$

where x and y are any two isotopes having mass number about 40% to 60% of original nucleus and p is number of neutrons which may be 2 or 3.

7. Nuclear Fusion : Synthesis of lighter nuclei into heavier nuclei at a very high temperature $= 2 \times 10^7$ K at high pressure.

In a nuclear reactor :

(i) A moderator is used to slowdown neutrons. Graphite and heavy water are suitable moderators.

(ii) Cadmium, boron and steel rods are used as controller in nuclear reactor.

Objective Questions

Level-1

1. The penetrating powers of α, β and γ radiations, in decreasing order are :

(a) γ, α, β (b) γ, β, α
(c) α, β, γ (d) β, γ, α

2. A sample of radioactive material has mass m, decay constant λ and molecular weight M. Avagadro's constant $= N_A$. The initial activity of the sample is :

(a) λm (b) $\frac{\lambda m}{M}$
(c) $\frac{\lambda m N_A}{M}$ (d) $m N_A e^{\lambda}$

3. If radium has half-life of 5 years. Thus for a nucleus in a sample of radium, the probability of decay in ten years is :

(a) 50%
(b) 75%
(c) 100%
(d) 60%

4. The binding energies per nucleon for a deuteron and an α-particle are x_1 and x_2 respectively. What will be the energy Q released in the reaction ?

$$_1H^2 + {_1H^2} \longrightarrow {_2He^4} + Q$$

(a) $4(x_1 + x_2)$ (b) $4(x_2 - x_1)$
(c) $2(x_1 + x_2)$ (d) $2(x_2 - x_1)$

5. n alpha particles per second are emitted from N atoms of a radioactive element. The half-life of radioactive element is :

(a) $\frac{n}{N}$ sec (b) $\frac{N}{n}$ sec
(c) $\frac{0.693\,N}{n}$ sec (d) $\frac{0.693\,n}{N}$ sec

6. The half-life period of radium is 1600 years. Its average life time will be :

(a) 3200 year (b) 4800 year
(c) 2319 year (d) 4217 year

7. A sample of a radioactive element of 16 g is taken from Kota to Patna in 2 hour and it was found that 1 g of the element remained undisintegrated. Half-life of the element is :

(a) 2 hr (b) 1 hr
(c) $\frac{1}{2}$ hr (d) $\frac{1}{4}$ hr

8. The half-life of radioactive substance is 3.8 days. The time at the end of which $\left(\frac{1}{20}\text{th}\right)$ of the radioactive substance will remain undecayed is : (given $\log_{10} e = 0.4343$)

(a) 13.8 days (b) 16.5 days
(c) 33 days (d) 76 days

9. A parent nucleus $^m_n p$ decays into a daughter nucleus D through α emission in the following way $^m_n p \longrightarrow D + \alpha$. The subscript and superscript on the daughter nucleus D will be written as :

(a) $^m_n D$ (b) $^{m+4}_n D$
(c) $^{m-4}_n D$ (d) $^{m-4}_{n-2} D$

10. The number of nuclei present in a mass m gram of radioactive element of mass number A is :

(a) $6.02 \times 10^{23}\, m/A$ (b) $6.6 \times 10^{34}\, m/A$
(c) $6.02 \times 10^{23}\, mA$ (d) $6.02 \times 10^{34}\, A/m$

11. The activity of a sample of radioactive material is A_1 at time t_1 and A_2 at time t_2 $(t_2 > t_1)$. Its mean life is T such that :

(a) $A_1 t_1 = A_2 t_2$ (b) $\frac{A_1 - A_2}{t_2 - t_1} = \text{constant}$
(c) $A_2 = A_1 e^{(t_1 - t_2)/T}$ (d) $A_2 = A_1 e^{(t_1/t_2)}$

12. Mark the correct option, for the substance which cannot be emitted by radioactive substances during their decay :

(a) electrons (b) protons
(c) neutrinoes (d) helium nuclei

13. α, β and γ radiations come out of a radioactive substance :

(a) when it is heated
(b) when put in atomic reactor
(c) spontaneously
(d) under pressure

14. In the nucleus of $_{11}Na^{23}$, the number of protons, neutrons and electrons is :

(a) 11, 12, 11 (b) 23, 12, 11
(c) 12, 11, 0 (d) 23, 11, 12

15. The nucleus of nucleon number 16, has nuclear radius 3×10^{-15} m, then the radius of nucleus having nucleon number 128 is :

(a) 3×10^{-15} m (b) 1.5×10^{-15} m
(c) 6×10^{-15} m (d) 4.5×10^{-15} m

16. A particle moving with a velocity $\frac{1}{10}$th of light will cross a nucleus in about :

(a) 10^{-8} sec (b) 10^{-12} sec
(c) 10^{-47} sec (d) 10^{-21} sec

17. The alpha and beta particles cause ionisation because of :

(a) photoelectric emission
(b) compton collision
(c) pair production
(d) the electrostatic force

18. One milligram of matter converted into energy will give :

(a) 90 J (b) 9×10^{5} J
(c) 9×10^{10} J (d) 9×10^{5} J

19. In the fission of uranium, 0.5 g mass disappears. The energy obtained is :

(a) 1.25 kWh
(b) 1.25×10^7 kWh
(c) 0.25 kWh
(d) 1.25×10^4 kWh

20. In nuclear reaction

$$_2He^4 + {_ZX^A} \longrightarrow {_{Z+2}Y^{A+3}} + {_{Z'}M^{A'}}$$

where M denotes :

(a) electron (b) positron
(c) proton (d) neutron

21. In the given reaction

$$_ZX^A \longrightarrow {_{Z+1}Y^A} \longrightarrow {_{Z-1}K^{A-4}} \longrightarrow {_{Z-1}K^{A-4}}$$

Radioactive radiations are emitted in the sequence :

(a) α, β, γ (b) β, α, γ
(c) γ, α, β (d) β, γ, α

22. The critical mass of fissionable uranium 235 can be reduced by :

(a) surrounding it by neutron absorbing material
(b) surrounding it by neutron reflecting material
(c) heating the material
(d) adding impurities

23. When number of nucleons in nuclei increases, the binding energy per nucleon :
(a) increases continuously with mass number
(b) decreases continuously with mass number
(c) remains constant with mass number
(d) first increases and then decreases with increase of mass number

Level-2

1. The radius of Na^{23} nucleus is :
(a) 3.125×10^{-15} m (b) 23×10^{-15} m
(c) 11×10^{-15} m (d) 1.1×10^{-15} m

2. A heavy nucleus (mass number = A) splits into two new nuclei, whose mass numbers are in the ratio 3 : 2. The ratio of radii of these new nuclei are :
(a) 3 : 2 (b) 2 : 3
(c) $3^{1/3} : 2^{1/3}$ (d) $2^{1/3} : 3^{1/3}$

3. The rest mass energy of electron is :
(a) 0.8 MeV (b) 1.66 amu
(c) 0.5119 MeV (d) none of these

4. The mass of electron in atomic mass unit is :
(a) 0.0005498 (b) 0.5119
(c) 0.5498 (d) none of these

5. The atomic mass of Al^{27} is 26.9815 amu. The mass of electron is 0.0005498 amu. The rest mass energy of Al^{27} nucleus is
(a) 1862 MeV (b) 25119.78 MeV
(c) 25113.12 MeV (d) none of these

6. The atomic mass of B^{10} is 10.811 amu. The binding energy of B^{10} nucleus is [Given : The mass of electron is 0.0005498 amu, the mass of proton is $m_p = 1.007276$ amu and the mass of neutron is $m_n = 1.008665$ amu] :
(a) – 678.272 MeV (b) 678.932 MeV
(c) 378.932 MeV (d) none of these

7. The binding energy of Na^{23} is [Given : Atomic mass of Na^{23} is 22.9898 amu and that of $^1H_1$ is 1.00783 amu. The mass of neutron = 1.00867 amu] :
(a) 931 MeV (b) 186.54 MeV
(c) 5.38 MeV (d) none of these

8. The binding energies per nucleon are 5.3 MeV, 6.2 MeV and 7.4 MeV for the nuclei with mass numbers 3, 4 and 5 respectively. If one nucleus of mass number 3 combines with one nucleus of mass number 5 to give two nuclei of mass number 4, then :
(a) 0.3 MeV energy is absorbed
(b) 0.3 MeV energy is released
(c) 28.1 MeV energy is absorbed
(d) 3.3 MeV energy is absorbed

9. What is the binding energy per nucleon of $_6C^{12}$ nucleus ?
Given: mass of C^{12} (m_c) = 12.000 u
mass of proton (m_p) = 1.0078 u
mass of neutron (m_n) = 1.0087 u
and 1 amu = 931.4 MeV
(a) 5.26 MeV (b) 10.11 MeV
(c) 15.65 MeV (d) 7.68 MeV

10. $O^{19} \longrightarrow F^{19} + e + \bar{v}$
In this decay, the rest mass energy of O^{19} and F^{19} are 17692.33 MeV and 17687.51 MeV respectively. The Q factor of the decay is :
(a) 4.82 MeV (b) 7 MeV
(c) 17.69 MeV (d) none of these

11. The binding energy expressed in MeV is given for the following nuclear reactions :
$$_2He^3 + {_0n^1} \longrightarrow {_2He^4} + 20 \text{ MeV}$$
$$_2He^4 + {_0n^1} \longrightarrow {_2He^5} - 0.9 \text{ MeV}$$
Which of the following conclusions is correct?
(a) $_2He^4$ is less stable than both $_2He^3$ and $_2He^5$
(b) $_2He^4$ is less stable than $_2He^3$ but more stable than $_2He^5$
(c) $_2He^4$ is less stable than $_2He^5$ but more stable than $_2He^3$
(d) $_2He^4$ is more stable than both $_2He^3$ and $_2He^5$

12. The energy of the reaction
$$Li^7 + p \longrightarrow 2\,{_2He^4}$$
if the binding energy per nucleon in Li^7 and He^4 nuclei are 5.60 MeV and 7.06 MeV, respectively, is :
(a) 19.6 MeV (b) 2.4 MeV
(c) 8.4 MeV (d) 17.28 MeV

13. $n = p + e$, n = neutron, p = proton, e = electron
The decay equation is
(a) correct
(b) wrong
(c) sometimes correct
(d) sometimes wrong

14. $^{19}_{8}O = {^{19}_{9}F} + A + B$
In the given decay equation, A and B indicate
(a) electron and anti-neutrino
(b) positron and anti-neutrino
(c) positron and neutrino
(d) electron and positron

15. Electric field and magnetic field do not cause deflection in :
(a) α-rays (b) β-rays
(c) γ-rays (d) positron

16. Which one of the following processes is an example of weak decay?
(a) $\pi^0 \to y + e^+ + e^-$ (b) $\pi^0 \to y + y$
(c) $n \to p + e^- + \nu_e^-$ (d) $y \to e^+ + e^-$

17. The mass number of a nucleus is :
(a) always less than its atomic number
(b) always more than its atomic number
(c) sometimes equal to its atomic number
(d) all of the above

18. When the atomic number A of a nucleus increases :
(a) initially the neutron-proton ratio is constant
(b) initially the neutron-proton ratio increases and then decreases
(c) initially the binding energy per nucleon increases and then decreases
(d) the binding energy per nucleon increases when neutron proton ratio increases

19. Which of the following is wrong about β^+- emission?
(a) Proton convert into neutron
(b) β^+-emission is associated with emission of anti-neutrino
(c) β^+-emission is caused by decay of π^+
(d) No change in mass number due to this emission

20. β-emission must be associated with :
(a) neutrino emission (b) anti-neutrino emission
(c) positron emission (d) proton emission

21. The most stable nucleus should have :
(a) even number of protons and odd number of neutrons
(b) odd number of neutrons and odd number of protons
(c) even number of protons and even number of neutrons
(d) even number of neutrons and odd number of protons

22. Nuclear isomers differ in :
(a) number of protons (b) number of neutrons
(c) number of n^- (d) energy

23. Radioactivity can be effected by :
(a) temperature (b) pressure
(c) radiation (d) all of these

24. A sample contains one kg O^{19} nuclei. The sample decays according to following equation.

$$O^{19} \longrightarrow F^{19} + e + \bar{v}$$

The mass of sample after one half-life period is :
(a) lesser than 1/2 kg (b) equal to 1/2 kg
(c) slightly less than 1 kg (d) equal to 1 kg

25. The number of C^{14} atoms in a sample is 100. The half-life period of C^{14} is 5730 year. The number of C^{14} atoms in the sample after 5730 year :
(a) must be equal to 50
(b) must be equal to 100
(c) may be equal to 90
(d) must be equal to 90

26. Which of the following nuclear reactions occurs in nature for the formation of tritium?
(a) ${}_3Li^6 + {}_0n^1 \longrightarrow {}_2He^4 + {}_1H^3$
(b) ${}_5B^{10} + {}_0n^1 \longrightarrow 2\,{}_2He^4 + {}_1H^3$
(c) ${}_5B^{11} + {}_2He^4 \longrightarrow {}_6C^{12} + {}_1H^3$
(d) ${}_4Be^9 + {}_1D^2 \longrightarrow 2\,{}_2He^4 + {}_1H^3$

27. Which of the following is correct statement?
(a) Average life is time in which no disintegration takes place
(b) Average life is the average time upto which the unstable nuclei exist, before its disintegration
(c) $t_{3/4}$ is the time in which one-fourth of radionuclide will decay
(d) The product of half-life and average life have same value for all radio isotopes

28. Four vessels A, B, C and D contain respectively 20 g-atom ($t_{1/2} = 5$ hour), 2 g-atom ($t_{1/2} = 1$ hour), 5 g-atom ($t_{1/2} = 2$ hour) and 10 g-atom ($t_{1/2} = 3$ hour) of different radio nuclides in the beginning, the maximum activity would be exhibited by the vessel is :
(a) A (b) B
(c) C (d) D

29. The half-life of Tc^{99} is 6 hour. The activity of Tc^{99} in a patient, 60 hour after receiving an injection containing this radioisotope is at least 0.125 µci. What was the minimum activity (in µci) of the sample injected?
(a) 1.25 µci (b) 12.5 µci
(c) 128 µci (d) 125 µci

30. A radioactive sample has an initial activity of 50 dpm, 20 minute later, the activity is 25 dpm. How many atoms of the radioactive nuclide were there originally?
(a) 20 (b) 1000
(c) 1443 (d) 2

31. The radioactive decay rate of a radioactive element is found to be 10^3 disintegrations per second at a certain time. If the half life of the element is one second, the decay rate after three second is :
(a) 1000 (b) 250
(c) $\frac{1000}{3}$ (d) 125

32. The count rate of a radioactive nuclei falls from 992 counts per minute to 62 counts per minute in 10 hour. The half-life of the element is :
(a) 1 hour (b) 2.5 hour
(c) 5 hour (d) 6 hour

33. Half-life period of a given radioactive sample is τ. Its average life would be :
(a) $\tau \ln 2$ (b) $\frac{\tau}{\ln 2}$
(c) $\frac{1}{\tau}$ (d) $\frac{\ln 2}{\tau}$

34. Choose the correct option, if T_n and T_m denote the half-value period and the mean-value period, respectively of a radioactive element :
(a) $T_n = T_m$ (b) $T_n > T_m$
(c) $T_n < T_m$ (d) $T_n > T_m$

35. The half-life of radium is 1600 years. The number of atoms that will decay from 1 g sample of radium per second is (Given : Atomic weight of radium = 226) :
(a) 3.6×10^{10} (b) 7.2×10^{10}
(c) 4.2×10^{10} (d) 14.6×10^{10}

36. At certain time the activity of three radioactive materials are in the ratio of 3 : 4 : 5. What will be the ratio of their activities at any further date?

(a) 1 : 2 : 3 (b) 2 : 3 : 4
(c) 3 : 4 : 5 (d) 5 : 6 : 8

37. 20% of a radioactive substance decay in 10 days. The amount of the original material left after 30 days is :

(a) 51.2% (b) 62.6%
(c) 15% (d) 21.27%

38. In how many months, $(3/4)^{th}$ of the substance will decay, if half-life of the radioactive substance is 2 months?

(a) 4 month (b) 6 month
(c) 8 month (d) 14 month

39. The half-life of a freshly prepared radioactive sample is 2 hours. If the sample emits radiation of intensity which is 32 times the permissible safe level, then the minimum time taken after which it would be possible to work safely with source is :

(a) 8 hour (b) 10 hour
(c) 16 hour (d) 2 hour

40. The ratio of half-life to the mean life of a radioactive sample, if λ be the decay constant of a radioactive sample is :

(a) 0.693 (b) 0.746
(c) $\frac{1}{0.693}$ (d) $(0.693)^2$

41. The number of β-particles, if a radioactive element ${}_{90}X^{238}$ decays into ${}_{83}Y^{222}$ is :

(a) 4 (b) 6
(c) 2 (d) 1

42. A particular nucleus in a large population of identical radioactive nuclei survives 10 half lives of that isotopes. The probability that this surviving nucleus will survive the next half-life is :

(a) 1/10 (b) 2/5
(c) 1/2 (d) $1/2^{10}$

43. How long will it take for 75% of the atoms of a certain radioactive element, originally present to disintegrate? The half-life of the element is 10 days :

(a) 240 days (b) 3.6 days
(c) 15.6 days (d) 4.15 days

44. For measuring the activity of a radioactive sample, a count rate meter is used. At certain observation, count rate meter recorded 5050 counts per minute but after 10 minutes later, the count rate showed 2300 counts per minute. The disintegration constant (λ) is :

(a) 0.065 per min (b) 0.078 per min
(c) 0.24 per min (d) 0.868 per min

45. What should be the activity of a radioactive sample of mass m and decay constant λ, after time t ? Take molecular weight of the sample be M and the Avagadro number be N_A :

(a) $A = \left(\frac{MN_A\lambda}{m}\right)e^{-\lambda t}$ (b) $A = \left(\frac{mN_A\lambda}{M}\right)e^{-\lambda t}$

(c) $A = \left(\frac{mN_A\lambda}{t}\right)e^{-\lambda t}$ (d) $A = \left(\frac{Mm\lambda}{N_A}\right)e^{-\lambda t}$

46. The radioactive nucleus may emit :

(a) all the three α, β and γ radiations simultaneously
(b) all the three α, β and γ, one after the other
(c) only α and β simultaneously
(d) only one α or β or γ at a time

47. Half-life of radioactive ${}_6C^{14}$ is 8000 years. What will be the age of wooden article if its ${}_6C^{14}$ activity is 1/3 of that of newly cut wood? (Take $\log_{10} 3 = 0.477$)

(a) 6788 (b) 8748
(c) 8788 (d) None of these

48. The nucleus ${}^{242}Pu_{94}$ decays to ${}^{206}Pb_{82}$ by emitting :

(a) 9α and 12β-particles
(b) 6α and 9β-particles
(c) 9α and 6β-particles
(d) 6α and 12β-particles

49. The activity of a radioactive sample goes down to about 6% in a time of 2 hours. The half life of the sample in minutes is about :

(a) 30 (b) 15
(c) 60 (d) 120

50. A radio isotope disintegrates both by α and β-emission. The half-life with respect to each decay is T_1 and T_2, respectively. The overall half-life, T with respect to disintegration will be :

(a) $T = T_1 + T_2$ (b) $T = T_1 \times T_2$

(c) $T = \frac{T_1 \times T_2}{T_1 + T_2}$ (d) $T = \frac{T_1 + T_2}{T_1 \times T_2}$

51. A radioactive sample decays with an average life of 2 min. An inductor is shorted through a resistance R, then the value of resistance R for which the ratio of the current through the resistance to the activity of the radioactive sample remains constant is :

