Exercise - I (Objective Problems)

1. In a region of space, the electric field is in the x direction and is given as $\vec{E} = E_0 x\hat{i}$. Consider an imaginary cubical volume of edge a, with its edges parallel to the axes of coordinates. The charge inside this volume is

(A) zero (B) $\varepsilon_0 E_0 a^3$ (C) $\frac{1}{\varepsilon_0} E_0 a^3$ (D) $\frac{1}{6}\varepsilon_0 E_0 a^2$

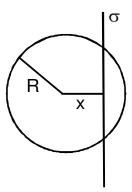
Sol.

2. Electric flux through a surface of area 100 m^2 lying in the xy plane is (in V-m) if $\vec{E} = \hat{i} + \sqrt{2}\,\hat{j} + \sqrt{3}\,\hat{k}$

(A) 100 (B) 141.4 (C) 173.2 (D) 200

Sol.

3. An infinite, uniformly charged sheet with surface charge density σ cuts through a spherical Gaussian surface of radius R at a distance x from its center, as shown in the figure. The electric flux Φ through the Gaussian surface is

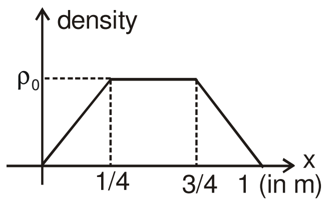


(A) $\frac{\pi R^2 \sigma}{\varepsilon_0}$ (B) $\frac{2\pi(R^2 - x^2)\sigma}{\varepsilon_0}$

(C) $\frac{\pi(R - x)^2 \sigma}{\varepsilon_0}$ (D) $\frac{\pi(R^2 - x^2)\sigma}{\varepsilon_0}$

Sol.

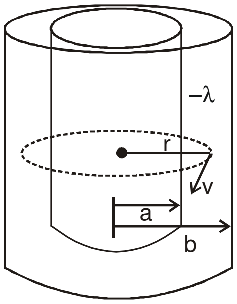
4. The volume charge density as a function of distance X from one face inside a unit cube is varying as shown in the figure. Then the total flux (in S.I. units) through the cube if (ρ_0 = 8.85 × 10^{-12} C/m^3) is :



(A) 1/4 (B) 1/2 (C) 3/4 (D) 1

Sol.

5. Figure shows two large cylindrical shells having uniform linear charge densities $+\lambda$ and $-\lambda$. Radius of inner cylinder is 'a' and that of outer cylinder is 'b'. A charged particle of mass m, charge q revolves in a circle of radius r, Then its speed 'v' is : (Neglect gravity and assume the radii of both the cylinders to be very small in comparison to their length.)

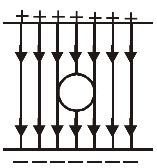


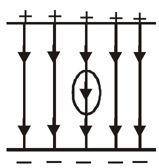
(A) $\sqrt{\frac{\lambda q}{2\pi \epsilon_0 m}}$ (B) $\sqrt{\frac{2\lambda q}{\pi \epsilon_0 m}}$

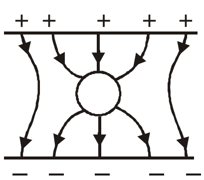
(C) $\sqrt{\frac{\lambda q}{\pi \epsilon_0 m}}$ (D) $\sqrt{\frac{\lambda q}{4\pi \epsilon_0 m}}$

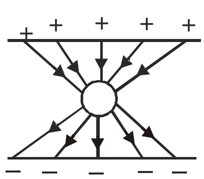
Sol.

6. An uncharged sphere of metal is placed in a uniform electric field produced by two large conducting parallel plates having equal and opposite charges, then lines of force look like :

(A) 

(B) 

(C) 

(D) 

Sol.

7. A hollow metal sphere of radius 5 cm is charged such that the potential on its surface is 10 V. The potential at the centre of the sphere is

(A) 0 V

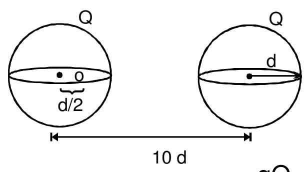
(B) 10 V

(C) same as at point 5 cm away from the surface out side sphere

(D) same as a point 25 cm away from the surface

Sol.