(a) $10 \ln 2\,\Omega$ (b) $5\,\Omega$
(c) $10\,\Omega$ (d) $5 \ln 2\,\Omega$

52. Find the number N of nuclei of a radioactive element X at time t, if at time $t = 0$, the element has N_0 number of nuclei. Assume nuclei of the element X is being produced at a constant rate 'α' and the element has a decay constant λ :

(a) $N = \frac{\alpha}{\lambda}(1 - e^{-\lambda t}) + N_0 e^{-\lambda t}$

(b) $N = \frac{\lambda}{\alpha}(1 - e^{-\lambda t}) + N_0 e^{-\lambda t}$

(c) $dN = \frac{\alpha}{\lambda}(1 - e^{-\alpha t}) + N_0 e^{-\lambda t}$

(d) $N = \frac{\alpha}{\lambda}(1 - e^{-\alpha t}) + N_0 e^{\lambda t}$

53. The half-life of a radioactive sample is T. If the radioactivities of the sample are R_1 and R_2 at time T_1 and T_2 respectively, then number of atoms disintegrated in time $(T_2 - T_1)$ is proportional to :
(a) $(R_1 + R_2)\,T$ (b) $(R_1 - R_2)\,T$
(c) $\dfrac{(R_1 - R_2)}{T}$ (d) $\dfrac{(R_1 + R_2)}{T}$

54. Analysis of potassium and argon atoms in a moon rock sample by a mass spectrometer shows that the ratio of the number of stable Ar^{40} atoms present to the number of radioactive K^{40} atoms is $7:1$. Assume that all the argon atoms were produced by the decay of potassium atoms, with a half-life of 1.25×10^9 year. How old is the rock?
(a) 1.25×10^9 year (b) 3.75×10^9 year
(c) 8.75×10^9 year (d) 1.00×10^{10} year

55. Consider : $A \xrightarrow{-\alpha} B \xrightarrow{-\alpha} C$ where the decay constants of A and B are $3 \times 10^{-5}\ s^{-1}$ and $2 \times 10^{-8}\ s^{-1}$, respectively. If the disintegration starts with A only, the time at which B will have maximum activity, is :
(a) infinite (b) 3.33×10^4 s
(c) 5×10^7 s (d) 2.44×10^5 s

56. Consider : $X \xrightarrow{-\alpha} Y \xrightarrow{-\alpha} Z$ where half- lives of X and Y are 2 year and one month respectively. The ratio of atoms of X and Y, when transient equilibrium $[T_{1/2}(X) > T_{1/2}(Y)]$ has been established, is :
(a) $24:1$ (b) $1:24$
(c) $23:1$ (d) $1:23$

57. Consider: $P \xrightarrow{-\alpha} Q \xrightarrow{-\alpha} R$ where decay constants of P and Q are $4\ yr^{-1}$ and $1\ min^{-1}$, respectively. The ratio of number of atoms of P and Q, when secular equilibrium $[T_{1/2}(P) >> T_{1/2}(Q)]$ has been achieved, is :
(a) $4:1$
(b) $1:4$
(c) $1:131400$
(d) $131400:1$

58. Isotopes, which undergo spontaneous fission are found in n-p graph :
(a) above the belt of stability
(b) below the belt of stability
(c) above or below the belt of stability
(d) in the belt of stability

59. Which of the following nuclei is fissionable but not possible?
(a) $_{92}U^{233}$ (b) $_{92}U^{235}$
(c) $_{92}U^{238}$ (d) $_{94}Pu^{239}$

60. Moderator in a nuclear reactor slows down the neutrons to :
(a) decrease the probability of escape
(b) increase the probability of nuclear fission
(c) decrease the probability of absorption
(d) all of the above

61. When the nucleus of $^{238}U_{92}$ disintegrates to give one nucleus of $^{206}Pb_{82}$, the number of α-particles emitted and the number of β-particles emitted are :
(a) 4 and 8 respectively
(b) 6 and 8 respectively
(c) 8 and 6 respectively
(d) 8 and 10 respectively

62. In a particular fission reaction, a $^{235}U_{92}$ nucleus captures a slow neutron. The fission products are three neutrons, a $^{142}La_{57}$ nucleus and a fission product $_ZX$. Then Z is :
(a) 30 (b) 34
(c) 35 (d) 36

63. The number of fissions of $^{235}U_{92}$ required to produce a power of 1 W is :
(a) 3.1×10^{10} (b) 3.1×10^{13}
(c) 3.1×10^{19} (d) 3.1×10^{8}

64. $_{92}U^{238}$ decays to $_{90}Th^{234}$ with half-life 4.5×10^9 year. The resulting $_{90}Th^{234}$ is in excited state and hence, emits further a gamma ray to come to the ground state, with half-life 10^{-8} s. A sample of $_{92}U^{238}$ emits 20 gamma rays per second. In what time, the emission rate will drop to 5 gamma ray per second?
(a) 2×10^{-8} s (b) 0.25×10^{-8} s
(c) 9×10^9 year (d) 1.125×10^9 year

65. In which of the following nuclear reactions, the product is incorrectly matched?
(a) $_{96}Cm^{242}\ (\alpha, 2n)\ _{97}Bk^{243}$
(b) $_5B^{10}\ (\alpha, n)\ _7N^{13}$
(c) $_7N^{14}\ (n, p)\ _6C^{14}$
(d) $_{14}Si^{28}\ (d, n)\ _{15}P^{29}$

66. Which of the following nuclei is produced when a $_{92}U^{238}$ nucleus undergoes a $(d, 2n)$ reaction followed by a beta decay?
(a) $_{93}Np^{238}$ (b) $_{94}Pu^{239}$
(c) $_{94}Pu^{238}$ (d) $_{92}U^{238}$

67. Name the following nuclear reaction :
$$_{92}U^{238}\ (\alpha, 6p, 13n)\ _{88}Ra^{228}$$
(a) particle-particle reaction
(b) capture reaction
(c) fission reaction
(d) separation

68. In a nuclear fission :
(i) in elements of high atomic mass number, energy is released.
(ii) linear momentum and total energy are conserved, but not angular momentum.
(iii) linear momentum, angular momentum and total energy are conserved.
(iv) the probability of neutron being absorbed by a fissionable nucleus, increases when the neutrons are slowed down.
(a) (i), (ii) and (iii) are correct
(b) (i), (iii) and (iv) are correct
(c) (ii), (iii) and (iv) are correct
(d) (ii) and (iv) are correct

69. If $_{92}U^{235}$ reactor takes 30 days to consume 4 kg of fuel and each fission gives 185 MeV of usable energy then the power output is :
(a) 2.75×10^{10} W (b) 0.012×10^{10} W
(c) 3.5×10^{10} W (d) 7.63×10^{10} W

70. What is the total energy released during a fission reaction

$$_0^1n + {}_{92}^{235}U \longrightarrow {}_{92}^{236}U \longrightarrow {}_{40}^{98}Zr + {}_{52}^{136}Te + 2\,{}_0^1n$$

if the resulting fission fragments are unstable hence, decay into stable end products $_{42}^{98}M_0$ and $_{54}^{136}Xe$ by successive emission of β-particles? Take mass of neutron = 1.0087 amu, mass of $_{92}^{235}U = 236.0439$ amu, mass of $_{42}^{98}M_0 = 97.9054$ amu and mass of $_{54}^{136}Xe = 135.9170$ amu :
(a) 198 MeV (b) 220 MeV
(c) 185 MeV (d) 230 MeV

71. According to drop model of nucleus which of the following cannot be explained?
(a) Fission (b) Fusion
(c) α-spectrum (d) All of these

72. It is proposed to use the nuclear reaction

$$_1^2H + {}_1^2H \longrightarrow {}_2^4He$$

The energy released in this reaction is :
(a) 23.834 MeV
(b) 200 MeV
(c) 931 MeV
(d) none of these

73. In a fusion process, a proton and a neutron combine to give a deuterium nucleus. If m_n and m_p be the masses of neutron and proton respectively, the mass of deuterium nucleus is :
(a) equal to $m_n + m_p$
(b) more than $m_n + m_p$
(c) less than $m_n + m_p$
(d) can be less than or more than $(m_n + m_p)$

74. Fission of a heavy nucleus can be performed by :
(a) neutron (b) proton
(c) α^{2+}-particle (d) photon of X-ray
(e) all of the above

75. The energy released per nucleon of the reactant, in the thermonuclear reaction is

$$3\,{}_1H^2 \longrightarrow {}_2He^4 + {}_1H^1 + {}_0n^1 + 21.6 \text{ MeV}$$

(a) 21.6 MeV (b) 7.2 MeV
(c) 3.6 MeV (d) 1.8 MeV

Answers

Level-1

1. (b)	2. (c)	3. (b)	4. (b)	5. (c)	6. (c)	7. (c)	8. (b)	9. (d)	10. (a)
11. (c)	12. (b)	13. (c)	14. (a)	15. (c)	16. (d)	17. (d)	18. (c)	19. (b)	20. (d)
21. (b)	22. (b)	23. (d)							

Level-2

1. (a)	2. (c)	3. (c)	4. (a)	5. (c)	6. (a)	7. (b)	8. (d)	9. (d)	10. (a)
11. (d)	12. (d)	13. (b)	14. (a)	15. (c)	16. (c)	17. (c)	18. (c)	19. (c)	20. (b)
21. (c)	22. (d)	23. (c)	24. (c)	25. (c)	26. (a)	27. (b)	28. (a)	29. (c)	30. (c)
31. (d)	32. (b)	33. (b)	34. (c)	35. (a)	36. (c)	37. (a)	38. (a)	39. (b)	40. (a)
41. (d)	42. (c)	43. (d)	44. (b)	45. (b)	46. (d)	47. (c)	48. (c)	49. (d)	50. (c)
51. (b)	52. (a)	53. (b)	54. (b)	55. (d)	56. (c)	57. (d)	58. (b)	59. (c)	60. (d)
61. (c)	62. (c)	63. (a)	64. (c)	65. (a)	66. (c)	67. (d)	68. (b)	69. (b)	70. (a)
71. (c)	72. (a)	73. (c)	74. (e)	75. (c)					

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Semi-conductor Devices

Syllabus: Energy bands in solids, conductors, insulators and semi-conductors, p-n junction, diodes as rectifier, junction transistor, transistor as an amplifier.

Review of Concepts

1. Pure or Intrinsic Semi-conductor: Generally, the elements of fourth group behave as semi-conductors. *e.g.*, silicon, germanium.

(a) The resistivity of semi-conductor decreases with increase of temperature.

(b) At 0 K, conduction band is completely vacant and semi-conductor behaves as insulator.

(c) A pure semi-conductor has negative temperature coefficient.

(d) In the case of pure semi-conductor, number of conduction electrons = number of holes.

(e) Electric current is

$$I = I_e + I_h$$

Here, I_e = current due to conduction electrons, I_h = hole current

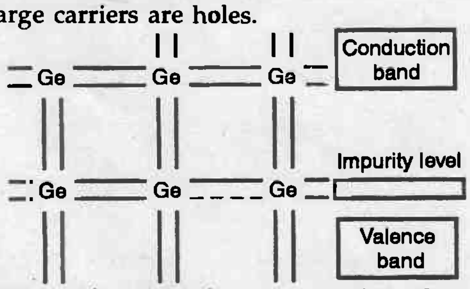
(f) Pure semi-conductor is also known as intrinsic semi-conductor.

2. Impure or Extrinsic Semi-conductor: If impurity is added to intrinsic semi-conductor, then the semi-conductor is known as extrinsic semi-conductor.

The process of adding impurity to semi-conductor, is known as doping.

(a) **For *p*-type semi-conductor:** If trivalent elements (*e.g.*, indium, gallium, thallium etc.) are doped to semi-conductor, the resultant semi-conductor, is known as *p*-type semi-conductor.

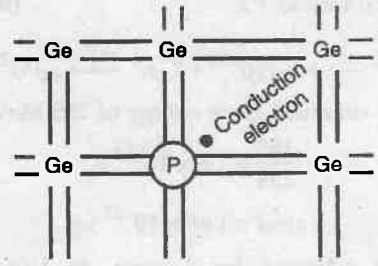
(i) In the case of *p*-type semi-conductor, majority charge carriers are holes.



(ii) The impurity atoms in *p*-type semi-conductor are known as acceptor atoms.

(b) **For *n*-type semi-conductor:** If pentavalent element (*e.g.*, phosphorus) is added to semi-conductor as impurity, the resultant semi-conductor is known as *n*-type semi-conductor.

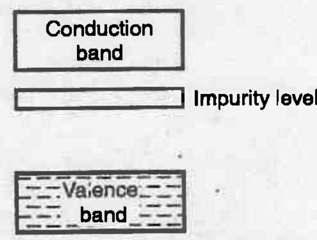
(i) The impurity atoms in *n*-type semi-conductor are known as donor atoms.



(ii) In the case of *n*-type semi-conductor, majority charge carriers are electrons.

(iii) The conductivity of semi-conductor is

$$\sigma = n_e e\, \mu_e + n_h e\, \mu_n$$



Here, n_e = density of conduction electrons

n_h = density of holes

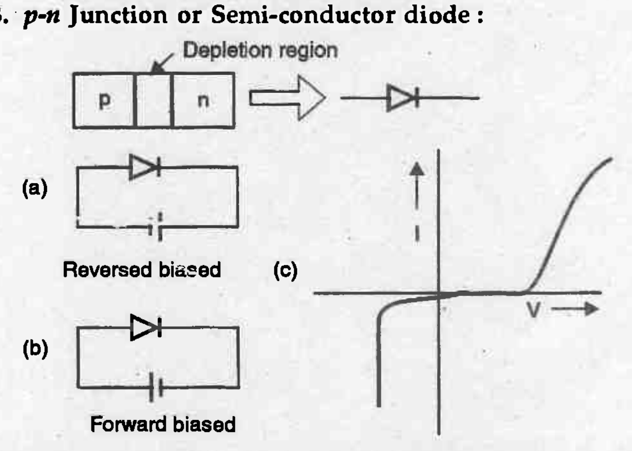
μ_e = mobility of electron

(iv) The number of hole-electron pairs is proportional to $T^{3/2}\, e^{-\Delta E/2kT}$

Here, ΔE = energy gap

T = temperature in kelvin

3. *p-n* Junction or Semi-conductor diode:



(d) For ideal diode, the resistance in forward biased connection is zero.

(e) For ideal diode, the resistance in reversed biased connection is infinite.

(f) In the case of ideal diode, drift current is zero.

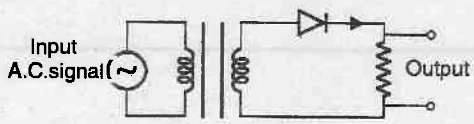
(g) If no voltage is applied to diode, drift current and diffusion current are same in magnitude.

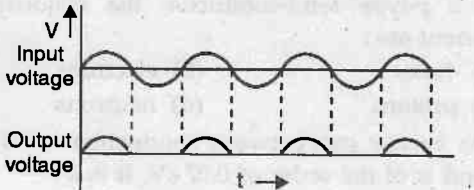
(h) The drift current and diffusion current are always opposite to each other.

(i) *p-n* junction does not obey Ohm's law.

4. *p-n* Junction as a Rectifier : A rectifier circuit converts A.C. into D.C.

(a) Half wave rectifier circuit :





(i) $I = \dfrac{V_0 \sin(\omega t + \phi)}{R_L + R_F}$

where R_F is forward resistance of junction.

In forward biasing, $R_F <<< R_L$

$$\therefore \quad I = \frac{V_0 \sin(\omega t + \phi)}{R_L}$$

(ii) Currents $I_{dc} = \dfrac{I_0}{\pi}$, $I_{rms} = \dfrac{I_0}{\sqrt{2}}$

(iii) Power $P_{dc} = I_{dc}^2 R_L$

$P_{ac} = I_{rms}^2 (R_L + R_F)$

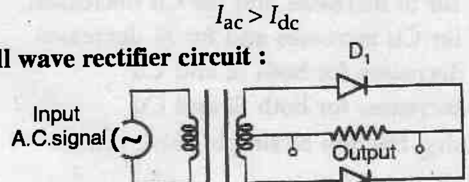
(iv) Efficiency of rectification

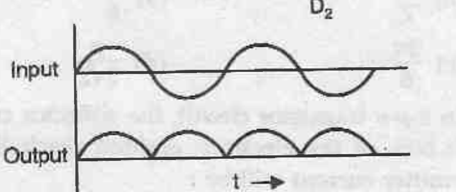
$$\eta_R = \frac{P_{dc}}{P_{ac}} \times 100\% = \frac{40.6\%}{\left(1 + \dfrac{R_F}{R_L}\right)}$$

(v) Ripple factor $r = \dfrac{I_{ac}}{I_{dc}} = 1.21$

$I_{ac} > I_{dc}$

(b) Full wave rectifier circuit :





(i) $I = \dfrac{V_0 \sin(\omega t + \phi)}{R_L + R_F}$

where R_F is the forward resistance of junction.