8. Two spherical, nonconducting, and very thin shells of uniformly distributed positive charge Q and radius d are located a distance 10d from each other. A positive point charge q is placed inside one of the shells at a distance d/2 from the center, on the line connecting the centers of the two shells, as shown in the figure. What is the net force on the charge q ?



(A) $\frac{qQ}{361\pi\varepsilon_0 d^2}$ to the left (B) $\frac{qQ}{361\pi\varepsilon_0 d^2}$ to the right

(C) $\frac{362\,qQ}{361\pi\varepsilon_0 d^2}$ to the left (D) $\frac{360\,qQ}{361\pi\varepsilon_0 d^2}$ to the right

Sol.

9. Potential difference between centre & the surface of sphere of radius R and uniform volume charge density ρ within it will be -

(A) $\frac{\rho R^2}{6 \epsilon_0}$ (B) $\frac{\rho R^2}{4 \epsilon_0}$ (C) 0 (D) $\frac{\rho R^2}{2 \epsilon_0}$

Sol.

10. A solid sphere of radius R is charged uniformly. At what distance from its surface is the electrostatic potential half of the potential at the centre ?

(A) R (B) R/2 (C) R/3 (D) 2R

Sol.

11. Two similar conducting spherical shells having charges 40 μC and −20μC are some distance apart. Now they are touched and kept at same distance. The ratio of the initial to the final force between them is :

(A) 8 : 1 (B) 4 : 1 (C) 1 : 8 (D) 1 : 1

Sol.

12. n small drops of same size are charged to V volts each. If they coalesce to form a signal large drop, then its potential will be -

(A) V/n (B) Vn (C) $Vn^{1/3}$ (D) $Vn^{2/3}$

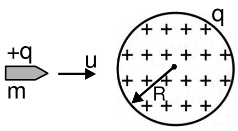
Sol.

13. 1000 identical drops of mercury are charged to a potential of 1 V each. They join to form a single drop. The potential of this drop will be -

(A) 0.01 V (B) 0.1 V (C) 10 V (D) 100 V

Sol.

14. A bullet of mass m and charge q is fired towards a solid uniformly charged sphere of radius R and total charge +q. If it strikes the surface of sphere with speed u, find the minimum speed u so that it can penetrate through the sphere. (Neglect all resistance forces or friction acting on bullet except electrostatic forces)

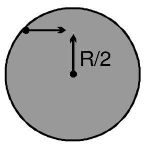


(A) $\frac{q}{\sqrt{2\pi\varepsilon_0 mR}}$ (B) $\frac{q}{\sqrt{4\pi\varepsilon_0 mR}}$

(C) $\frac{q}{\sqrt{8\pi\varepsilon_0 mR}}$ (D) $\frac{\sqrt{3}\,q}{\sqrt{4\pi\varepsilon_0 mR}}$

Sol.

15. A unit positive point charge of mass m is projected with a velocity V inside the tunnel as shown. The tunnel has been made inside a uniformly charged nonconducting sphere. The minimum velocity with which the point charge should be projected such it can it reach the opposite end of the tunnel, is equal to -



(A) $[\rho R^2/4m\varepsilon_0]^{1/2}$
(B) $[\rho R^2/24m\varepsilon_0]^{1/2}$
(C) $[\rho R^2/6m\varepsilon_0]^{1/2}$
(D) zero because the initial and the final points are at same potential.

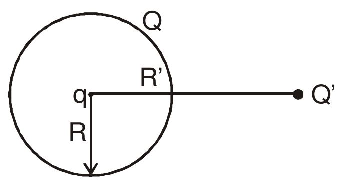
Sol.