In forward biasing, $R_F <<< R_L$

$$\therefore \quad I = \frac{V_0 \sin(\omega t + \phi)}{R_L}$$

(ii) Currents $I_{dc} = \dfrac{2I_0}{\pi}$ and $I_{rms} = \dfrac{I_0}{\sqrt{2}}$

(iii) Power $P_{dc} = I_{dc}^2 R_L$

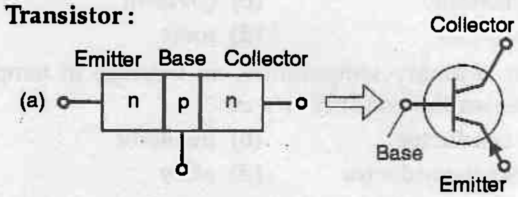
(iv) Efficiency of rectification

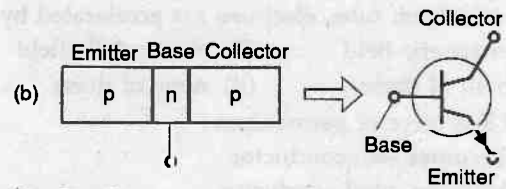
$$\eta_R = \frac{P_{dc}}{P_{ac}} \times 100\% = \frac{81.2}{\left(1 + \dfrac{R_F}{R_L}\right)} \%$$

(v) Ripple factor $r = \dfrac{I_{ac}}{I_{dc}} = 0.482$

$I_{ac} < I_{dc}$

5. Transistor :





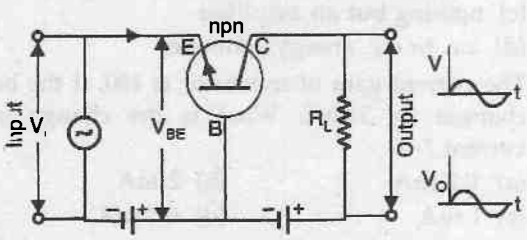
(c) $I_E = I_B + I_C$

(d) $\alpha = \dfrac{I_C}{I_E} = \dfrac{\Delta I_C}{\Delta I_E} < 1$ (common base configuration)

(e) $\beta = \dfrac{I_C}{I_B} = \dfrac{\Delta I_C}{\Delta I_B} > 1$ (common emitter configuration)

(f) $\beta = \dfrac{\alpha}{1-\alpha}$ or $\alpha = \dfrac{\beta}{\beta + 1}$

6. Common Base Transistor Amplifier : *npn* transistor used as amplifier in *CB* mode is shown below :



***npn* transistor used as amplifier in *CB* mode**

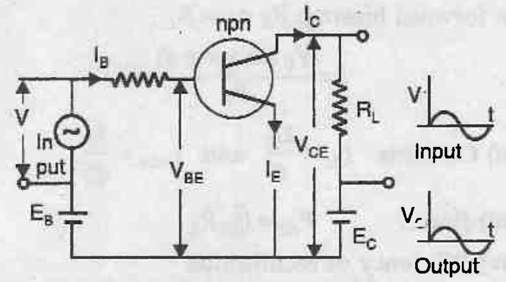
(a) Current gain $\alpha = \left(\dfrac{\Delta I_C}{\Delta I_E}\right)_{V_{CB}}$ = constant

(b) Voltage gain $A_V = \dfrac{\Delta V_{out}}{\Delta V_{in}} = \dfrac{R}{R_{in}} \times \alpha$

(c) Power gain $A_P = \alpha \times \dfrac{\alpha R}{R_{in}}$

$= \alpha^2 \dfrac{R}{R_{in}}$

7. Common Emitter Transistor Amplifier :



npn transistor used as amplifier in CE mode

(a) Current gain $\beta = \left(\frac{\Delta I_C}{\Delta I_B}\right)_{V_{CE}}$ = constant

(b) Voltage gain $A_V = \frac{\Delta V_{out}}{\Delta V_{in}} = \beta \frac{R}{R_{in}}$

(c) Power gain $A_P = \beta \times \beta \frac{R}{R_{in}}$

$= \beta^2 \frac{R}{R_{in}}$

Objective Questions

Level-1

1. The nature of binding for a crystal with alternate and evenly spaced positive and negative ions is :
(a) metallic (b) covalent
(c) dipolar (d) ionic

2. After ordinary temperature, an increase in temperature increases the conductivity of :
(a) conductor (b) insulator
(c) semi-conductor (d) alloy

3. In a television tube, electrons are accelerated by :
(a) magnetic field (b) electrostatic field
(c) both of these (d) none of these

4. At 0 K a piece of germanium :
(a) becomes semiconductor
(b) becomes good conductor
(c) becomes bad conductor
(d) has maximum conductivity

5. Solid CO_2 form :
(a) ionic bond (b) van der Waal's bond
(c) chemical bond (d) covalent bond

6. An electronic oscillator is :
(a) just like an alternator
(b) an amplifier with feedback
(c) nothing but an amplifier
(d) a.c. to d.c. energy converter

7. The current gain of transistor is 100, if the base current changes by 10 μA. What is the change in collector current ?
(a) 0.2 mA (b) 2 mA
(c) 1 mA (d) 0.5 mA

8. With the increase in temperature, the width of the forbidden gap will :
(a) decrease (b) increase
(c) remain same (d) become zero

9. The impurity added in germanium crystal to make n-type semi-conductor is :
(a) aluminium
(b) gallium
(c) iridium
(d) phosphorus

10. In a p-type semi-conductor, the majority carriers of current are :
(a) holes (b) electrons
(c) protons (d) neutrons

11. The energy gap between conduction band and valence band is of the order of 0.07 eV. It is a :
(a) insulator (b) conductor
(c) semiconductor (d) alloy

12. In a common emitter amplifier, input resistance is 3 Ω and load resistance 24 Ω. What is the voltage gain ? (take $\alpha = 0.6$)
(a) 8.4 (b) 4.8
(c) 2.4 (d) 1.2

13. Potential barrier developed in a junction diode opposes :
(a) minority carries in both region only
(b) majority carriers only
(c) electrons in n-region
(d) holes in p-region

14. Depletion layer consists of :
(a) electrons
(b) protons
(c) mobile ions
(d) immobile ions

15. Si and Cu are cooled to a temperature of 300 K, then resistivity :
(a) for Si increases and for Cu decreases
(b) for Cu increases and for Si decreases
(c) decreases for both Si and Cu
(d) increases for both Si and Cu

16. Packing fraction of simple cubic cell is :
(a) $\frac{\pi}{2}$ (b) $\frac{\pi}{6}$
(c) $\frac{3\pi}{6}$ (d) $\frac{\pi}{2\sqrt{2}}$

17. In n-p-n transistor circuit, the collector current is 20 mA. If 80% of the electrons emitted reach the collector, the emitter current will be :
(a) 9 mA (b) 11 mA
(c) 12.5 mA (d) 0.1 mA

Level-2

1. A n-type semi-conductor has impurity level 20 meV below the conduction band. In a thermal collision, transferrable energy is kT. The value of T for which electrons start to jump in conduction band is :
(a) 232 K (b) 348 K
(c) 400 K (d) none of these

2. The band gap for a pure semi-conductor is 2.1 eV. The maximum wavelength of a photon which is able to create a hole- electron pair is :
(a) 600 nm (b) 589 nm
(c) 400 nm (d) none of these

3. Assume that the number of hole-electron pair in an intrinsic semi-conductor is proportional to $e^{-\Delta E/2kT}$.
Here, ΔE = energy gap
and $k = 8.62 \times 10^{-5}$ eV/kelvin
The energy gap for silicon is 1.1 eV. The ratio of electron-hole pairs at 300 K and 400 K is :
(a) $e^{-5.31}$ (b) e^{-5}
(c) e (d) none of these

4. Electronic current is in
(a) conduction band (b) valence band
(c) either of the two (d) none of these

5. Semi-conductors are formed if the bonds are
(a) van der Waals (b) ionic
(c) metallic (d) covalent

6. Semi-conductor devices are
(a) temperature dependent
(b) current dependent
(c) voltage dependent
(d) none of the above

7. Which one of the following is not the advantage of semi-conductor device in the electron tubes ?
(a) Unlimited life
(b) Greater efficiency
(c) No-warming up time for switching
(d) Low consumption of power for cathode heating

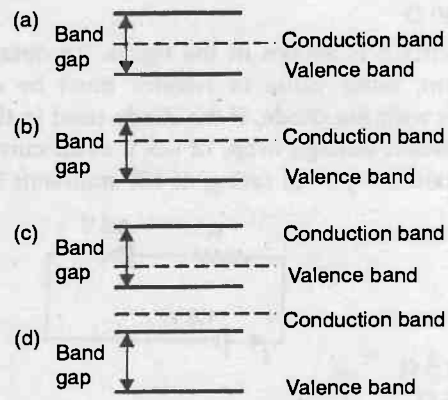
8. If μ_e and μ_h are electron and hole mobility, E be the applied electric field, the current density J for intrinsic semi-conductor is equal to
(a) $n_i e (\mu_e + \mu_h) E$ (b) $n_i e (\mu_n - \mu_h) E$
(c) $\frac{n_i e (\mu_e + \mu_h)}{E}$ (d) $\frac{E}{n_i e (\mu_e + \mu_h)}$

9. If the resistivity of copper is 1.7×10^{-6} Ω cm, then the mobility of electrons in copper, if each atom of copper contributes one free electron for conduction, is [The atomic weight of copper is 63.54 and its density is 8.96 g/cc] :
(a) 23.36 cm²/Vs (b) 503.03 cm²/Vs
(c) 43.25 cm²/Vs (d) 88.0 cm²/Vs

10. A pure silicon crystal of length l (0.1 m) and area A (10^{-4} m²) has the mobility of electron (μ_e) and holes (μ_h) as 0.135 m²/Vs and 0.048 m²/Vs, respectively. If the voltage applied across it is 2 V and the intrinsic charge concentration is $n_i = 1.5 \times 10^6$ m^{-3}, then the total current flowing through the crystal is :
(a) 8.78×10^{-17} A (b) 6.25×10^{-17} A
(c) 7.98×10^{-17} A (d) 2.456×10^{-17} A

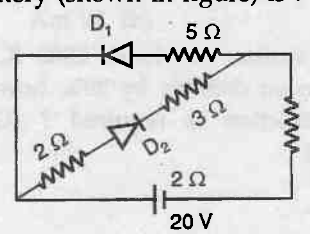
11. In a semi-conductor diode, the barrier potential offers opposition to only
(a) majority carrier in both regions
(b) minority carrier in both regions
(c) free electrons in the n-region
(d) holes in the p-region

12. Which one of the following diagrams correctly represents the energy levels in the p-type semi-conductor?



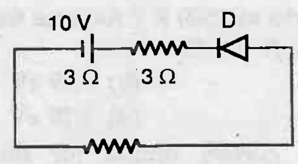
13. A potential barrier of 0.4 V exists across a p-n junction. A constant electric field of magnitude 10^6 V/m exists in the depletion region. The width of depletion region is :
(a) 4×10^{-7} m (b) 0.1 mm
(c) 5×10^{-7} m (d) none of these

14. In the given circuit all diodes are ideal. The current through battery (shown in figure) is :



(a) 2 A (b) 1 A
(c) 3 A (d) none of these

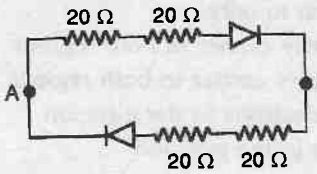
15. In the given circuit, diode D is ideal.
The potential difference across 4 Ω resistance is :



(a) 10 V (b) 5 V
(c) 4 V (d) none of these

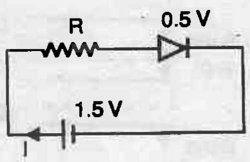
16. In previous problem, assume that diode is not ideal. The drift current for diode is 40 μA. The potential difference across the 4 Ω resistance is :
(a) 10 V
(b) 40×10^{-6} V
(c) 160×10^{-6} V
(d) none of these

17. In the given circuit, diodes are ideal.
The equivalent resistance between points *A* and *B* is :



(a) 20 Ω
(b) 10 Ω
(c) infinity
(d) 40 Ω

18. The circuit is shown in the figure. To obtain maximum current, what value of resistor must be connected in series with the diode, if the diode used in the circuit has a constant voltage drop, of 0.5 V at all currents and has a maximum power rating of 100 milliwatt ?



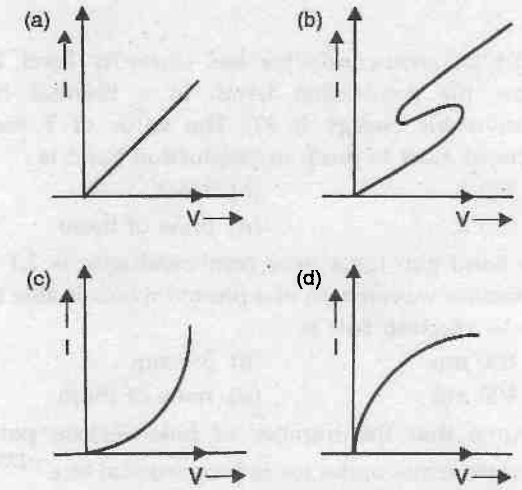
(a) 1.5 Ω
(b) 5 Ω
(c) 6.67 Ω
(d) 200 Ω

19. What is the plate current in a diode valve under the space charge limited operation, when the plate potential is 60 V ? In a diode valve, the plate current is 320 mA, when the plate potential is 240 volts :
(a) 30 mA (b) 20 mA
(c) 40 mA (d) 10 mA

20. A tungsten emitter works at 2500 K. To increase the emission current densitiy by 20%, how much change in the work function is required ? (Given: $\log 2 = 0.3$, $\log 3 = 0.477$)
(a) 0.016 eV
(b) 0.039 eV
(c) 2.54 eV
(d) 0.254 eV

21. What is the work function of tungsten at 1500 K temperature, when a diode valve with a tungsten filament works at 1500 K ? Assume the work function of tungsten at 0 K is 4.52 eV :
(a) 4.71 eV (b) 0.39 eV
(c) 8.86 eV (d) 1.25 eV

22. Choose the correct option for the forward biased characteristics of a *p-n* junction :



23. In a *p-n* junction diode, holes diffuse from the *p*-region to the *n*-region because :
(a) the free electrons in the *n*-region attract them
(b) they are swept across the junction by the potential difference
(c) there is greater concentration of holes in the *p*-region as compared to *n*-region
(d) none of the above

24. When we apply reverse bias to a junction diode, it :
(a) lowers the potential barrier
(b) raises the potential barrier
(c) greatly increases the minority carrier current
(d) greatly increases the majority carrier current

25. In case of *p-n* junction diode at high value of reverse bias, current rises sharply. The value of reverse bias is called :
(a) cut off voltage (b) inverse voltage
(c) zener voltage (d) critical voltage

26. A *p-n* diode is reverse biased. The resistance measured by an ohmmeter connected across it will be :
(a) zero (b) low
(c) high (d) infinite

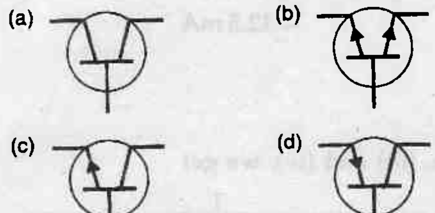
27. The depletion layer in a *p-n* junction diode consists of layer of :
(a) positively charged donors on the *p*-side and negatively charged acceptors on the *n*-side
(b) negatively charged donors on the *p*-side and positively charged acceptors on the *n*-side
(c) positively charged donors on the *n*-side and negatively charged acceptors on the *p*-side
(d) negatively charged donors on the *n*-side and positively charged acceptors on the *p*-side

28. A transistor operating in a common base configuration has forward current gain factor, $\alpha = 0.99$. If the emitter current changes by 1 mA, then the changes in the base current will be :
(a) 100 mA
(b) 0.01 mA
(c) 0.99 mA
(d) 99 mA

29. If both the collector and emitter junctions of a transistor are forward biased, the transistor is said to operate in the :
(a) active region (b) saturation region
(c) cut off region (d) none of these

30. In the active region operation of a transistor :
(a) the collector-emitter junction is forward biased
(b) the collector-emitter junction is reverse biased
(c) the collector-base junction is forward biased and the emitter junction is reverse biased
(d) the collector junction is reverse biased and emitter-base junction is forward biased

31. Choose the correct option for *n-p-n* transistor :



32. If the ratio of change in current in emitter and corresponding change in current in collector is 1.013, then the value of α is :
(a) 0.987 (b) 0.100
(c) 0.900 (d) none of these

33. In previous problem, the value of β is :
(a) 75.92 (b) 76.92
(c) 78.32 (d) 0.987

34. A signal of 20 mV is applied to common emitter transistor amplifier circuit. Due to this, the change in base current and the change in collector current are 20 μA and 2 mA. The load resistance is 10 kΩ. The voltage gain is :
(a) 20 V (b) 10 V
(c) 50 V (d) none of these

35. In previous problem, transconductance is
(a) $0.1\ \Omega^{-1}$
(b) $0.2\ \Omega^{-1}$
(c) $10\ \Omega^{-1}$
(d) none of these

36. In previous problem, input resistance is
(a) 10 Ω (b) 0.1 kΩ
(c) 2 kΩ (d) none of these

37. What is the current gain for a transistor used as common emitter amplifier, if the current gain of the common base *n-p-n* transistor is 0.96?
(a) 16 (b) 24
(c) 20 (d) 32

38. The input resistance of a common emitter transistor amplifier, if the output resistance is 500 kΩ, the current gain $\alpha = 0.98$ and the power gain is 6.0625×10^6, is :
(a) 198 Ω (b) 300 Ω
(c) 100 Ω (d) 400 Ω

39. The plate resistance, if for 5 kΩ of load the value of voltage gain of an amplifier be 1/3 of the amplification factor, is :
(a) 12 kΩ (b) 10 kΩ
(c) 15 kΩ (d) 5 kΩ

40. In the operation of *n-p-n* transistor compared to that of a triode, the *p* base acts as :
(a) emitter (b) cathode
(c) grid (d) plate

41. A transistor, when connected in common emitter mode, has a :
(a) high input resistance and a low output resistance
(b) medium input resistance and high output resistance
(c) very low input resistance and a low output resistance
(d) high input resistance and a high output resistance

Answers

Level-1

1. (d)	**2.** (c)	**3.** (b)	**4.** (c)	**5.** (c)	**6.** (b)	**7.** (c)	**8.** (a)	**9.** (d)	**10.** (a)
11. (c)	**12.** (b)	**13.** (b)	**14.** (d)	**15.** (a)	**16.** (d)	**17.** (c)			

Level-2

1. (a)	**2.** (b)	**3.** (a)	**4.** (a)	**5.** (d)	**6.** (a)	**7.** (a)	**8.** (a)	**9.** (c)	**10.** (a)
11. (a)	**12.** (c)	**13.** (a)	**14.** (a)	**15.** (a)	**16.** (c)	**17.** (d)	**18.** (b)	**19.** (c)	**20.** (b)
21. (a)	**22.** (c)	**23.** (a)	**24.** (b)	**25.** (c)	**26.** (c)	**27.** (c)	**28.** (b)	**29.** (a)	**30.** (a)
31. (c)	**32.** (a)	**33.** (a)	**34.** (a)	**35.** (a)	**36.** (b)	**37.** (b)	**38.** (a)	**39.** (b)	**40.** (c)
41. (c)									

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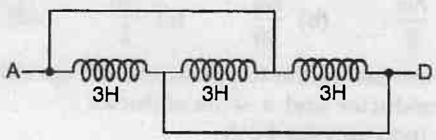
PHYSICS

1. The inductance between A and D is :



(a) 3.66 H (b) 9 H
(c) 0.66 H (d) 1 H

2. A ball whose kinetic energy is E, is projected at an angle of 45° to the horizontal. The kinetic energy of the ball at the highest point of its flight will be :
(a) E (b) $E/\sqrt{2}$ (c) $E/2$ (d) zero

3. From a building two balls A and B are thrown such that A is thrown upwards and B downwards (both vertically). If v_A and v_B are their respective velocities on reaching the ground, then
(a) $v_B > v_A$
(b) $v_A = v_B$
(c) $v_A > v_B$
(d) their velocities depends on their masses

4. If a body loses half of its velocity on penetrating 3 cm in a wooden block, then how much will it penetrate more before coming to rest ?
(a) 1 cm (b) 2 cm (c) 3 cm (d) 4 cm

5. If suddenly the gravitational force of attraction between earth and a satellite revolving around it becomes zero, then the satellite will :
(a) continue to move in its orbit with same velocity
(b) move tangentially to the original orbit with the same velocity
(c) become stationary in its orbit
(d) move towards the earth

6. If an ammeter is to be used in place of a voltmeter, then we must connect with the ammeter a :
(a) low resistance in parallel
(b) high resistance in parallel
(c) high resistance in series
(d) low resistance in series

7. If in a circular coil A of radius R, current i is flowing and in another coil B of radius $2R$ a current $2i$ is flowing, then the ratio of the magnetic fields, B_A and B_B produced by them will be :
(a) 1 (b) 2
(c) $\frac{1}{2}$ (d) 4

8. If two mirrors are kept at 60° to each other, then the number of images formed by them is :
(a) 5 (b) 6
(c) 7 (d) 8

9. A wire when connected to 220 V mains supply has power dissipation P_1. Now the wire is cut into two equal pieces which are connected in parallel to the same supply. Power dissipation in this case is P_2. Then $P_2 : P_1$ is
(a) 1 (b) 4
(c) 2 (d) 3

10. If 13.6 eV energy is required to ionize the hydrogen atom, then the energy required to remove an electron from $n = 2$ is :
(a) 10.2 eV (b) 0 eV
(c) 3.4 eV (d) 6.8 eV

11. Tube A has both ends open while tube B has one end closed, otherwise they are identical. The ratio of fundamental frequency of tubes A and B is :
(a) 1 : 2 (b) 1 : 4
(c) 2 : 1 (d) 4 : 1

12. A tuning fork arrangement (pair) produces 4 beats/sec with one fork of frequency 288 cps. A little wax is placed on the unknown fork and it then produces 2 beats/sec. The frequency of the unknown fork is :
(a) 286 cps (b) 292 cps
(c) 294 cps (d) 288 cps

13. A wave $y = a \sin(\omega t - kx)$ on a string meets with another wave producing a node at $x = 0$. Then the equation of the unknown wave is :
(a) $y = a \sin(\omega t + kx)$ (b) $y = -a \sin(\omega t + kx)$
(c) $y = a \sin(\omega t - kx)$ (d) $y = -a \sin(\omega t - kx)$

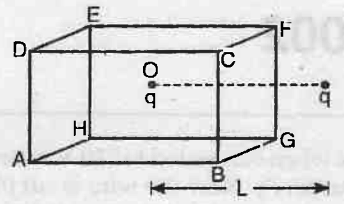
14. On moving a charge of 20 coulombs by 2 cm, 2 J of work is done, then the potential difference between the points is :
(a) 0.1 V (b) 8 V
(c) 2 V (d) 0.5 V

15. If an electron and a proton having same momenta enter perpendicularly to a magnetic field, then :
(a) curved path of electron and proton will be same (ignoring the sense of revolution)
(b) they will move undeflected
(c) curved path of electron is more curved than that of proton
(d) path of proton is more curved

16. Energy required to move a body of mass m from an orbit of radius $2R$ to $3R$ is :
(a) $GMm/12R^2$ (b) $GMm/3R^2$
(c) $GMm/8R$ (d) $GMm/6R$

17. If a spring has time period T, and is cut into n equal parts, then the time period of each part will be :
(a) $T\sqrt{n}$ (b) $T/\sqrt{n}$
(c) nT (d) T

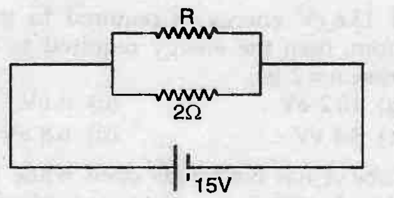
18. A charged particle q is placed at the centre O of cube of length L ($ABCDEFGH$). Another same charge q is placed at a distance L from O. Then the electrons flux through $ABCD$ is :



(a) $q/4\pi\varepsilon_0 L$ (b) zero
(c) $q/2\pi\varepsilon_0 L$ (d) $q/3\pi\varepsilon_0 L$

19. If in the circuit, power dissipation is 150 W, then R is :

(a) $2\,\Omega$
(b) $6\,\Omega$
(c) $5\,\Omega$
(d) $4\,\Omega$



20. Wavelength of light used in an optical instrument are $\lambda_1 = 4000$ Å and $\lambda_2 = 5000$ Å, then ratio of their respective resolving powers (corresponding to λ_1 and λ_2) is :
(a) 16 : 25 (b) 9 : 1 (c) 4 : 5 (d) 5 : 4

21. Two identical particles move towards each othe. with velocity $2v$ and v respectively. The velocity of centre of mass is
(a) v (b) $v/3$ (c) $v/2$ (d) zero

22. If a current is passed through a spring then the spring will :
(a) expand (b) compress
(c) remain same (d) none of these

23. Heat given to a body which raises its temperature by 1°C is :
(a) water equivalent (b) thermal capacity
(c) specific heat (d) temperature gradient

24. At absolute zero, Si acts as :
(a) non-metal (b) metal
(c) insulator (d) none of these

25. Electromagnetic waves are transverse in nature is evident by :
(a) polarization (b) interference
(c) reflection (d) diffraction

26. Which of the following is used in optical fibres ?
(a) Total internal reflection (b) Scattering
(c) Diffraction (d) Refraction

27. The escape velocity of a body depends upon mass as :
(a) m^0 (b) m^1 (c) m^2 (d) m^3

28. Which of the following are not electro- magnetic waves ?
(a) Cosmic-rays (b) γ-rays
(c) β-rays (d) X-rays

29. Identify the pair whose dimensions are equal :
(a) torque and work (b) stress and energy
(c) force and stress (d) force and work

30. If θ_i is the inversion temperature, θ_n is the neutral temperature, θ_c is the temperature of the cold junction then :
(a) $\theta_i + \theta_c = \theta_n$ (b) $\theta_i - \theta_c = 2\theta_n$
(c) $\dfrac{\theta_i + \theta_c}{2} = \theta_n$ (d) $\theta_c - \theta_i = 2\theta_n$

31. Infrared radiations are detected by :
(a) spectrometer (b) pyrometer
(c) nanometer (d) photometer

32. If N_0 is the original mass of the substance of half-life period $t_{1/2} = 5$ years, then the amount of substance left after 15 years is :
(a) $\dfrac{N_0}{8}$ (b) $\dfrac{N_0}{16}$ (c) $\dfrac{N_0}{2}$ (d) $\dfrac{N_0}{4}$

33. By increasing the temperature, the specific resistance of a conductor and a semiconductor :
(a) increases for both
(b) decreases for both
(c) increases, decreases respectively
(d) decreases, increases respectively

34. If there are n capacitors in parallel connected to V volt source, then the energy stored is equal to :
(a) CV (b) $\dfrac{1}{2}nCV^2$ (c) CV^2 (d) $\dfrac{1}{2n}CV^2$

35. Which of the following is more close to a black body ?
(a) Black board paint (b) Green leaves
(c) Black holes (d) Red roses

36. Which statement is incorrect ?
(a) All reversible cycles have same efficiency
(b) Reversible cycle has more efficiency than an irreversible one
(c) Carnot cycle is a reversible one
(d) Carnot cycle has the maximum efficiency in all cycles

37. Length of a string tied to two rigid supports is 40 cm. Maximum length (wavelength in cm) of a stationary wave produced on it, is :
(a) 20 (b) 80 (c) 40 (d) 120

38. The power factor of an A.C. circuit having resistance R and inductance L (connected in series) and an angular velocity ω is :
(a) $\dfrac{R}{\omega L}$ (b) $\dfrac{R}{(R^2 + \omega^2 L^2)^{1/2}}$
(c) $\dfrac{\omega L}{R}$ (d) $\dfrac{R}{(R^2 - \omega^2 L^2)^{1/2}}$

39. An astronomical telescope has a large aperture to :
(a) reduce spherical aberration
(b) have high resolution
(c) increase span of observation
(d) have low dispersion

40. The kinetic energy needed to project a body of mass m from the earth's surface (radius R) to infinity is :
(a) $mgR/2$ (b) $2mgR$ (c) mgR (d) $mgR/4$

41. Cooking gas containers are kept in a lorry moving with uniform speed. The temperature of the gas molecules inside will :
(a) increase
(b) decrease
(c) remain same
(d) decrease for some, while increase for others

42. When temperature increases, the frequency of a tuning fork :
(a) increases
(b) decreases
(c) remains same
(d) increases or decreases depending on the material

43. If mass-energy equivalence is taken into account, when water is cooled to form ice, the mass of water should :
(a) increase (b) remain unchanged
(c) decrease (d) first increase then decrease

44. The energy band gap is maximum in :
(a) metals (b) superconductors
(c) insulators (d) semiconductors

45. The part of a transistor which is most heavily doped to produce large number of majority carriers is :
(a) emitter
(b) base
(c) collector
(d) can be any of the above three

46. In a simple harmonic oscillator, at the mean position :
(a) kinetic energy is minimum, potential energy is maximum
(b) both kinetic and potential energies are maximum
(c) kinetic energy is maximum, potential energy is minimum
(d) both kinetic and potential energies are minimum

47. Initial angular velocity of a circular disc of mass M is ω_1. Then two small spheres of mass m are attached gently to two diametrically opposite points on the edge of the disc. What is the final angular velocity of the disc ?
(a) $\left(\frac{M+m}{M}\right)\omega_1$ (b) $\left(\frac{M+m}{m}\right)\omega_1$
(c) $\left(\frac{M}{M+4m}\right)\omega_1$ (d) $\left(\frac{M}{M+2m}\right)\omega_1$

48. The minimum velocity (in ms^{-1}) with which a car driver must traverse a flat curve of radius 150 m and coefficient of friction 0.6 to avoid skidding is :
(a) 60 (b) 30 (c) 15 (d) 25

49. A cylinder of height 20 m is completely filled with water. The velocity of efflux of water (in ms^{-1}) through a small hole on the side wall of the cylinder near its bottom, is :
(a) 10 (b) 20 (c) 25.5 (d) 5

50. A spring of force constant 800 N/m has an extension of 5 cm. The work done in extending it from 5 cm to 15 cm is :
(a) 16 J (b) 8 J (c) 32 J (d) 24 J

51. A child swinging on a swing in sitting position, stands up, then the time period of the swing will :
(a) increase
(b) decrease
(c) remain same
(d) increase if the child is long and decrease if the child is short

52. A lift is moving down with acceleration a. A man in the lift drops a ball inside the lift. The acceleration of the ball as observed by the man in the lift and a man standing stationary on the ground are respectively :
(a) g, g (b) $g-a, g-a$
(c) $g-a, g$ (d) a, g

53. The mass of a product liberated on anode in an electrochemical cell depends on :
(a) $(It)^{1/2}$ (b) It (c) I/t (d) I^2t
(where t is the time period for which the current is passed)

54. At what temperature is the rms velocity of a hydrogen molecule equal to that of an oxygen molecule at 47°C ?
(a) 80 K (b) –73 K
(c) 3 K (d) 20 K

55. The time period of a charged particle undergoing a circular motion in a uniform magnetic field is independent of its :
(a) speed (b) mass
(c) charge (d) magnetic induction

56. A solid sphere, a hollow sphere and a ring are released from top of an inclined plane (frictionless) so that they slide down the plane. Then maximum acceleration down the plane is for (no rolling) :
(a) solid sphere (b) hollow sphere
(c) ring (d) all same

57. In a transformer, number of turns in the primary are 140 and that in the secondary are 280. If current in primary is 4 A, then that in the secondary is :
(a) 4 A (b) 2 A
(c) 6 A (d) 10 A

58. Even Carnot engine cannot give 100% efficiency because we cannot :
(a) prevent radiation
(b) find ideal sources
(c) reach absolute zero temperature
(d) eliminate friction

59. Moment of inertia of a circular wire of mass M and radius R about its diameter is :
(a) $\frac{MR^2}{2}$ (b) MR^2 (c) $2MR^2$ (d) $\frac{MR^2}{4}$

60. When forces F_1, F_2, F_3 are acting on a particle of mass m such that F_2 and F_3 are mutually perpendicular, then the particle remains stationary. If the force F_1 is now removed then the acceleration of the particle is :
(a) F_1/m (b) F_2F_3/mF_1
(c) $(F_2-F_3)/m$ (d) F_2/m

61. Two forces are such that the sum of their magnitudes is 18 N and their resultant is perpendicular to the smaller force. Then the magnitudes of the forces are :
(a) 12 N, 6 N (b) 13 N, 5 N
(c) 10 N, 8 N (d) 16 N, 2 N

62. Speeds of two identical cars are u and $4u$ at a specific instant. The ratio of the respective distances at which the two cars are stopped from that instant is :
(a) 1 : 1 (b) 1 : 4 (c) 1 : 8 (d) 1 : 16

63. 1 mole of a gas with $\gamma = 7/5$ is mixed with 1 mole of a gas with $\gamma = 5/3$, then the value of γ for the resulting mixture is :
(a) 7/5 (b) 2/5
(c) 24/16 (d) 12/7

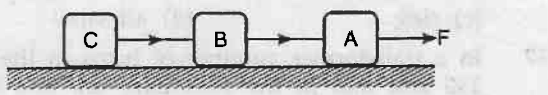
4. If a charge q is placed at the centre of the line joining two equal charges Q such that the system is in equilibrium then the value of q is :
(a) $Q/2$ (b) $-Q/2$ (c) $Q/4$ (d) $-Q/4$

65. Capacitance (in F) of a spherical conductor having radius 1 m, is :
(a) 1.1×10^{-10} (b) 10^{-6} (c) 9×10^{-9} (d) 10^{-3}

66. A light string passing over a smooth light pulley connects two blocks of masses m_1 and m_2 (vertically). If the acceleration of the system is $g/8$, then the ratio of the masses is :
(a) 8 : 1 (b) 9 : 7 (c) 4 : 3 (d) 5 : 3

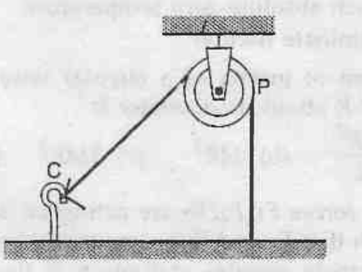
67. Two spheres of the same material have radii 1 m and 4 m and temperatures 4000 K and 2000 K respectively. The ratio of the energy radiated per second by the first sphere to that by the second is :
(a) 1 : 1 (b) 16 : 1 (c) 4 : 1 (d) 1 : 9

68. Three identical blocks of masses $m = 2$ kg are drawn by a force $F = 10.2$ N with an acceleration of 0.6 ms^{-2} on a frictionless surface, then what is the tension (in N) in the string between the blocks B and C ?



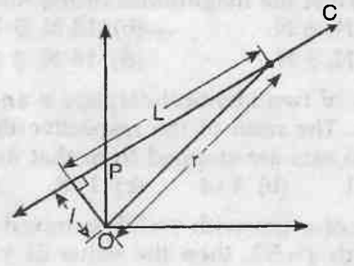
(a) 9.2 (b) 7.8 (c) 4 (d) 9.8

69. One end of massless rope, which passes over a massless and frictionless pulley P is tied to a hook C while the other end is free. Maximum tension that the rope can bear is 360 N. With what value of maximum safe acceleration (in ms^{-2}) can a man of 60 kg climb on the rope ?



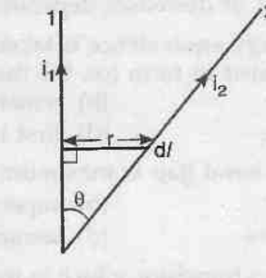
(a) 16 (b) 6
(c) 4 (d) 8

70. A particle of mass m moves along line PC with velocity v as shown. What is the angular momentum of the particle about P ?



(a) mvL (b) mvl
(c) mvr (d) zero

71. Wires 1 and 2 carrying currents i_1 and i_2 respectively are inclined at an angle θ to each other. What is the force on a small element dl of wire 2 at a distance r from wire 1 (as shown in figure) due to the magnetic field of wire 1 ?



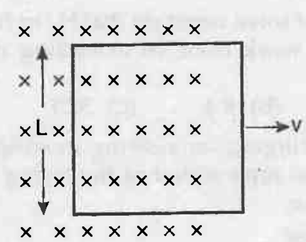
(a) $\frac{\mu_0}{2\pi r} i_1 i_2 \, dl \tan\theta$ (b) $\frac{\mu_0}{2\pi r} i_1 i_2 \, dl \sin\theta$
(c) $\frac{\mu_0}{2\pi r} i_1 i_2 \, dl \cos\theta$ (d) $\frac{\mu_0}{4\pi r} i_1 i_2 \, dl \sin\theta$

72. At a specific instant emission of radioactive compound is deflected in a magnetic field. The compound can emit :
(i) electrons (ii) protons
(iii) He^{2+} (iv) neutrons
The emission at the instant can be
(a) i, ii, iii (b) i, ii, iii, iv
(c) iv (d) ii, iii

73. Sodium and copper have work functions 2.3 eV and 4.5 eV respectively. Then the ratio of the wavelengths is nearest to :
(a) 1 : 2 (b) 4 : 1
(c) 2 : 1 (d) 1 : 4

74. Formation of covalent bonds in compounds exhibits :
(a) wave nature of electron
(b) particle nature of electron
(c) both wave and particle nature of electron
(d) none of these

75. A conducting square loop of side L and resistance R moves in its plane with a uniform velocity v perpendicular to one of its sides. A magnetic induction B constant in time and space, pointing perpendicular and into the plane at the loop exists everywhere with half the loop outside the field, as shown in figure. The induced emf is :



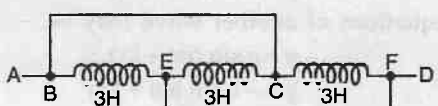
(a) zero (b) RvB
(c) $\frac{vBL}{R}$ (d) vBL

Answers

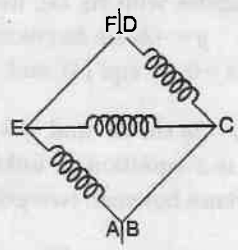
1.	(d)	2.	(c)	3.	(b)	4.	(a)	5.	(c)	6.	(c)	7.	(a)	8.	(a)
9.	(b)	10.	(c)	11.	(c)	12.	(b)	13.	(b)	14.	(a)	15.	(a)	16.	(d)
17.	(b)	18.	(b)	19.	(b)	20.	(d)	21.	(c)	22.	(b)	23.	(b)	24.	(c)
25.	(a)	26.	(a)	27.	(a)	28.	(c)	29.	(a)	30.	(c)	31.	(b)	32.	(a)
33.	(c)	34.	(b)	35.	(a)	36.	(a)	37.	(b)	38.	(b)	39.	(b)	40.	(c)
41.	(c)	42.	(b)	43.	(a)	44.	(c)	45.	(a)	46.	(c)	47.	(c)	48.	(b)
49.	(b)	50.	(b)	51.	(b)	52.	(c)	53.	(b)	54.	(d)	55.	(a)	56.	(d)
57.	(b)	58.	(c)	59.	(b)	60.	(a)	61.	(b)	62.	(b)	63.	(c)	64.	(d)
65.	(a)	66.	(b)	67.	(a)	68.	(b)	69.	(c)	70.	(d)	71.	(c)	72.	(a)
73.	(c)	74.	(a)	75.	(d)										

Hints & Solutions

1.



Here, inductors are in parallel



$$\therefore \quad \frac{1}{L} = \frac{1}{3} + \frac{1}{3} + \frac{1}{3}$$

$$L = 1$$

2. At the highest point of its flight, vertical component of velocity is zero and only horizontal component is left which is

$$u_x = u\cos\theta$$

Given : $\theta = 45°$

$$\therefore \quad u_x = u\cos 45° = \frac{u}{\sqrt{2}}$$

Hence, at the highest point kinetic energy

$$E' = \frac{1}{2}mu_x^2 = \frac{1}{2}m\left(\frac{u}{\sqrt{2}}\right)^2 = \frac{1}{2}m\left(\frac{u^2}{2}\right)$$

$$= \frac{E}{2} \qquad \left(\because \frac{1}{2}mu^2 = E\right)$$

3. From conservation of energy, potential energy at height h

$$= \text{K.E. at ground}$$

Therefore, at height h, P.E. of ball A

$$\text{P.E.} = m_A gh$$

$$\text{K.E. at ground} = \frac{1}{2}m_A v_A^2$$

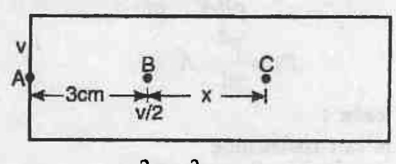
So, $$m_A gh = \frac{1}{2}m_A v_A^2$$

$$v_A = \sqrt{2gh}$$

Similarly, $$v_B = \sqrt{2gh}$$

Therefore, $$v_A = v_B$$

4. Let initial velocity of body at point A is v, AB is 3 cm.



From $$v^2 = u^2 - 2as$$

$$\left(\frac{v}{2}\right)^2 = v^2 - 2a \times 3$$

$$a = \frac{v^2}{8}$$

Let on penetrating 3 cm in a wooden block, the body moves x distance from B to C.