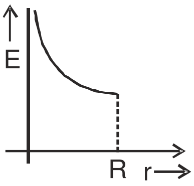
16. A positively charged body 'A' has been brought near a neutral brass sphere B mounted on a glass stand as shown in the figure. The potetial of B will be:

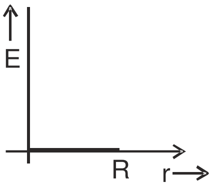
(A) Zero (B) Negative
(C) Positive (D) Infinite

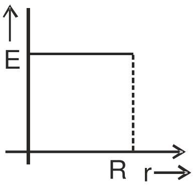
Sol.

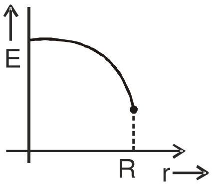
17. A charge 'q' is placed at the centre of a conducting spherical shell of radius R, which is given a charge Q. An external charge Q′ is also present at distance R′ (R′ > R) from 'q'. Then the resultant field will be best represented for region r < R by :
[where r is the distance of the point from q]



(A) 

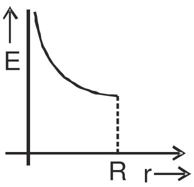
(B) 

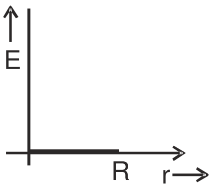
(C) 

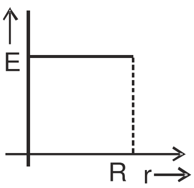
(D) 

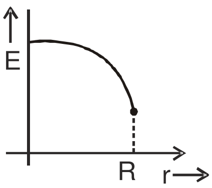
Sol.

18. In the above questins, if Q' is removed then which option is correct :

(A) 

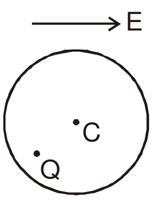
(B) 

(C) 

(D) 

Sol.

19. A positive point charge Q is kept (as shown in the figure) inside a neutral conducting shell whose centre is at C. An external uniform electric field E is applied. Then :

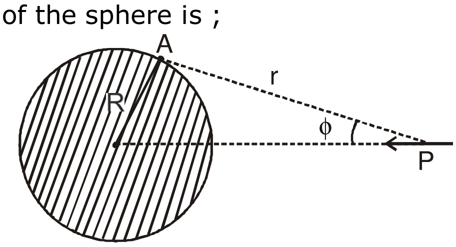


(A) Force on Q due to E is zero
(B) Net force on Q is zero
(C) Net force acting on Q and conducting shell considered as a system is zero
(D) Net force acting on the shell due to E is zero.
Sol.

20. The net charge given to an isolated conducting solid sphere :
(A) must be distributed uniformly on the surface
(B) may be distributed uniformly on the surface
(C) must be distributed uniformly in the volume
(D) may be distributed uniformly in the volume.
Sol.

21. The net charge given to a solid insulating sphere:
(A) must be distributed uniformly in its volume
(B) may by distributed uniformly in its volume.
(C) must be distributed uniformly on its surface.
(D) the distribution will depend upon whether other charges are present or not.
Sol.

22. A dipole having dipole moment p is placed in front of a solid uncharged conducting sphere as shown in the diagram. The net potential at point. A lying on the surface of the sphere is ;



(A) $\frac{kp\cos\phi}{r^2}$ (B) $\frac{kp\cos^2\phi}{r^2}$

(C) zero (D) $\frac{2kp\cos^2\phi}{r^2}$

Sol.

23. Three concentric conducting spherical shells carry charges as follows +4Q on the inner shell, −2Q on the middle shell and −5Q on the outer shell. The charge on the inner surface of the outer shell is :

(A) 0 (B) 4 Q (C) −Q (D) −2Q

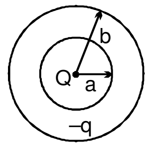
Sol.

24. Three concentric metallic spherical shell A, B and C or radii a, b and c (a < b < c) have surface charge densities $-\sigma$, $+\sigma$, and $-\sigma$ respectively. The potential of shell A is -

(A) $(\sigma/\varepsilon_0)[a + b - c]$ (B) $(\sigma/\varepsilon_0)[a - b + c]$
(C) $(\sigma/\varepsilon_0)[b - a - c]$ (D) none

Sol.

25. Both question (a) and (b) refer to the system of charges as shown in the figure. A spherical shell with an inner radius 'a' and an outer radius 'b' is made of conducting material. A point charge +Q is placed at the centre of the spherical shell and a total charge −q is placed on the shell.



(i) charge −q is distributed on the surfaces as
(A) −Q on the inner surface, − q on outer surface
(B) −Q on the inner surface, − q + Q on the outer surface
(C) +Q on the inner surface, − q − Q on the outer surface
(D) The charge −q is spread uniformly between the inner and outer surface

Sol.

(ii) Assume that the electrostatic potential is zero at an infinite distance from the spherical shell. The electrostatic potential at a distance R(a < R < b) from the centre of the shell is

(A) 0 (B) $\frac{KQ}{a}$ (C) $K\frac{Q-q}{R}$

(D) $K\frac{Q-q}{b}$ (where $K = \frac{1}{4\pi\varepsilon_0}$)

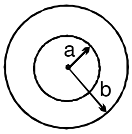
Sol.

26. A positive charge q is placed in a spherical cavity made in a positively charged sphere. The centres of sphere and cavity are displaced by a small distance $\vec{l}$. Force on charge q is :

(A) in the direction parallel to vector $\vec{l}$
(B) in radial direction
(C) in a direction which depends on the magnitude of charge density in sphere
(D) direction can not be determined

Sol.

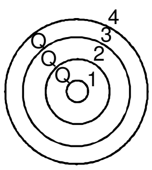
27. If the electric potential of the inner metal sphere is 10 volt & that of the outer shell is 5 volt, then the potential at the centre will be -



(A) 10 volt (B) 5 volt (C) 15 volt (D) 0

Sol.

28. An infinite number of concentric rings carry a charge Q each alternately positive and negative. Their radii are 1, 2, 4, 8... meters in geometric progression as shown in the figure. The potential at the centre of the rings will be



(A) zero (B) $\frac{Q}{12\pi\varepsilon_0}$ (C) $\frac{Q}{8\pi\varepsilon_0}$ (D) $\frac{Q}{6\pi\varepsilon_0}$

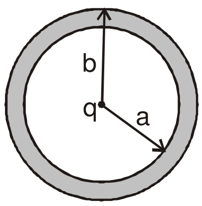
Sol.

29. Two uniformly charged non-conducting hemispherical sheels each having uniform charge density σ and radius R form a complete sphere (not stuck together) and surround a concentric spherical conducting shell of radius R/2. If hemispherical parts are in equilibrium then minimum surface charge density of inner conducting shell is :

(A) −2σ (B) −σ/2 (C) −σ (D) 2σ

Sol.

30. A point charge q is borught from infinity (slowly so that heat developed in the shell is negligible) and is placed at the centre of a conducting neutral spherical shell of inner radius a and outer radius b, then work done by external agent is:



(A) 0 (B) $\frac{kq^2}{2b}$ (C) $\frac{kq^2}{2b} - \frac{kq^2}{2a}$ (D) $\frac{kq^2}{2a} - \frac{kq^2}{2b}$

Sol.

31. A charge Q is kept at the centre of a conducting sphere of inner radius R_1 and outer radius R_2. A point charge q is kept at a distance r (> R_2) from the centre. If q experiences an electrostatic force 10 N then assuming that no other charges are present, electrostatic force experienced by Q will be :

(A) – 10 N (B) 0

(C) 20 N (D) none of these

Sol.

32. A solid metallic sphere has a charge +3Q. Concentric with this sphere is a conducting spherical shell having charge –Q. The radius of the sphere is a and that of the spherical shell is b (>a). What is the electric field at a distance r (a < r < b) from the centre ?

(A) $\frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$ (B) $\frac{1}{4\pi\varepsilon_0}\frac{3Q}{r}$

(C) $\frac{1}{4\pi\varepsilon_0}\frac{3Q}{r^2}$ (D) $\frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$

Sol.