So, for B to C

$$u = \frac{v}{2}, \quad v = 0,$$

$$s = x, \quad a = \frac{v^2}{8} \qquad \text{(deceleration)}$$

$$\therefore \quad (0)^2 = \left(\frac{v}{2}\right)^2 - 2 \cdot \frac{v^2}{8} \cdot x$$

$$x = 1$$

5. When gravitational force becomes zero, then centripetal force on satellite becomes zero and therefore, the satellite will become stationary in its orbit.

6. A voltmeter is a high resistance device and is always connected in parallel with the circuit. While an ammeter is a low resistance device and is always connected in series with the circuit. So, to use voltmeter in place of ammeter a high resistance must be connected in series with the circuit.

7. Magnetic field in circular coil A is

Similarly $$B_A = \frac{\mu_0 Ni}{2R}$$

R is radius and i is current flowing in coil.

AIEEE

Solved Paper 2003

PHYSICS

1. A particle of mass M and charge Q moving with velocity $\vec{v}$ describes a circular path of radius R when subjected to a uniform transverse magnetic field of induction B. The work done by the field when the particle completes one full circle is :
(a) $\left(\frac{Mv^2}{R}\right)2\pi R$ (b) zero
(c) $BQ\,2\pi R$ (d) $BQv\,2\pi R$

2. A particle of charge -16×10^{-18} coulomb moving with velocity $10\ \text{ms}^{-1}$ along the x-axis enters a region where a magnetic field of induction B is along the y-axis and an electric field of magnitude 10^4 V/m is along the negative z-axis. If the charged particle continues moving along the x-axis, the magnitude of B is :
(a) $10^3\ \text{Wb/m}^2$ (b) $10^5\ \text{Wb/m}^2$
(c) $10^{16}\ \text{Wb/m}^2$ (d) $10^{-3}\ \text{Wb/m}^2$

3. A thin rectangular magnet suspended freely has a period of oscillation equal to T. Now it is broken into two equal halves (each having half of the original length) and one piece is made to oscillate freely in the same field. If its period of oscillation is T', the ratio T'/T is :
(a) $\frac{1}{2}\sqrt{2}$ (b) $\frac{1}{2}$
(c) 2 (d) $\frac{1}{4}$

4. 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 :
(a) $\sqrt{3}\,W$ (b) W
(c) $(\sqrt{3}/2)\,W$ (d) $2W$

5. The magnetic lines of force inside a bar magnet :
(a) are from north-pole to south-pole of the magnet
(b) do not exist
(c) depend upon the area of cross-section of the bar magnet
(d) are from south-pole to north-pole of the magnet

6. Curie temperature is the temperature above which :
(a) a ferromagnetic material becomes para- magnetic
(b) a paramagnetic material becomes diamagnetic
(c) a ferromagnetic material becomes diamagnetic
(d) a paramagnetic material becomes ferro- magnetic

7. A spring balance is attached to the ceiling of a lift. A man hangs his bag on the spring and the spring reads 49 N, when the lift is stationary. If the lift moves downward with an acceleration of $5\ \text{m/s}^2$, the reading of the spring balance will be :
(a) 24 N (b) 74 N (c) 15 N (d) 49 N

8. The length of a wire of a potentiometer is 100 cm, and the emf of its stand and cell is E volt. It is employed to measure the emf of a battery whose internal resistance is 0.5 Ω. If the balance point is obtained at $l = 30$ cm from the positive end, the emf of the battery is :
(a) $\frac{30E}{100.5}$
(b) $\frac{30E}{100-0.5}$
(c) $\frac{30(E-0.5i)}{100}$, where i is the current in the potentiometer wire
(d) $\frac{30E}{100}$

9. A strip of copper and another of germanium are cooled from room temperature to 80 K. The resistance of :
(a) each of these decreases
(b) copper strip increases and that of germanium decreases
(c) copper strip decreases and that of germanium increases
(d) each of these increases

10. Consider telecommunication through optical fibres. Which of the following statements is not true ?
(a) Optical fibres can be of graded refractive index
(b) Optical fibres are subjected to electro- magnetic interference from outside
(c) Optical fibres have extremely low transmission loss
(d) Optical fibres may have homogeneous core with a suitable cladding

11. The thermo-emf of a thermocouple is 25 μV/°C at room temperature. A galvanometer of 40 ohm resistance, capable of detecting current as low as 10^{-5} A, is connected with the thermocouple. The smallest temperature difference that can be detected by this system is :
(a) 16°C (b) 12°C
(c) 8°C (d) 20°C

12. The negative Zn pole of Daniell cell, sending a constant current through a circuit, decreases in mass by 0.13 g in 30 minutes. If the electrochemical equivalent of Zn and Cu are 32.5 and 31.5 respectively, the increase in the mass of the positive Cu pole in this time is :
(a) 0.180 g (b) 0.141 g
(c) 0.126 g (d) 0.242 g

13. Dimensions of $\frac{1}{\mu_0 \varepsilon_0}$, where symbols have their usual meaning, are :
(a) $[L^{-1}T]$ (b) $[L^2T^2]$
(c) $[L^2T^{-2}]$ (d) $[LT^{-1}]$

14. A circular disc X of radius R is made from an iron plate of thickness t, and another disc Y of radius $4R$ is made from an iron plate of thickness $t/4$. Then the relation between the moment of inertia I_X and I_Y is :

(a) $I_Y = 32I_X$ (b) $I_Y = 16I_X$
(c) $I_Y = I_X$ (d) $I_Y = 64I_X$

15. The time period of a satellite of earth is 5 hours. If the separation between the earth and the satellite is increased to 4 times the previous value, the new time period will become :

(a) 10 hour (b) 80 hour
(c) 40 hour (d) 20 hour

16. A particle performing uniform circular motion has angular momentum L. If its angular frequency is doubled and its kinetic energy halved, then the new angular momentum is :

(a) $L/4$ (b) $2L$ (c) $4L$ (d) $L/2$

17. Which of the following radiations has the least wavelength ?

(a) γ-rays (b) β-rays
(c) α-rays (d) X-rays

18. When U^{238} nucleus originally at rest, decays by emitting an alpha particle having a speed u, the recoil speed of the residual nucleus is :

(a) $\dfrac{4u}{238}$ (b) $-\dfrac{4u}{234}$
(c) $\dfrac{4u}{234}$ (d) $-\dfrac{4u}{238}$

19. Two spherical bodies of mass M and $5M$ and radii R and $2R$ respectively are released in free space with initial separation between their centres equal to $12R$. If they attract each other due to gravitational force only, then the distance covered by the smaller body just before collision is :

(a) $2.5R$ (b) $4.5R$
(c) $7.5R$ (d) $1.5R$

20. The difference in the variation of resistance with temperature in a metal and a semiconductor arises essentially due to the difference in the :

(a) crystal structure
(b) variation of the number of charge carriers with temperature
(c) type of bonding
(d) variation of scattering mechanism with temperature

21. A car moving with a speed of 50 km/hr, can be stopped by brakes after at least 6 m. If the same car is moving at a speed of 100 km/hr, the minimum stopping distance is :

(a) 12 m (b) 18 m
(c) 24 m (d) 6 m

22. A boy playing on the roof of a 10 m high building throws a ball with a speed of 10 m/s at an angle of 30° with the horizontal. How far from the throwing point will the ball be at the height of 10 m from the ground ? [$g = 10$ m/s^2, $\sin 30° = 1/2$, $\cos 30° = \sqrt{3}/2$]

(a) 5.20 m (b) 4.33 m
(c) 2.60 m (d) 8.66 m

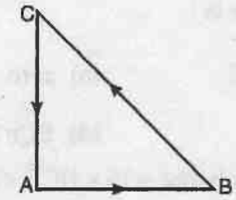
23. An ammeter reads upto 1 ampere. Its internal resistance is 0.81 ohm. To increase the range to 10 A, the value of the required shunt is :

(a) 0.03 Ω (b) 0.3 Ω
(c) 0.9 Ω (d) 0.09 Ω

24. The physical quantities not having same dimensions are :

(a) torque and work
(b) momentum and Planck's constant
(c) stress and Young's modulus
(d) speed and $(\mu_0\varepsilon_0)^{-1/2}$

25. Three forces start acting simultaneously on a particle moving with velocity $\vec{v}$. These forces are represented in magnitude and direction by the three sides of a triangle ABC (as shown). The particle will now move with velocity :

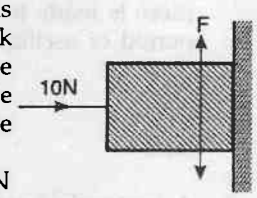


(a) less than $\vec{v}$
(b) greater than $\vec{v}$
(c) $|v|$ in the direction of largest force BC
(d) $\vec{v}$, remaining unchanged

26. If the electric flux entering and leaving an enclosed surface respectively is ϕ_1 and ϕ_2, the electric charge inside the surface will be :

(a) $(\phi_2 - \phi_1)\,\varepsilon_0$ (b) $(\phi_1 + \phi_2)/\varepsilon_0$
(c) $(\phi_2 - \phi_1)/\varepsilon_0$ (d) $(\phi_1 + \phi_2)\,\varepsilon_0$

27. A horizontal force of 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 :



(a) 20 N (b) 50 N
(c) 100 N (d) 2 N

28. A marble block of mass 2 kg lying on ice when given a velocity of 6 m/s is stopped by friction in 10 s. Then the coefficient of friction is :

(a) 0.02 (b) 0.03
(c) 0.06 (d) 0.01

29. Consider the following two statements :

A. Linear momentum of a system of particles is zero.
B. Kinetic energy of a system of particles is zero.

Then :

(a) A does not imply B and B does not imply A
(b) A implies B but B does not imply A
(c) A does not imply B but B implies A
(d) A implies B and B implies A

30. Two coils are placed close to each other. The mutual inductance of the pair of coils depends upon :

(a) the rates at which currents are changing in the two coils
(b) relative position and orientation of the two coils
(c) the materials of the wires of the coils
(d) the currents in the two coils

31. A block of mass M is pulled along a horizontal frictionless surface by a rope of mass m. If a force P is applied at the free end of the rope, the force exerted by the rope on the block is :

(a) $\frac{Pm}{M+m}$ (b) $\frac{Pm}{M-m}$

(c) P (d) $\frac{PM}{M+m}$

32. A light spring balance hangs from the hook of the other light spring balance and a block of mass M kg hangs from the former one. Then the true statement about the scale reading is :

(a) both the scales read M kg each

(b) the scale of the lower one reads M kg and of the upper one zero

(c) the reading of the two scales can be anything but the sum of the reading will be M kg

(d) both the scales read $M/2$ kg

33. A wire suspended vertically from one of its ends is stretched by attaching a weight of 200 N to the lower end. The weight stretches the wire by 1 mm. Then the elastic energy stored in the wire is :

(a) 0.2 J (b) 10 J

(c) 20 J (d) 0.1 J

34. The escape velocity for a body projected vertically upwards from the surface of earth is 11 km/s. If the body is projected at an angle of 45° with the vertical, the escape velocity will be :

(a) $11\sqrt{2}$ km/s (b) 22 km/s

(c) 11 km/s (d) $11/\sqrt{2}$ m/s

35. A mass M is suspended from a spring of negligible mass. The spring is pulled a little and then released so that the mass executes SHM of time period T. If the mass is increased by m, the time period becomes $5T/3$. Then the ratio of $\frac{m}{M}$ is :

(a) 3/5 (b) 25/9

(c) 16/9 (d) 5/3

36. "Heat cannot be itself flow from a body at lower temperature to a body at higher temperature" is a statement or consequence of :

(a) second law of thermodynamics

(b) conservation of momentum

(c) conservation of mass

(d) first law of thermodynamics

37. Two particles A and B of equal masses are suspended from two massless springs of spring constants k_1 and k_2, respectively. If the maximum velocities, during oscillations are equal, the ratio of amplitudes of A and B is :

(a) $\sqrt{k_1/k_2}$ (b) k_1/k_2

(c) $\sqrt{k_2/k_1}$ (d) k_1/k_2

38. The length of a simple pendulum executing simple harmonic motion is increased by 21%. The percentage increase in the time period of the pendulum of increased length is :

(a) 11% (b) 21%

(c) 42% (d) 10.5%

39. The displacement y of a wave travelling in the x-direction is given by

$$y = 10^{-4}\sin\left(600t - 2x + \frac{\pi}{3}\right) \text{ metre},$$

where x is expressed in metres and t in seconds. The speed of the wave-motion, in ms^{-1} is :

(a) 300 (b) 600

(c) 1200 (d) 200

40. When the current changes from + 2 A to − 2 A in 0.05 second, an emf of 8 V is induced in a coil. The coefficient of self-induction of the coil is :

(a) 0.2 H (b) 0.4 H

(c) 0.8 H (d) 0.1 H

41. In an oscillating LC circuit the maximum charge on the capacitor is Q. The charge on the capacitor when the energy is stored equally between the electric and magnetic fields is :

(a) $Q/2$ (b) $Q/\sqrt{3}$

(c) $Q/\sqrt{2}$ (d) Q

42. The core of any transformer is laminated so as to :

(a) reduce the energy loss due to eddy currents

(b) make it light weight

(c) make it robust and strong

(d) increase the secondary voltage

43. Let $\vec{F}$ be the force acting on a particle having position vector $\vec{r}$ and $\vec{\tau}$ be the torque of this force about the origin. Then :

(a) $\vec{r}\cdot\vec{F}=0$ and $\vec{F}\cdot\vec{\tau}\neq 0$

(b) $\vec{r}\cdot\vec{\tau}\neq 0$ and $\vec{F}\cdot\vec{\tau}=0$

(c) $\vec{r}\cdot\vec{\tau}\neq 0$ and $\vec{F}\cdot\vec{\tau}\neq 0$

(d) $\vec{r}\cdot\vec{\tau}=0$ and $\vec{F}\cdot\vec{\tau}=0$

44. A radioactive sample at any instant has its disintegration rate 5000 disintegrations per minute. After 5 minutes, the rate is 1250 disintegrations per minute. Then, the decay constant (per minute) is :

(a) $0.4\ ln\ 2$ (b) $0.2\ ln\ 2$

(c) $0.1\ ln\ 2$ (d) $0.8\ ln\ 2$

45. A nucleus with $Z = 92$ emits the following in a sequence : $\alpha, \alpha, \beta^-, \beta^-, \alpha, \alpha, \alpha, \alpha; \beta^-, \beta^-, \alpha, \beta^+, \beta^+, \alpha$. The Z of the resulting nucleus is :

(a) 76 (b) 78

(c) 82 (d) 74

46. Two identical, photocathodes receive light of frequencies f_1 and f_2. If the velocities of the photoelectrons (of mass m) coming out are respectively v_1 and v_2, then :

(a) $v_1^2 - v_2^2 = \frac{2h}{m}(f_1 - f_2)$ (b) $v_1 + v_2 = \left[\frac{2h}{m}(f_1+f_2)\right]^{1/2}$

(c) $v_1^2 + v_2^2 = \frac{2h}{m}(f_1 + f_2)$ (d) $v_1 - v_2 = \left[\frac{2h}{m}(f_1-f_2)\right]^{1/2}$

47. Which of the following cannot be emitted by radioactive substances during their decay ?

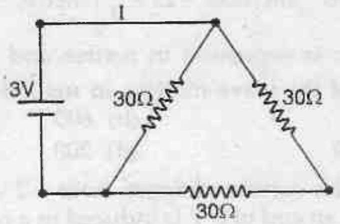
(a) Protons

(b) Neutrinos

(c) Helium nuclei

(d) Electrons

48. A 3 volts battery with negligible internal resistance is connected in a circuit as shown in the figure. The current I, in the circuit will be :



(a) 1 A (b) 1.5 A
(c) 2 A (d) $\frac{1}{3}$ A

49. A sheet of aluminium foil of negligible thickness is introduced between the plates of a capacitor. The capacitance of the capacitor :
(a) decreases (b) remains unchanged
(c) becomes infinite (d) increases

50. The displacement of a particle varies according to the relation $x = 4(\cos \pi t + \sin \pi t)$. The amplitude of the particle is :
(a) -4 (b) 4
(c) $4\sqrt{2}$ (d) 8

51. A thin spherical conducting shell of radius R has a charge q. Another charge Q is placed at the centre of the shell. The electrostatic potential at a point P at a distance $R/2$ from the centre of the shell is :
(a) $\frac{2Q}{4\pi\varepsilon_0 R}$ (b) $\frac{2Q}{4\pi\varepsilon_0 R} - \frac{2q}{4\pi\varepsilon_0 R}$
(c) $\frac{2Q}{4\pi\varepsilon_0 R} + \frac{q}{4\pi\varepsilon_0 R}$ (d) $\frac{(q+Q)}{4\pi\varepsilon_0} \frac{2}{R}$

52. The work done in placing a charge of 8×10^{-18} coulomb on a condenser of capacity 100 micro-farad is :
(a) 16×10^{-32} joule (b) 3.1×10^{-26} joule
(c) 4×10^{-10} joule (d) 32×10^{-32} joule

53. The coordinates of a moving particle at any time t are given by $x = \alpha t^3$ and $y = \beta t^3$. The speed of the particle at time t is given by :
(a) $3t\sqrt{\alpha^2 + \beta^2}$ (b) $3t^2\sqrt{\alpha^2 + \beta^2}$
(c) $t^2\sqrt{\alpha^2 + \beta^2}$ (d) $\sqrt{\alpha^2 + \beta^2}$

54. During an adiabatic process, the pressure of a gas is found to be proportional to the cube of its absolute temperature. The ratio C_P/C_V for the gas is :
(a) $\frac{4}{3}$ (b) 2 (c) $\frac{5}{3}$ (d) $\frac{3}{2}$

55. Which of the following parameters does not characterize the thermodynamic state of matter ?
(a) Temperature (b) Pressure
(c) Work (d) Volume

56. A Carnot engine takes 3×10^6 cal of heat from a reservoir at 627°C and gives it to a sink at 27°C. The work done by the engine is :
(a) 4.2×10^6 J (b) 8.4×10^6 J
(c) 16.8×10^6 J (d) zero

57. A spring of spring constant 5×10^3 N/m is stretched initially by 5 cm from the unstretched position. Then the work required to stretch it further by another 5 cm is :
(a) 12.50 N-m (b) 18.75 N-m
(c) 25.00 N-m (d) 6.25 N-m

58. A metal wire of linear mass density of 9.8 g/m is stretched with a tension of 10 kg-wt between two rigid supports 1 metre apart. The wire passes at its middle point between the poles of a permanent magnet and it vibrates in resonance when carrying an alternating current of frequency n. The frequency n of the alternating source is :
(a) 50 Hz (b) 100 Hz
(c) 200 Hz (d) 25 Hz

59. A tuning fork of known frequency 256 Hz makes 5 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 :
(a) $(256 + 2)$ Hz (b) $(256 - 2)$ Hz
(c) $(256 - 5)$ Hz (d) $(256 + 5)$ Hz

60. A body executes simple harmonic motion. The potential energy (P.E.), the kinetic energy (K.E.) and total energy (T.E.) are measured as function of displacement x. Which of the following statements is true ?
(a) K.E. is maximum when $x = 0$
(b) T.E. is zero when $x = 0$
(c) K.E. is maximum when x is maximum
(d) P.E. is maximum when $x = 0$

61. In the nuclear fusion reaction,

$$^2_1H + ^3_1H \longrightarrow ^4_2He + n$$

given that the repulsive potential energy between the two nuclei is $\sim 7.7 \times 10^{-14}$ J, the temperature at which the gases must be heated to initiate the reaction is nearly [Boltzmann's constant $k = 1.38 \times 10^{-23}$ J/K] :
(a) 10^7 K (b) 10^5 K
(c) 10^3 K (d) 10^9 K