33. Two identical conducting spheres, having charges of opposite sign, attract each other with a force of 0.108 N when separated by 0.5 m. The spheres are connected by a conducting wire, which is then removed, and thereafter, they repel each other with a force of 0.036 N. The initial charges on the spheres are

(A) $\pm 5 \times 10^{-6}$ C and $\mp 15 \times 10^{-6}$ C

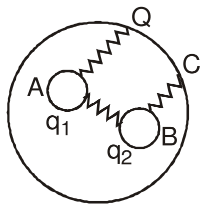
(B) $\pm 1.0 \times 10^{-6}$ C and $\mp 3.0 \times 10^{-6}$ C

(C) $\pm 2.0 \times 10^{-6}$ C and $\mp 6.0 \times 10^{-6}$ C

(D) $\pm 0.5 \times 10^{-6}$ C and $\mp 1.5 \times 10^{-6}$ C

Sol.

34. Two small conductors A and B are given charges q_1 and q_2 respectively. Now they are placed inside a hollow metallic conductor (C) carrying a charge Q. If all the three conductors A, B and C are connected by a conducting wire as shown, the charges on A, B and C will be respectively.



(A) $\frac{q_1+q_2}{2}, \frac{q_1+q_2}{2}, Q$

(B) $\frac{Q+q_1+q_3}{3}, \frac{Q+q_1+q_2}{3}, \frac{Q+q_1+q_2}{3}$

(C) $\frac{q_1+q_2+Q}{2}, \frac{q_1+q_2+Q}{3}, 0$

(D) 0, 0, $Q + q_1 + q_2$

Sol.

35. There are four concentric shells A, B, C and D of radii a, 2a, 3a and 4a respectively. Shells B and D are given charges +q and −q respectively. Shell C is now earthed. The potential difference $V_A - V_C$ is :

(A) $\frac{Kq}{2a}$ (B) $\frac{Kq}{3a}$ (C) $\frac{Kq}{4a}$ (D) $\frac{Kq}{6a}$

Sol.

36. You are travelling in a car during a thunder storm. In order to protect yoursefl from lightening, would you prefer to :

(A) Remain in the car

(B) Take shelter under a tree

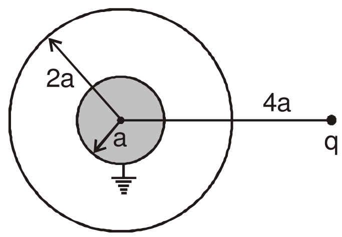
(C) Get out and be flat on the ground

(D) Touch the nearest electrical pole

Sol.

COMPREHENSION

A solid conducting sphere of radius 'a' is surronded by a thin uncharged concentric conducting shell of radius 2a. A point charge q is placed at a distance 4a from common centre of conducting sphere and shell. The inner sphere is then grounded.



37. The charge on solid sphere is :

(A) $-\frac{q}{2}$ (B) $-\frac{q}{4}$ (C) $-\frac{q}{8}$ (D) $-\frac{q}{16}$

Sol.

38. Pick up the correct statement :
(A) Charge on surface on inner sphere is non-uniformly distributed
(B) Charge on inner surface of outer shell in non-uniformly distributed.
(C) Charge on outer surface of outer shell is non-uniformly distributed.
(D) All the above statement are false.
Sol.

39. The potential of outer shell is :

(A) $\frac{q}{32\pi\varepsilon_0 a}$ (B) $\frac{q}{16\pi\varepsilon_0 a}$

(C) $\frac{q}{8\pi\varepsilon_0 a}$ (D) $\frac{q}{4\pi\varepsilon_0 a}$

Sol.

REASONING TYPE QUESTION

40. Statement - 1 : If a concentric spherical Gaussian surface is drawn inside thin spheical shell of charge, electric field (E) at each point of surface must be zero.
Statement - 2 : In accordance with Gauss's law

$$\phi_E = \oint \vec{E}.d\vec{A} = \frac{Q_{\text{net enclosed}}}{\varepsilon_0}$$

$$Q_{\text{net enclosed}} = 0 \text{ implies } \phi_E = 0$$

(A) Statement - 1 is true, Statement - 2 is true and statement - 2 is correct explanation for statement - 1.
(B) Statement - 1 is true, Statement - 2 is true and statement - 2 is NOT correct explanation for statement - 1.
(C) Statement - 1 is true, statement - 2 is false.
(D) Statement - 1 is false, statement - 2 is true.
Sol.