62. Which of the following atoms has the lowest ionization potential ?
(a) $^{14}_{7}N$ (b) $^{133}_{55}Cs$ (c) $^{40}_{18}Ar$ (d) $^{16}_{8}O$

63. The wavelengths involved in the spectrum of deuterium $\left(^2_1D\right)$ are slightly different from that of hydrogen spectrum, because :
(a) size of the two nuclei are different
(b) nuclear forces are different in the two cases
(c) masses of the two nuclei are different
(d) attraction between the electron and the nucleus is different in the two cases

64. In the middle of the depletion layer of reverse biased p-n junction, the :
(a) electric field is zero
(b) potential is maximum
(c) electric field is maximum
(d) potential is zero

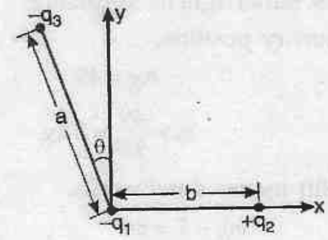
65. If the binding energy of the electron in a hydrogen atom is 13.6 eV, the energy required to remove the electron from the first excited state of Li^{2+} is :
(a) 30.6 eV (b) 13.6 eV
(c) 3.4 eV (d) 122.4 eV

66. A body is moved along a straight line by a machine delivering a constant power. The distance moved by the body in time t is proportional to :
(a) $t^{3/4}$ (b) $t^{3/2}$ (c) $t^{1/4}$ (d) $t^{1/2}$

67. A rocket with a lift-off mass 3.5×10^4 kg is blasted upwards with an initial acceleration of $10\ m/s^2$. Then the initial thrust of the blast is :
(a) 3.5×10^5 N (b) 7.0×10^5 N
(c) 14.0×10^5 N (d) 1.75×10^5 N

68. To demonstrate the phenomenon of interference we require two sources which emit radiation of :
(a) nearly the same frequency
(b) the same frequency
(c) different wavelength
(d) the same frequency and having a definite phase relationship

69. Three charges $-q_1, +q_2$ and $-q_3$ are placed as shown in the figure. The x-component of the force on $-q_1$ is proportional to :



(a) $\frac{q_2}{b^2} - \frac{q_3}{a^2} \cos\theta$ (b) $\frac{q_2}{b^2} + \frac{q_3}{a^2} \sin\theta$
(c) $\frac{q_2}{b^2} + \frac{q_3}{a^2} \cos\theta$ (d) $\frac{q_2}{b^2} - \frac{q_3}{a^2} \sin\theta$

70. A 220 volt, 1000 watt bulb is connected across a 110 volt mains supply. The power consumed will be :
(a) 750 watt (b) 500 watt
(c) 250 watt (d) 1000 watt

71. The image formed by an objective of a compound microscope is :
(a) virtual and diminished
(b) real and diminished
(c) real and enlarged
(d) virtual and enlarged

72. The earth radiates in the infra-red region of the spectrum. The spectrum is correctly given by :
(a) Rayleigh Jeans law
(b) Planck's law of radiation
(c) Stefan's law of radiation
(d) Wien's law

73. To get three images of a single object, one should have two plane mirrors at an angle of :
(a) 60° (b) 90° (c) 120° (d) 30°

74. According to Newton's law of cooling, the rate of cooling of a body is proportional to $(\Delta\theta)^n$, where $\Delta\theta$ is the difference of the temperature of the body and the surroundings, and n is equal to :
(a) two (b) three
(c) four (d) one

75. The length of a given cylindrical wire is increased by 100%. Due to the consequent decrease in diameter the change in the resistance of the wire will be :
(a) 200% (b) 100%
(c) 50% (d) 300%

Answers

1.	(b)	2.	(a)	3.	(b)	4.	(a)	5.	(d)	6.	(a)	7.	(a)	8.	(d)
9.	(c)	10.	(b)	11.	(a)	12.	(c)	13.	(c)	14.	(d)	15.	(c)	16.	(a)
17.	(a)	18.	(b)	19.	(c)	20.	(b)	21.	(c)	22.	(d)	23.	(d)	24.	(b)
25.	(d)	26.	(a)	27.	(d)	28.	(c)	29.	(c)	30.	(b)	31.	(d)	32.	(a)
33.	(d)	34.	(c)	35.	(c)	36.	(a)	37.	(c)	38.	(d)	39.	(a)	40.	(d)
41.	(c)	42.	(a)	43.	(d)	44.	(a)	45.	(b)	46.	(a)	47.	(a)	48.	(b)
49.	(b)	50.	(c)	51.	(c)	52.	(d)	53.	(b)	54.	(d)	55.	(c)	56.	(b)
57.	(b)	58.	(a)	59.	(c)	60.	(a)	61.	(d)	62.	(b)	63.	(c)	64.	(a)
65.	(a)	66.	(b)	67.	(a)	68.	(d)	69.	(b)	70.	(c)	71.	(c)	72.	(a)
73.	(b)	74.	(d)	75.	(d)										

AIEEE

Solved Paper 2004

PHYSICS

1. Which one of the following represents the correct dimensions of the coefficient of viscosity ?
(a) $[ML^{-1}T^{-2}]$ (b) $[MLT^{-1}]$
(c) $[ML^{-1}T^{-1}]$ (d) $[ML^{-2}T^{-2}]$

2. A particle moves in a straight line with retardation proportional to its displacement. Its loss of kinetic energy for any displacement x is proportional to :
(a) x^2 (b) e^x (c) x (d) $\log_e x$

3. A ball is released from the top of a tower of height h metres. It takes T seconds to reach the ground. What is the position of the ball in $T/3$ seconds ?
(a) $h/9$ metre from the ground
(b) $7h/9$ metre from the ground
(c) $8h/9$ metre from the ground
(c) $17h/18$ metre from the ground

4. If $\vec{A} \times \vec{B} = \vec{B} \times \vec{A}$, then the angle between A and B is :
(a) π (b) $\pi/3$ (c) $\pi/2$ (d) $\pi/4$

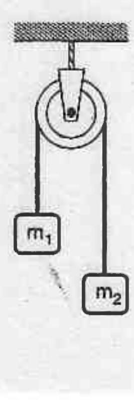
5. A projectile can have the same range R for two angles of projection. If T_1 and T_2 be the time of flights in the two cases, then the product of the two times of flights is directly proportional to :
(a) $1/R^2$ (b) $1/R$ (c) R (d) R^2

6. Which of the following statements is false for a particle moving in a circle with a constant angular speed ?
(a) The velocity vector is tangent to the circle
(b) The acceleration vector is tangent to the circle
(c) The acceleration vector points to the centre of the circle
(d) The velocity and acceleration vectors are perpendicular to each other

7. An automobile travelling with a speed of 60 km/h, can brake to stop within a distance of 20 m. If the car is going twice as fast, *i.e.* 120 km/h, the stopping distance will be :
(a) 20 m (b) 40 m (c) 60 m (d) 80 m

8. A machine gun fires a bullet of mass 40 g with a velocity 1200 ms^{-1}. The man holding it, can exert a maximum force of 144 N on the gun. How many bullets can he fire per second at the most ?
(a) One (b) Four (c) Two (d) Three

9. Two masses $m_1 = 5$ kg and $m_2 = 4.8$ kg tied to a string are hanging over a light frictionless pulley. What is the acceleration of the masses when lift is free to move ? ($g - 9.8$ m/s^2)
(a) 0.2 m/s^2
(b) 9.8 m/s^2
(c) 5 m/s^2
(d) 4.8 m/s^2



10. A uniform chain of length 2 m is kept on a table such that a length of 60 cm hangs freely from the edge of the table. The total mass of the chain is 4 kg. What is the work done in pulling the entire chain on the table ?
(a) 7.2 J (b) 3.6 J (c) 120 J (d) 1200 J

11. A block rests on a rough inclined plane making an angle of 30° with the horizontal. The coefficient of static friction between the block and the plane is 0.8. If the frictional force on the block is 10 N, the mass of the block (in kg) is (take $g = 10$ m/s^2) :
(a) 2.0 (b) 4.0 (c) 1.6 (d) 2.5

12. A force $\vec{F} = (5\hat{i} + 3\hat{j} + 2\hat{k})$ N is applied over a particle which displaces it from its origin to the point $\vec{r} = (2\hat{i} - \hat{j})$ m. The work done on the particle in joules is :
(a) – 7 (b) + 7 (c) + 10 (d) + 13

13. A body of mass m accelerates uniformly from rest to v_1 in time t_1. The instantaneous power delivered to the body as a function of time t is :
(a) $\frac{mv_1 t}{t_1}$ (b) $\frac{mv_1^2 t}{t_1^2}$ (c) $\frac{mv_1 t^2}{t_1}$ (d) $\frac{mv_1^2 t}{t_1}$

14. A particle is acted upon by a force of constant magnitude which is always perpendicular to the velocity of the particle. The motion of the particle takes place in a plane, it follows that :
(a) its velocity is constant
(b) its acceleration is constant
(c) its kinetic energy is constant
(d) it moves in a straight line

15. A solid sphere is rotating in free space. If the radius of the sphere is increased keeping mass same which one of the following will not be affected ?
(a) Moment of inertia (b) Angular momentum
(c) Angular velocity (d) Rotational kinetic energy

16. A ball is thrown from a point with a speed v_0 at an angle of projection θ. From the same point and at the same instant, a person starts running with a constant speed $\frac{v_0}{2}$ to catch the ball. Will the person be able to catch the ball ? If yes, what should be the angle of projection ?
(a) Yes, 60° (b) Yes, 30° (c) No (d) Yes, 45°

17. One solid sphere A and another hollow sphere B are of same mass and same outer radii. Their moment of inertia about their diameters are respectively I_A and I_B such that :
(a) $I_A = I_B$ (b) $I_A > I_B$ (c) $I_A < I_B$ (d) $\frac{I_A}{I_B} = \frac{d_A}{d_B}$
where d_A and d_B are their densities.

18. A satellite of mass m revolves around the earth of radius R at a height x from its surface. If g is the acceleration due to gravity on the surface of the earth, the orbital speed of the satellite is :

(a) gx (b) $\frac{gR}{R-x}$

(c) $\frac{gR^2}{R+x}$ (d) $\left(\frac{gR^2}{R+x}\right)^{1/2}$

19. The time period of an earth satellite in circular orbit is independent of :

(a) the mass of the satellite
(b) radius of its orbit
(c) both the mass and radius of the orbit
(d) neither the mass of the satellite nor the radius of its orbit

20. If g is the acceleration due to gravity on the earth's surface, the gain in the potential energy of an object of mass m raised from the surface of the earth to a height equal to the radius R of the earth, is :

(a) $2mgR$ (b) $\frac{1}{2}mgR$ (c) $\frac{1}{4}mgR$ (d) mgR

21. Suppose the gravitational force varies inversely as the n^{th} power of distance. Then the time period of a planet in circular orbit of radius R around the sun will be proportional to :

(a) $R^{\left(\frac{n+1}{2}\right)}$ (b) $R^{\left(\frac{n-1}{2}\right)}$

(c) R^n (d) $R^{\left(\frac{n-2}{2}\right)}$

22. A wire fixed at the upper end stretches by length l by applying a force F. The work done in stretching is :

(a) $\frac{F}{2l}$ (b) Fl (c) $2Fl$ (d) $\frac{Fl}{2}$

23. Spherical balls of radius R are falling in a viscous fluid of viscosity η with a velocity v. The retarding viscous force acting on the spherical ball is :

(a) directly proportional to R but inversely proportional to v
(b) directly proportional to both radius R and velocity v
(c) inversely proportional to both radius R and velocity v
(d) inversely proportional to R but directly proportional to velocity v

24. If two soap bubbles of different radii are connected by a tube :

(a) air flows from the bigger bubble to the smaller bubble till the sizes become equal
(b) air flows from bigger bubble to the smaller bubble till the sizes are interchanged
(c) air flows from the smaller bubble to the bigger
(d) there is no flow of air

25. The bob of a simple pendulum executes simple harmonic motion in water with a period t, while the period of oscillation of the bob is t_0 in air. Neglecting frictional force of water and given that the density of the bob is $(4/3) \times 1000$ kg/m^3. What relationship between t and t_0 is true ?

(a) $t = t_0$ (b) $t = t_0/2$ (c) $t = 2t_0$ (d) $t = 4t_0$

26. A particle at the end of a spring executes simple harmonic motion with a period t_1, while the corresponding period for another spring is t_2. If the period of oscillation with the two springs in series is T, then :

(a) $T = t_1 + t_2$ (b) $T^2 = t_1^2 + t_2^2$

(c) $T^{-1} = t_1^{-1} + t_2^{-1}$ (d) $T^{-2} = t_1^{-2} + t_2^{-2}$

27. The total energy of a particle, executing simple harmonic motion is :

(a) $\propto x$ (b) $\propto x^2$

(c) independent of x (d) $\propto x^{1/2}$

where x is the displacement from the mean position.

28. The displacement y of a particle in a medium can be expressed as :

$y = 10^{-6}\sin\left(100t + 20x + \frac{\pi}{4}\right)$ m, where t is in second and x in metre. The speed of the wave is :

(a) 2000 m/s (b) 5 m/s

(c) 20 m/s (d) 5π m/s

29. A particle of mass m is attached to a spring (of spring constant k) and has a natural angular frequency ω_0. An external force $F(t)$ proportional to $\cos \omega t$ $(\omega \neq \omega_0)$ is applied to the oscillator. The time displacement of the oscillator will be proportional to :

(a) $\frac{m}{\omega_0^2 - \omega^2}$ (b) $\frac{1}{m(\omega_0^2 - \omega^2)}$

(c) $\frac{1}{m(\omega_0^2 + \omega^2)}$ (d) $\frac{m}{\omega_0^2 + \omega^2}$

30. In forced oscillation of a particle, the amplitude is maximum for a frequency ω_1 of the force, while the energy is maximum for a frequency ω_2 of the force, then :

(a) $\omega_1 = \omega_2$
(b) $\omega_1 > \omega_2$
(c) $\omega_1 < \omega_2$ when damping is small and $\omega_1 > \omega_2$ when damping is large
(d) $\omega_1 < \omega_2$

31. One mole of ideal monoatomic gas $(\nu = 5/3)$ is mixed with one mole of diatomic gas $(\gamma = 7/5)$. What is γ for the mixture ? γ denotes the ratio of specific heat at constant pressure, to that at constant volume.

(a) 3/2 (b) 23/15

(c) 35/23 (d) 4/3

32. If the temperature of the sun were to increase from T to $2T$ and its radius from R to $2R$, then the ratio of the radiant energy received on earth to what it was previously, will be :

(a) 4 (b) 16

(c) 32 (d) 64

33. Which of the following statements is correct for any thermodynamic system ?

(a) The internal energy changes in all processes
(b) Internal energy and entropy are state functions
(c) The change in entropy can never be zero
(d) The work done in an adiabatic process is always zero

34. 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 :

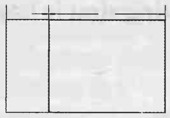
(a) $T_1 + T_2$ (b) $(T_1 + T_2)/2$

(c) $\dfrac{T_1T_2(P_1V_1 + P_2V_2)}{P_1V_1T_2 + P_2V_2T_1}$ (d) $\dfrac{T_1T_2(P_1V_1 + P_2V_2)}{P_1V_1T_1 + P_2V_2T_2}$

35. A radiation of energy E falls normally on a perfectly reflecting surface. The momentum transferred to the surface is :

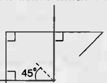
(a) E/c (b) $2E/c$ (c) Ec (d) E/c^2

36. The temperature of the two outer surfaces of a composite slab, consisting of two materials having coefficients of thermal conductivity K and $2K$ and thickness x and $4x$, respectively are T_2 and T_1 ($T_2 > T_1$). The rate of heat transfer through the slab, in a steady state is $\left(\dfrac{\quad}{\quad}\right)f$, with f equals to :



(a) 1 (b) 1/2 (c) 2/3 (d) 1/3

37. A light ray is incident perpendicular to one face of a 90° prism and is totally internally reflected at the glass-air interface. If the angle of reflection is 45°, we conclude that the refractive index n :



$\left(\dfrac{A(T_2 - T_1)K}{}\right)$

(a) $n < \frac{1}{\sqrt{2}}$ (b) $n > \sqrt{2}$ (c) $n > \frac{1}{\sqrt{2}}$ (d) $n < \sqrt{2}$

38. A plano-convex lens of refractive index 1.5 and radius of curvature 30 cm is silvered at the curved surface. Now this lens has been used to form the image of an object. At what distance from this lens, an object be placed in order to have a real image of the size of the object ?

(a) 20 cm (b) 30 cm (c) 60 cm (d) 80 cm

39. The angle of incidence at which reflected light is totally polarized for reflection from air to glass (refractive index n), is :

(a) $\sin^{-1}(n)$ (b) $\sin^{-1}(1/n)$

(c) $\tan^{-1}(1/n)$ (d) $\tan^{-1}(n)$

40. The maximum number of possible interference maxima for slit-separation equal to twice the wavelength in Young's double-slit experiment, is :

(a) infinite (b) five (c) three (d) zero

41. An electromagnetic wave of frequency $\nu = 3.0$ MHz passes from vacuum into a dielectric medium with permittivity $\varepsilon = 4.0$. Then :

(a) wavelength is doubled and the frequency remains unchanged

(b) wavelength is doubled and frequency becomes half

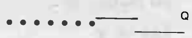
(c) wavelength is halved and frequency remains unchanged

(d) wavelength and frequency both remain unchanged

42. Two spherical conductors B and C having equal radii and carrying equal charges in them repel each other with a force F when kept apart at some distance. A third spherical conductor having same radius as that of B but uncharged, is brought in contact with B, then brought in contact with C and finally removed away from both. The new force of repulsion between B and C is :

(a) $\frac{F}{4}$ (b) $\frac{3F}{4}$ (c) $\frac{F}{8}$ (d) $\frac{3F}{8}$

43. A charged particle q is shot 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 was given a speed $2v$, the closest distance of approach would be :



(a) r (b) $2r$

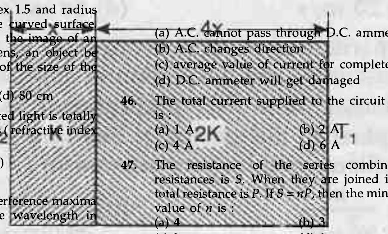
(c) $r/2$ (d) $r/4$

44. Four charges equal to $-Q$ are placed at the four corners of a square and a charge q is at its centre. If the system is in equilibrium, the value of q is :

(a) $-\frac{Q}{4}(1 + 2\sqrt{2})$ (b) $\frac{Q}{4}(1 + 2\sqrt{2})$

(c) $-\frac{Q}{2}(1 + 2\sqrt{2})$ (d) $\frac{Q}{2}(1 + 2\sqrt{2})$

45. Alternating current can not be measured by D.C. ammeter because :



(a) A.C. cannot pass through D.C. ammeter

(b) A.C. changes direction

(c) average value of current for complete cycle is zero

(d) D.C. ammeter will get damaged

46. The total current supplied to the circuit by the battery is :

(a) 1 A (b) 2 A

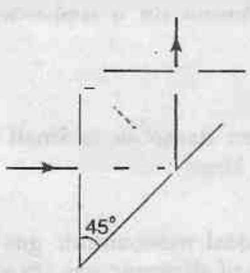
(c) 4 A (d) 6 A

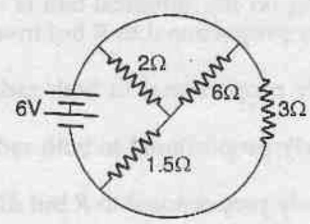
47. The resistance of the series combination of two resistances is S. When they are joined in parallel, the total resistance is P. If $S = nP$, then the minimum possible value of n is :

(a) 4 (b) 3

(c) 2 (d) 1

4 4





48. An electric current is passed through a circuit containing two wires of the same material, connected in parallel. If the lengths and radii of the wires are in the ratio of 4/3 and 2/3, then the ratio of the currents passing through the wire will be :
(a) 3 (b) 1/3 (c) 8/9 (d) 2

49. In a metre bridge experiment, null point is obtained at 20 cm from one end of the wire when resistance X is balanced against another resistance Y. If $X < Y$, then where will be the new position of the null point from the same end, if one decides to balance a resistance of $4X$ against Y?
(a) 50 cm (b) 80 cm (c) 40 cm (d) 70 cm

50. The thermistors are usually made of :
(a) metals with low temperature coefficient of resistivity
(b) metals with high temperature coefficient of resistivity
(c) metal oxides with high temperature coefficient of resistivity
(d) semiconducting materials having low temperature coefficient of resistivity

51. Time taken by a 836 W heater to heat one litre of water from 10°C to 40°C is :
(a) 50 s (b) 100 s (c) 150 s (d) 200 s

52. The thermo-emf of a thermocouple varies with the temperature θ of the hot junction as $E = a\,\theta + b\theta^2$ in volts where the ratio a/b is 700°C. If the cold junction is kept at 0°C, then the neutral temperature is :
(a) 700°C
(b) 350°C
(c) 1400°C
(d) no neutral temperature is possible for this thermocouple

53. The electrochemical equivalent of metal is 3.3×10^{-7} kg per coulomb. The mass of the metal liberated at the cathode when a 3 A current is passed for 2 seconds, will be :
(a) 19.8×10^{-7} kg (b) 9.9×10^{-7} kg
(c) 6.6×10^{-7} kg (d) 1.1×10^{-7} kg

54. A current i ampere flows along an infinitely long straight thin walled tube, then the magnetic induction at any point inside the tube is :
(a) infinite (b) zero
(c) $\frac{\mu_0}{4\pi} \cdot \frac{2i}{r}$ tesla (d) $\frac{2i}{r}$ tesla

55. A long wire carries a steady current. It is bent into a circle of one turn and the magnetic field at the centre of the coil is B. It is then bent into a circular loop of n turns. The magnetic field at the centre of the coil will be :
(a) nB (b) n^2B (c) $2nB$ (d) $2n^2B$

56. The magnetic field due to a current carrying circular loop of radius 3 cm at a point on the axis at a distance of 4 cm from the centre is 54 μT. What will be its value at the centre of the loop ?
(a) 250 μT (b) 150 μT
(c) 125 μT (d) 75 μT

57. Two long conductors, separated by a distance d carry currents I_1 and I_2 in the same direction. They exert a force F on each other. Now the current in one of them is increased to two times and its direction is reversed. The distance is also increased to $3d$. The new value of the force between them is :
(a) $-2F$ (b) $F/3$ (c) $-2F/3$ (d) $-F/3$

58. The length of a magnet is large compared to its width and breadth. The time period of its oscillation in a vibration magnetometer is 2 s. The magnet is cut along its length into three equal parts and three parts are then placed on each other with their like poles together. The time period of this combination will be :
(a) 2 s (b) 2/3 s (c) $2\sqrt{3}$ s (d) $2/\sqrt{3}$ s

59. The materials suitable for making electromagnets should have :
(a) high retentivity and high coercivity
(b) low retentivity and low coercivity
(c) high retentivity and low coercivity
(d) low retentivity and high coercivity

60. In an LCR series a.c. circuit, the voltage across each of the components. L, C and R is 50 V. The voltage across the LC combination will be :
(a) 50 V (b) $50\sqrt{2}$ V
(c) 100 V (d) 0 V (zero)

61. A coil having n turns and resistance $R\,\Omega$ is connected with a galvanometer of resistance $4R\,\Omega$. This combination is moved in time t seconds from a magnetic field W_1 weber to W_2 weber. The induced current in the circuit is :
(a) $\frac{W_2 - W_1}{5Rnt}$ (b) $-\frac{n(W_2 - W_1)}{5Rt}$
(c) $-\frac{(W_2 - W_1)}{Rnt}$ (d) $-\frac{n(W_2 - W_1)}{Rt}$

62. In a uniform magnetic field of induction B, a wire in the form of semicircle of radius r rotates about the diameter of the circle with angular frequency ω. If the total resistance of the circuit is R, the mean power generated per period of rotation is :
(a) $\frac{B\pi r^2\omega}{2R}$ (b) $\frac{(B\pi r^2\omega)^2}{8R}$
(c) $\frac{(B\pi r\omega)^2}{2R}$ (d) $\frac{(B\pi r\omega^2)^2}{8R}$

63. In an LCR circuit, capacitance is changed from C to 2C. For the resonant frequency to remain unchanged, the inductance should be changed from L to :
(a) $4L$ (b) $2L$ (c) $L/2$ (d) $L/4$

64. A metal conductor of length 1 m rotates vertically about one of its ends at angular velocity 5 radians per second. If the horizontal component of earth's magnetic field is 0.2×10^{-4} T, then the emf developed between the two ends of the conductor is :
(a) 5 μV (b) 50 μV (c) 5 mV (d) 50 mV

65. According to Einstein's photoelectric equation, the plot of the kinetic energy of the emitted photoelectrons from a metal *Vs* the frequency, of the incident radiation gives a straight line whose slope :
(a) depends on the nature of the metal used
(b) depends on the intensity of the radiation
(c) depends both on the intensity of the radiation and the metal used
(d) is the same for all metals and independent of the intensity of the radiation

66. The work function of a substance is 4.0 eV. The longest wavelength of light that can cause photoelectron emission from this substance is approximately :
(a) 540 nm (b) 400 nm
(c) 310 nm (d) 220 nm

67. A charged oil drop is suspended in uniform field of 3×10^4 V/m so that it neither falls nor rises. The charge on the drop will be :
(take the mass of the charge $= 9.9 \times 10^{-15}$ kg and $g = 10$ m/s^2)
(a) 3.3×10^{-18} C (b) 3.2×10^{-18} C
(c) 1.6×10^{-18} C (d) 4.8×10^{-18} C

68. A nucleus disintegrates into two nuclear parts which have their velocities in the ratio 2 : 1. The ratio of their nuclear sizes will be :
(a) $2^{1/3} : 1$ (b) $1 : 3^{1/2}$ (c) $3^{1/2} : 1$ (d) $1 : 2^{1/3}$

69. The binding energy per nucleon of deuteron $\left({}^2_1\text{H}\right)$ and helium nucleus $\left({}^4_2\text{He}\right)$ is 1.1 MeV and 7 MeV respectively. If two deuteron nuclei react to form a single helium nucleus, then the energy released is :
(a) 13.9 MeV (b) 26.9 MeV
(c) 23.6 MeV (d) 19.2 MeV

70. An α- particle of energy 5 MeV is scattered through 180° by a fixed uranium nucleus. The distance of the closest approach is of the order of :
(a) 1 Å (b) 10^{-10} cm
(c) 10^{-12} cm (d) 10^{-15} cm

71. When *npn* transistor is used as an amplifier :
(a) electrons move from base to collector
(b) holes move from emitter to base
(c) electrons move from collector to base
(d) holes move from base to emitter

72. For a transistor amplifier in common emitter configuration for load impedance of 1 kΩ ($h_{fe} = 50$ and $h_{oe} = 25$ μA/V), the current gain is :
(a) – 5.2 (b) – 15.7 (c) – 24.8 (d) – 48.78

73. A piece of copper and another of germanium are cooled from room temperature to 77 K, the resistance of :
(a) each of them increases
(b) each of them decreases
(c) copper decreases and germanium increases
(d) copper increases and germanium decreases

74. The manifestation of band structure in solids is due to :
(a) Heisenberg's uncertainty principle
(b) Pauli's exclusion principle
(c) Bohr's correspondence principle
(d) Boltzmann's law

75. When *p-n* junction diode is forward biased, then :
(a) the depletion region is reduced and barrier height is increased
(b) the depletion region is widened and barrier height is reduced
(c) both the depletion region and barrier height are reduced
(d) both the depletion region and barrier height are increased

Answers

1.	(c)	2.	(a)	3.	(c)	4.	(a)	5.	(c)	6.	(b)	7.	(d)	8.	(d)
9.	(a)	10.	(b)	11.	(a)	12.	(b)	13.	(b)	14.	(c)	15.	(b)	16.	(a)
17.	(c)	18.	(d)	19.	(a)	20.	(b)	21.	(a)	22.	(d)	23.	(b)	24.	(c)
25.	(c)	26.	(b)	27.	(c)	28.	(b)	29.	(b)	30.	(a)	31.	(a)	32.	(d)
33.	(b)	34.	(c)	35.	(b)	36.	(d)	37.	(b)	38.	(a)	39.	(d)	40.	(b)
41.	(c)	42.	(d)	43.	(d)	44.	(b)	45.	(c)	46.	(c)	47.	(a)	48.	(b)
49.	(a)	50.	(c)	51.	(c)	52.	(d)	53.	(a)	54.	(b)	55.	(b)	56.	(a)
57.	(c)	58.	(b)	59.	(c)	60.	(d)	61.	(b)	62.	(b)	63.	(c)	64.	(b)
65.	(d)	66.	(c)	67.	(a)	68.	(d)	69.	(c)	70.	(c)	71.	(d)	72.	(d)
73.	(c)	74.	(b)	75.	(c)										

Hints & Solutions

1. From Newton's formula

$$\eta = \frac{F}{A\,(\Delta v_x/\Delta z)}$$

∴ Dimensions of

$$\eta = \frac{\text{dimensions of force}}{\text{dimensions of area} \times \text{dimensions of velocity -gradient}}$$

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

2. As given in question, retardation (negative acceleration)
$a \propto x$

$\Rightarrow \quad a = kx$

where k is a proportionality constant

$\Rightarrow \quad \dfrac{dv}{dt} = kx$

$\Rightarrow \quad \dfrac{dv}{dx} \cdot \dfrac{dx}{dt} - kx$

$\Rightarrow \quad v\dfrac{dv}{dx} - kx \qquad \left(\because v = \dfrac{dx}{dt}\right)$

AIEEE

Solved Paper 2005

PHYSICS

1. A projectile can have the same range 'R' for two angles of projection. If 't_1' and 't_2' be the times of flights in the two cases, then the product of the two times of flights is proportional to :
(a) R^2 (b) $\frac{1}{R^2}$
(c) $\frac{1}{R}$ (d) R

2. An annular ring with inner and outer radii R_1 and R_2 is rolling without slipping with a uniform angular speed. The ratio of the forces experienced by the two particles situated on the inner and outer parts of the ring, $\frac{F_1}{F_2}$ is :
(a) $\frac{R_2}{R_1}$ (b) $\left(\frac{R_1}{R_2}\right)^2$
(c) 1 (d) $\frac{R_1}{R_2}$

3. A smooth block is released at rest on a 45° incline and then slides a distance 'd'. The time taken to slide is 'n' times as much to slide on rough incline than on a smooth incline. The coefficient of friction is :
(a) $\mu_k = 1 - \frac{1}{n^2}$ (b) $\mu_k = \sqrt{1 - \frac{1}{n^2}}$
(c) $\mu_s = 1 - \frac{1}{n^2}$ (d) $\mu_s = \sqrt{1 - \frac{1}{n^2}}$

4. The upper half of an inclined plane with inclination ϕ is perfectly smooth, while the lower half is rough. A body starting from rest at the top will again come to rest at the bottom, if the coefficient of friction for the lower half is given by :
(a) $2 \sin \phi$ (b) $2 \cos \phi$
(c) $2 \tan \phi$ (d) $\tan \phi$

5. A bullet fired into a fixed target loses half of its velocity after penetrating 3 cm. How much further it will penetrate before coming to rest, assuming that it faces constant resistance to motion ?
(a) 3.0 cm (b) 2.0 cm
(c) 1.5 cm (d) 1.0 cm

6. Out of the following pairs, which one does not have identical dimensions ?
(a) Angular momentum and Planck's constant
(b) Impulse and momentum
(c) Moment of inertia and moment of a force
(d) Work and torque

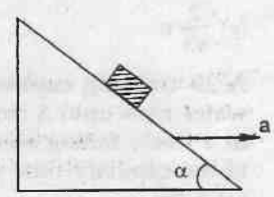
7. The relation between time t and distance x is $t = ax^2 + bx$, where a and b are constants. The acceleration is :
(a) $-2abv^2$ (b) $2bv^3$ (c) $-2av^3$ (d) $2av^2$

8. A car, starting from rest, accelerates at the rate f through a distance S, then continues at constant speed for time t and then decelerates at the rate $\frac{f}{2}$ to come to rest. If the total distance travelled is 15 S, then :
(a) $S = ft$ (b) $S = \frac{1}{6}ft^2$
(c) $S = \frac{1}{2}ft^2$ (d) $S = \frac{1}{4}ft^2$

9. A particle is moving eastwards with a velocity of $5\ ms^{-1}$. In 10 seconds the velocity changes to $5\ ms^{-1}$ northwards. The average acceleration in this time is :
(a) $\frac{1}{\sqrt{2}}\ ms^{-2}$ towards north-east
(b) $\frac{1}{2}\ ms^{-2}$ towards north
(c) zero
(d) $\frac{1}{2}\ ms^{-2}$ towards north-west

10. A parachutist after bailing out falls 50 m without friction. When parachute opens, it decelerates at $2\ m/s^2$. He reaches the ground with a speed of 3 m/s. At what height, did he bail out ?
(a) 91 m (b) 182 m (c) 293 m (d) 111 m

11. A block is kept on a frictionless inclined surface with angle of inclination 'α'. The incline is given an acceleration 'a' to keep the block stationary. Then 'a' is equal to :



(a) $g/\tan \alpha$ (b) $g \operatorname{cosec} \alpha$ (c) g (d) $g \tan \alpha$

12. A spherical ball of mass 20 kg is stationary at the top of a hill of height 100 m. It rolls down a smooth surface to the ground, then climbs up another hill of height 30 m and finally rolls down to a horizontal base at a height of 20 m above the ground. The velocity attained by the ball is :
(a) 40 m/s (b) 20 m/s (c) 10 m/s (d) $10\sqrt{30}$ m/s

13. A body A of mass M while falling vertically downwards under gravity breaks into two parts; a body B of mass $\frac{1}{3}M$ and, a body C of mass $\frac{2}{3}M$. The centre of mass of bodies B and C taken together shifts compared to that of body A towards :
(a) depends on height of breaking
(b) does not shift
(c) body C
(d) body B

14. The moment of inertia of uniform semicircular disc of mass M and radius r about a line perpendicular to the plane of the disc through the centre is :

(a) $\frac{1}{4}Mr^2$ (b) $\frac{2}{5}Mr^2$

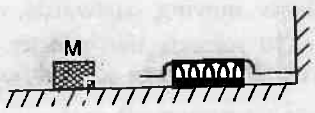
(c) Mr^2 (d) $\frac{1}{2}Mr^2$

15. A particle of mass 0.3 kg is subjected to a force $F = -kx$ with $k = 15$ N/m. What will be its initial acceleration, if it is released from a point 20 cm away from the origin ?

(a) 3 m/s^2 (b) 15 m/s^2

(c) 5 m/s^2 (d) 10 m/s^2

16. The block of mass M moving on the frictionless horizontal surface collides with the spring of spring constant k and compresses it by length L. The maximum momentum of the block after collision is :



(a) $\sqrt{Mk}\,L$ (b) $\frac{kL^2}{2M}$

(c) zero (d) $\frac{ML^2}{k}$

17. A mass 'm' moves with a velocity 'v' and collides inelastically with another identical mass. After collision the Ist mass moves with velocity $\frac{v}{\sqrt{3}}$ in a direction perpendicular to the initial direction of motion. Find the speed of the 2nd mass after collision :

(a) v (b) $\sqrt{3}\,v$

(c) $\frac{2}{\sqrt{3}}v$ (d) $\frac{v}{\sqrt{3}}$

18. A 20 cm long capillary tube is dipped in water. The water rises upto 8 cm. If the entire arrangement is put in a freely falling elevator, the length of water column in the capillary tube will be :

(a) 8 cm (b) 10 cm

(c) 4 cm (d) 20 cm

19. If 'S' is stress and 'Y' is Young's modulus of material of a wire, the energy stored in the wire per unit volume is :

(a) $2S^2Y$ (b) $\frac{S^2}{2Y}$

(c) $\frac{2Y}{S^2}$ (d) $\frac{S}{2Y}$

20. Average density of the earth :

(a) does not depend on g

(b) is a complex function of g

(c) is directly proportional to g

(d) is inversely proportional to g

21. A body of mass m is accelerated uniformly from rest to a speed v in a time T. The instantaneous power delivered to the body as a function of time, is given by :

(a) $\frac{mv^2}{T^2}\cdot t$ (b) $\frac{mv^2}{T^2}\cdot t^2$ (c) $\frac{1}{2}\frac{mv^2}{T^2}\cdot t$ (d) $\frac{1}{2}\frac{mv^2}{T^2}\cdot t^2$

22. Consider a car moving on a straight road with a speed of 100 m/s. The distance at which car can be stopped, is : [$\mu_k = 0.5$]

(a) 800 m (b) 1000 m

(c) 100 m (d) 400 m

23. Which of the following is incorrect regarding the first law of thermodynamics ?

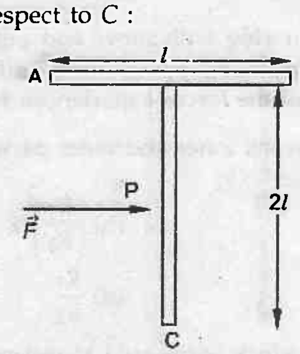
(a) It is not applicable to any cyclic process

(b) It is a restatement of the principle of conservation of energy

(c) It introduces the concept of the internal energy

(d) It introduces the concept of the entropy

24. A 'T' shaped object with dimensions shown in the figure, is lying on a smooth floor. A force '$\vec{F}$' is applied at the point P parallel to AB, such that the object has only the translational motion without rotation. Find the location of P with respect to C :



(a) $\frac{2}{3}l$ (b) $\frac{3}{2}l$

(c) $\frac{4}{3}l$ (d) l

25. The change in the value of 'g' at a height 'h' above the surface of the earth is the same as at a depth 'd' below the surface of earth. When both 'd' and 'h' are much smaller than the radius of earth, then, which one of the following is correct ?