41. Statement - 1 : Electric field of a dipole can't be found using only Gauss law. (i.e. without using superposition principle)
Statement - 2 : Gauss law is valid only for symmetrical charge distribution
(A) Statement - 1 is true, Statement - 2 is true and statement - 2 is correct explanation for statement - 1.
(B) Statement - 1 is true, Statement - 2 is true and statement - 2 is NOT correct explanation for statement - 1.
(C) Statement - 1 is true, statement - 2 is false.
(D) Statement - 1 is false, statement - 2 is true.
Sol.

42. Statement - 1 : In a given situation of arrangement of charges, an extra charge is placed outside the Gaussian surface. In the Gauss Theorem

$$\oint \vec{E}.d\vec{A} = \frac{Q_{in}}{\epsilon_0}$$

Q_{in} remains unchanged whereas electric field $\vec{E}$ at the site of the element is changed.

Statement - 2 : Electric field $\vec{E}$ at any point on the Gaussian surface is due to inside charge only.

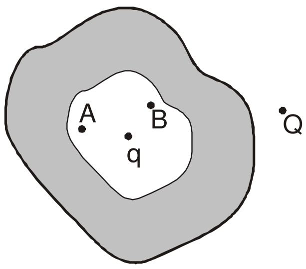
(A) Statement - 1 is true, Statement - 2 is true and statement - 2 is correct explanation for statement - 1.
(B) Statement - 1 is true, Statement - 2 is true and statement - 2 is NOT correct explanation for statement - 1.
(C) Statement - 1 is true, statement - 2 is false.
(D) Statement - 1 is false, statement - 2 is true.
Sol.

43. Statement - 1 : The flux crossing through a closed surface is independent of the location of encloses charge.
Statement - 2 : Upon the displacement of charges within a closed surface, the $\vec{E}$ at any point on surface does not change.
(A) Statement - 1 is true, Statement - 2 is true and statement - 2 is correct explanation for statement - 1.
(B) Statement - 1 is true, Statement - 2 is true and statement - 2 is NOT correct explanation for statement - 1.
(C) Statement - 1 is true, statement - 2 is false.
(D) Statement - 1 is false, statement - 2 is true.
Sol.

44. The electrostatic potential on the surface of a charged solid conducting sphere is 100 volts. Two statements are made in this regard
Statement - 1 : At any point inside the sphere, electrostatic potetial is 100 volt.
Statement - 2 : At any point inside the sphere, electric field is zero.
(A) Statement - 1 is true, Statement - 2 is true and statement - 2 is correct explanation for statement - 1.
(B) Statement - 1 is true, Statement - 2 is true and statement - 2 is NOT correct explanation for statement - 1.
(C) Statement - 1 is true, statement - 2 is false.
(D) Statement - 1 is false, statement - 2 is true.
Sol.

45. When two charged concentric spherical conductors have electric potential V_1 and V_2 respectively
Statement - 1 : The potential at centre is $V_1 + V_2$
Statement - 2 : Potential is scalar quantity.
(A) Statement - 1 is true, Statement - 2 is true and statement - 2 is correct explanation for statement - 1.
(B) Statement - 1 is true, Statement - 2 is true and statement - 2 is NOT correct explanation for statement - 1.
(C) Statement - 1 is true, statement - 2 is false.
(D) Statement - 1 is false, statement - 2 is true.
Sol.

46. Statement - 1 : A point charge q is placed inside a cavity of conductor as shown. Another point charge Q is placed outside the conductor as shown. Now as the point charge Q pushed away from conductor, the potential difference $(V_A - V_B)$ between two point A and B within the cavity of sphere remains constant.
Statement - 2 : The electric field due to charges on outer surface of conductor and outside the conductor is zero at all points inside the conductor.