(a) $d = \frac{h}{2}$ (b) $d = \frac{3h}{2}$

(c) $d = 2h$ (d) $d = h$

26. A particle of mass 10 g is kept on the surface of a uniform sphere of mass 100 kg and radius 10 cm. Find the work to be done against the gravitational force between them, to take the particle far away from the sphere (you may take $G = 6.67 \times 10^{-11}$ Nm^2/kg^2) :

(a) 13.34×10^{-10} J (b) 3.33×10^{-10} J

(c) 6.67×10^{-9} J (d) 6.67×10^{-10} J

27. A gaseous mixture consists of 16 g of helium and 16 g of oxygen. The ratio $\frac{C_p}{C_v}$ of the mixture is :

(a) 1.59 (b) 1.62

(c) 1.4 (d) 1.54

28. The intensity of gamma radiation from a given source is I. On passing through 36 mm of lead, it is reduced to $\frac{I}{8}$. The thickness of lead, which will reduce the intensity to $\frac{I}{2}$ will be :

(a) 6 mm (b) 9 mm (c) 18 mm (d) 12 mm

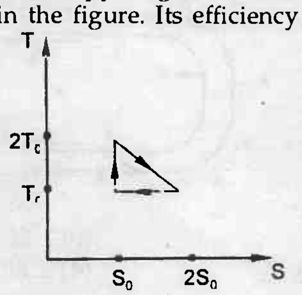
29. The electrical conductivity of a semiconductor increases when electromagnetic radiation of wavelength shorter than 2480 nm, is incident on it. The band gap in (eV) for the semiconductor is :
(a) 1.1 eV (b) 2.5 eV
(c) 0.5 eV (d) 0.7 eV

30. A photocell is illuminated by a small bright source placed 1 m away. When the same source of light is placed $\frac{1}{2}$ m away, the number of electrons emitted by photocathode would :
(a) decrease by a factor of 4
(b) increase by a factor of 4
(c) decrease by a factor of 2
(d) increase by a factor of 2

31. Starting with a sample of pure ^{66}Cu, $\frac{7}{8}$ of it decays into Zn in 15 minutes. The corresponding half-life is :
(a) 10 minute (b) 15 minute
(c) 5 minute (d) $7\frac{1}{2}$ minute

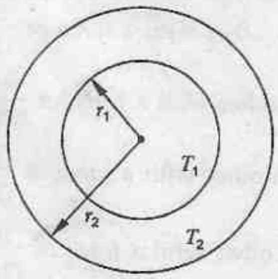
32. If radius of the $^{27}_{13}Al$ nucleus is estimated to be 3.6 Fermi, then the radius of $^{125}_{52}Te$ nucleus be nearly :
(a) 6 Fermi (b) 8 Fermi
(c) 4 Fermi (d) 5 Fermi

33. The temperature-entropy diagram of a reversible engine cycle is given in the figure. Its efficiency is :



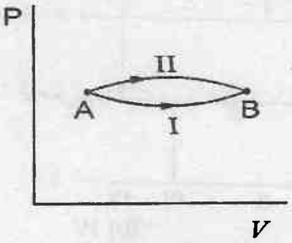
(a) $\frac{1}{2}$ (b) $\frac{1}{4}$
(c) $\frac{1}{3}$ (d) $\frac{2}{3}$

34. The figure shows a system of two concentric spheres of radii r_1 and r_2 and kept at temperatures T_1 and T_2, respectively. The radial rate of flow of heat in a substance between the two concentric spheres, is proportional to :



(a) $\frac{(r_2 - r_1)}{(r_1 r_2)}$ (b) $\ln\left(\frac{r_2}{r_1}\right)$
(c) $\frac{r_1 r_2}{(r_2 - r_1)}$ (d) $(r_2 - r_1)$

35. A system goes from A to B *via* two processes I and II as shown in figure. If ΔU_1 and ΔU_2 are the changes in internal energies in the processes I and II respectively, then :



(a) $\Delta U_1 = \Delta U_2$
(b) relation between ΔU_1 and ΔU_2 cannot be determined
(c) $\Delta U_2 > \Delta U_1$
(d) $\Delta U_2 < \Delta U_1$

36. The function $\sin^2(\omega t)$ represents :
(a) a periodic, but not simple harmonic, motion with a period $\frac{2\pi}{\omega}$
(b) a periodic, but not simple harmonic, motion with a period $\frac{\pi}{\omega}$
(c) a simple harmonic motion with a period $2\pi/\omega$
(d) a simple harmonic motion with a period π/ω

37. A Young's double slit experiment uses a monochromatic source. The shape of the interference fringes formed on a screen is :
(a) hyperbola (b) circle
(c) straight line (d) parabola

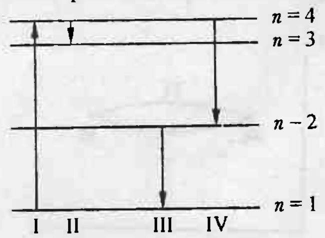
38. Two simple harmonic motions are represented by the equations $y_1 = 0.1 \sin\left(100\pi t + \frac{\pi}{3}\right)$ and $y_2 = 0.1 \cos \pi t$. The phase difference of the velocity of particle 1, with respect to the velocity of particle 2 is :
(a) $\frac{-\pi}{6}$ (b) $\frac{\pi}{3}$
(c) $\frac{-\pi}{3}$ (d) $\frac{\pi}{6}$

39. 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 water surface, the radius of this circle in cm is :
(a) $36\sqrt{7}$ (b) $\frac{36}{\sqrt{7}}$
(c) $36\sqrt{5}$ (d) $4\sqrt{5}$

40. Two point white dots are 1 mm apart on a black paper. They are viewed by eye of pupil diameter 3 mm. Approximately, what is the maximum distance at which these dots can be resolved by the eye ? [Take wavelength of light = 500 nm]
(a) 5 m (b) 1 m
(c) 6 m (d) 3 m

41. A thin glass (refractive index 1.5) lens has optical power of − 5 D in air. Its optical power in a liquid medium with refractive index 1.6 will be :
(a) 1 D (b) − 1 D
(c) 25 D (d) − 25 D

42. The diagram shows the energy levels for an electron in a certain atom. Which transition shown represents the emission of a photon with the most energy ?



(a) III (b) IV
(c) I (d) II

43. If the kinetic energy of a free electron doubles, its de-Broglie wavelength changes by the factor :

(a) $\frac{1}{2}$ (b) 2

(c) $\frac{1}{\sqrt{2}}$ (d) $\sqrt{2}$

44. In a common base amplifier, the phase difference between the input signal voltage and output voltage is :

(a) $\frac{\pi}{4}$ (b) π (c) zero (d) $\frac{\pi}{2}$

45. In a full wave rectifier circuit operating from 50 Hz mains frequency, the fundamental frequency in the ripple would be :

(a) 50 Hz (b) 25 Hz
(c) 100 Hz (d) 70.7 Hz

46. A nuclear transformation is denoted by $X(n, \alpha) \rightarrow {}^{7}_{3}\text{Li}$. Which of the following is the nucleus of element X ?

(a) ${}^{12}_{6}\text{C}$ (b) ${}^{10}_{5}\text{B}$
(c) ${}^{9}_{5}\text{B}$ (d) ${}^{11}_{4}\text{Be}$

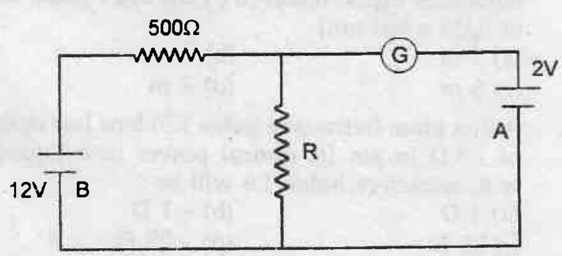
47. A moving coil galvanometer has 150 equal divisions. Its current sensitivity is 10 divisions per milliampere and voltage sensitivity is 2 divisions per millivolt. In order that each division reads 1 volt, the resistance in ohms needed to be connected in series with the coil will be :

(a) 10^3 (b) 10^5 (c) 99995 (d) 9995

48. Two voltameters, one of copper and another of silver, are joined in parallel. When a total charge q flows through the voltameters, equal amount of metals are deposited. If the electrochemical equivalents of copper and silver are z_1 and z_2 respectively, the charge which flows through the silver voltameter is :

(a) $\dfrac{q}{1+\dfrac{z_1}{z_2}}$ (b) $\dfrac{q}{1+\dfrac{z_2}{z_1}}$ (c) $q\dfrac{z_1}{z_2}$ (d) $q\dfrac{z_2}{z_1}$

49. In the circuit, the galvanometer G shows zero deflection. If the batteries A and B have negligible internal resistance, the value of the resistor R will be :



(a) 200 Ω (b) 100 Ω
(c) 500 Ω (d) 1000 Ω

50. Two sources of equal emf are connected to an external resistance R. The internal resistances of the two sources are R_1 and R_2 $(R_2 > R_1)$. If the potential difference across the source having internal resistance R_2, is zero, then :

(a) $R = \dfrac{R_2 \times (R_1 + R_2)}{(R_2 - R_1)}$ (b) $R = R_2 - R_1$

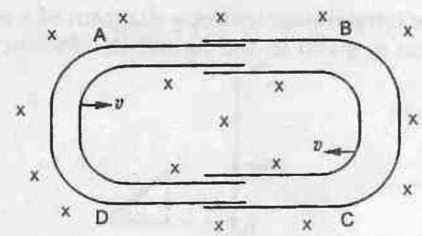
(c) $R = \dfrac{R_1 R_2}{(R_1 + R_2)}$ (d) $R = \dfrac{R_1 R_2}{(R_2 - R_1)}$

51. A fully charged capacitor has a capacitance 'C'. It is discharged through a small coil of resistance wire embedded in a thermally insulated block of specific heat capacity 's' and mass 'm'. If the temperature of the block is raised by 'ΔT', the potential difference 'V' across the capacitance is :

(a) $\sqrt{\dfrac{2mC\Delta T}{s}}$ (b) $\dfrac{mC\Delta T}{s}$

(c) $\dfrac{ms\Delta T}{C}$ (d) $\sqrt{\dfrac{2ms\Delta T}{C}}$

52. One conducting U tube can slide inside another as shown in figure, maintaining electrical contacts between the tubes. The magnetic field B is perpendicular to the plane of the figure. If each tube moves towards the other at a constant speed v, then the emf induced in the circuit in terms of B, l and v, where l is the width of each tube, will be :



(a) Blv (b) $-Blv$
(c) zero (d) $2Blv$

53. A heater coil is cut into two equal parts and only one part is now used in the heater. The heat generated will now be :

(a) doubled (b) four times
(c) one-fourth (d) halved

54. Two thin, long, parallel wires, separated by a distance 'd' carry a current of 'i' A in the same direction. They will :

(a) attract each other with a force of $\dfrac{\mu_0 i^2}{(2\pi d)}$

(b) repel each other with a force of $\dfrac{\mu_0 i^2}{(2\pi d)}$

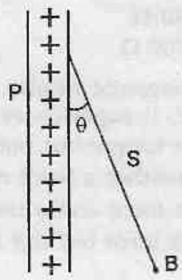
(c) attract each other with a force of $\dfrac{\mu_0 i^2}{(2\pi d^2)}$

(d) repel each other with a force of $\dfrac{\mu_0 i^2}{(2\pi d^2)}$

55. When an unpolarized light of intensity I_0 is incident on a polarizing sheet, the intensity of the light which does not get transmitted is :

(a) $\frac{1}{2} I_0$ (b) $\frac{1}{4} I_0$ (c) zero (d) I_0

56. A charged ball B hangs from a silk thread S, which makes an angle θ with a large charged conducting sheet P, as shown in the figure. The surface charge density σ of the sheet is proportional to :



(a) $\cos\theta$ (b) $\cot\theta$
(c) $\sin\theta$ (d) $\tan\theta$

57. Two point charges $+8q$ and $-2q$ are located at $x = 0$ and $x = L$ respectively. The location of a point on the x-axis at which the net electric field due to these two point charges is zero is :
(a) $2L$ (b) $\frac{L}{4}$
(c) $8L$ (d) $4L$

58. Two thin wire rings each having a radius R are placed at a distance d apart with their axes coinciding. The charges on the two rings are $+q$ and $-q$. The potential difference between the centres of the two rings is :
(a) $qR/4\pi\varepsilon_0 d^2$ (b) $\frac{q}{2\pi\varepsilon_0}\left[\frac{1}{R}-\frac{1}{\sqrt{R^2+d^2}}\right]$
(c) zero (d) $\frac{q}{4\pi\varepsilon_0}\left[\frac{1}{R}-\frac{1}{\sqrt{R^2+d^2}}\right]$

59. A parallel plate capacitor is made by stacking n equally spaced plates connected alternatively. If the capacitance between any two adjacent plates is 'C', then the resultant capacitance is :
(a) $(n-1)C$ (b) $(n+1)C$
(c) C (d) nC

60. When two tuning forks (fork 1 and fork 2) are sounded simultaneously, 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 ?
(a) 200 Hz (b) 202 Hz
(c) 196 Hz (d) 204 Hz

61. If a simple harmonic motion is represented by $\frac{d^2x}{dt^2} + \alpha x = 0$, its time period is :
(a) $\frac{2\pi}{\alpha}$ (b) $\frac{2\pi}{\sqrt{\alpha}}$
(c) $2\pi\alpha$ (d) $2\pi\sqrt{\alpha}$

62. The bob of a simple pendulum is a spherical hollow ball filled with water. A plugged hole near the bottom of the oscillating bob gets suddenly unplugged. During observation, till water is coming out, the time period of oscillation would :
(a) first increase and then decrease to the original value
(b) first decrease and then increase to the original value
(c) remain unchanged
(d) increase towards a saturation value

63. An observer moves towards a stationary source of sound, with a velocity one-fifth of the velocity of sound. What is the percentage increase in the apparent frequency ?
(a) Zero (b) 0.5% (c) 5% (d) 20%

64. If I_0 is the intensity of the principal maximum in the single slit diffraction pattern, then what will be its intensity when the slit width is doubled ?
(a) $2I_0$ (b) $4I_0$
(c) I_0 (d) $\frac{I_0}{2}$

65. Two concentric coils each of radius equal to 2π cm are placed at right angles to each other. 3 ampere and 4 ampere are the currents flowing in each coil respectively. The magnetic induction in weber/m^2 at the centre of the coils will be ($\mu_0 = 4\pi \times 10^{-7}$ Wb/A.m) :
(a) 12×10^{-5} (b) 10^{-5}
(c) 5×10^{-5} (d) 7×10^{-5}

66. A coil of inductance 300 mH and resistance 2 Ω is connected to a source of voltage 2V. The current reaches half of its steady state value in :
(a) 0.05 s (b) 0.1 s
(c) 0.15 s (d) 0.3 s

67. The self inductance of the motor of an electric fan is 10 H. In order to impart maximum power at 50 Hz, it should be connected to a capacitance of :
(a) 4 μF (b) 8 μF
(c) 1 μF (d) 2 μF

68. An energy source will supply a constant current into the load, if its internal resistance is :
(a) equal to the resistance of the load
(b) very large as compared to the load resistance
(c) zero
(d) non-zero but less than the resistance of the load

69. A circuit has a resistance of 12 ohm and an impedance of 15 ohm. The power factor of the circuit will be :
(a) 0.8 (b) 0.4
(c) 1.25 (d) 0.125

70. The phase difference between the alternating current and emf is $\frac{\pi}{2}$. Which of the following cannot be the constituent of the circuit ?
(a) C alone
(b) R, L
(c) L, C
(d) L alone

71. A uniform electric field and a uniform magnetic field are acting along the same direction in a certain region. If an electron is projected along the direction of the fields with a certain velocity, then :
(a) its velocity will decrease
(b) its velocity will increase
(c) it will turn towards right of direction of motion
(d) it will turn towards left of direction of motion

72. A charged particle of mass m and charge q travels on a circular path of radius r that is perpendicular to a magnetic field B. The time taken by the particle to complete one revolution is :
(a) $\frac{2\pi mq}{B}$ (b) $\frac{2\pi q^2 B}{m}$
(c) $\frac{2\pi qB}{m}$ (d) $\frac{2\pi m}{qB}$

73. In a potentiometer experiment the balancing with a cell is at length 240 cm. On shunting the cell with a resistance of 2 Ω, the balancing length becomes 120 cm. The internal resistance of the cell is :
(a) 1 Ω (b) 0.5 Ω
(c) 4 Ω (d) 2 Ω

74. The resistance of hot tungsten filament is about 10 times the cold resistance. What will be the resistance of 100 W and 200V lamp, when not in use ?
(a) 40 Ω (b) 20 Ω
(c) 400 Ω (d) 200 Ω

75. A magnetic needle is kept in a non-uniform magnetic field. It experiences :
(a) a torque but not a force
(b) neither a force nor a torque
(c) a force and a torque
(d) a force but not a torque

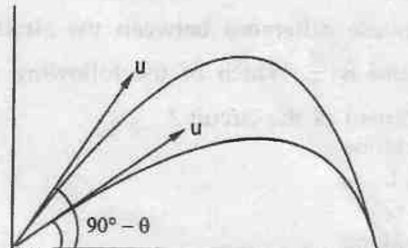
Answers

1.	(d)	2.	(d)	3.	(a)	4.	(c)	5.	(d)	6.	(c)	7.	(c)	8.	(*)
9.	(a)	10.	(c)	11.	(d)	12.	(a)	13.	(b)	14.	(d)	15.	(d)	16.	(a)
17.	(c)	18.	(d)	19.	(b)	20.	(c)	21.	(a)	22.	(b)	23.	(a,d)	24.	(c)
25.	(c)	26.	(d)	27.	(b)	28.	(d)	29.	(c)	30.	(b)	31.	(c)	32.	(a)
33.	(c)	34.	(c)	35.	(a)	36.	(b)	37.	(a)	38.	(a)	39.	(b)	40.	(a)
41.	(a)	42.	(a)	43.	(c)	44.	(c)	45.	(c)	46.	(b)	47.	(d)	48.	(b)
49.	(b)	50.	(b)	51.	(d)	52.	(d)	53.	(a)	54.	(a)	55.	(a)	56.	(d)
57.	(a)	58.	(b)	59.	(a)	60.	(c)	61.	(b)	62.	(b)	63.	(d)	64.	(c)
65.	(c)	66.	(b)	67.	(c)	68.	(c)	69.	(a)	70.	(c)	71.	(a)	72.	(d)
73.	(d)	74.	(a)	75.	(c)										

* None of the choices is correct.

Hints & Solutions

1. A projectile can have same range if angles of projection are complementary *i.e.*, θ and (90° – θ). Thus, in both cases :



$$t_1 = \frac{2u \sin \theta}{g} \quad \text{...(i)}$$

$$t_2 = \frac{2u \sin (90° - \theta)}{g}$$

$$= \frac{2u \cos \theta}{g} \quad \text{...(ii)}$$

From Eq. (i) and (ii)

$$t_1 t_2 = \frac{4u^2 \sin \theta \cos \theta}{g^2}$$

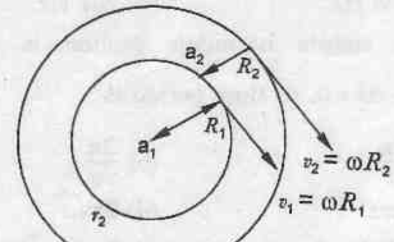
$$t_1 t_2 = \frac{2u^2 \sin 2\theta}{g^2}$$

$$= \frac{2}{g} \frac{u^2 \sin 2\theta}{g}$$

$$\therefore \quad t_1 t_2 = \frac{2R}{g} \quad \left(\because \; R = \frac{u^2 \sin 2\theta}{g} \right)$$

Hence, $t_1 t_2 \propto R$

2. $$ma_1 = \frac{mv_1^2}{R_1} \quad \text{...(i)}$$



and $$ma_2 = \frac{mv_2^2}{R_2} \quad \text{...(ii)}$$

and $$\frac{F_1}{F_2} = \frac{ma_1}{ma_2}$$

$$= \frac{mR_1^2\omega^2}{R_1} \cdot \frac{R_2}{mR_2^2\omega^2}$$

$$\therefore \quad \frac{F_1}{F_2} = \frac{R_1}{R_2}$$