(A) Statement - 1 is true, Statement - 2 is true and statement - 2 is correct explanation for statement - 1.
(B) Statement - 1 is true, Statement - 2 is true and statement - 2 is NOT correct explanation for statement - 1.
(C) Statement - 1 is true, statement - 2 is false.
(D) Statement - 1 is false, statement - 2 is true.
Sol.

EXERCISE - II

1. Units of electric flux are -

(A) $\frac{N-m^2}{Coul^2}$ (B) $\frac{N}{Coul^2-m^2}$

(C) volt-m (D) Volt-m^3

Sol.

2. An electric dipole is placed at the centre of a sphere. Mark the correct answer

(A) the flux of the electric field through the sphere is zero

(B) the electric field is zero at every point of the sphere.Ex

(C) the electric potential is zero everywhere on the sphere.

(D) the electric potential is zero on a circle on the surface.

Sol.

3. Which of the following statements are correct?

(A) Electric field calculated by Gauss law is the field due to only those charges which are enclosed inside the Gaussian surface.

(B) Gauss law is applicable only when there is a symmetrical distribution of charge.

(C) Electric flux through a closed surface will depends only on charges enclosed within that surface only.

(D) None of these

Sol.

4. Mark the correct options -

(A) Gauss's law is valid only for uniform charge distributions.

(B) Gauss's law is valid only for charges placed in vacuum.

(C) The electric field calculated by Gauss's law is the field due to all the charges.

(D) The flux of the electric field through a closed surface due to all the charges is equal to the flux due to the charges enclosed by the surface.

Sol.

5. Charges Q_1 and Q_2 lies inside and outside respectively of a closed surface S. Let E be the field at any point on S and ϕ be the flux of E over S.

(A) If Q_1 changes, both E and ϕ will change.

(B) If Q_2 changes, E will change but ϕ will not change.

(C) If $Q_1 = 0$ and $q_2 \neq 0$ then $E \neq 0$ but $\phi = 0$.

(D) If $Q_1 \neq 0$ and $Q_2 = 0$ then $E = 0$ but $\phi \neq 0$.

Sol.

6. An electric field converges at the origin whose magnitude is given by the expression E = 100rNt/Coul, where r is the distance measured from the origin.

(A) total charge contained in any spherical volume with its centre at origin in negative.

(B) total charge contained at any spherical volume, irrespective of the location of its centre, is negative.

(C) total charge contained in a spherical volume of radius 3 cm with its centre at origin has magnitude 3×10^{-13}C.

(D) total charge contained in a spherical volume of radius 3 cm with its centre at origin has magnitude 3×10^{-9} Coul.

Sol.

7. A conducting sphere of radius r has a charge. Then
(A) The charge is uniformly distributed over its surface, if there is an external electric field.
(B) Distribution of charge over its surface will be non unifrom if no external electric field exist in space.
(C) Electric field strength inside the sphere will be equal to zero only when no external electric field exists.
(D) Potential at every point of the sphere must be same
Sol.

8. For a spherical shell
(A) If potential inside it is zero then it necessarily electrically neutral
(B) electric field in a charged conducting spherical shell can be zero only when the charge is uniformly distributed
(C) electric potential due to induced charges at a point inside it will always be zero
(D) none of these
Sol.

9. At distance of 5cm and 10cm outwards from the surface of a uniformly charged solid sphere, the potentials are 100V and 75V respectively. Then
(A) potential at its surface is 150V
(B) the charge on the sphere is $(5/3) \times 10^{-10}$ C
(C) the electric field on the surface is 1500 V/m
(D) the electric potential at its centre is 225 V
Sol.

10. A thin-walled, spherical conducting shell S of radius R is given charge Q. The same amount of charge is also placed at its centre C. Which of the following statements are correct ?
(A) On the outer surface of S, the charge density is $\frac{Q}{2\pi R^2}$.
(B) The electric field is zero at all points inside S.
(C) At a point just outside S, the electric field is double the field at a point just inside S.
(D) At any point inside S, the electric field is inversely proportional to the square of its distance from C.

Sol.

11. A hollow closed conductor of irregular shape is given some charge. Which of the following statements are correct ?

(A) The entire charge will appear on its outer surface.

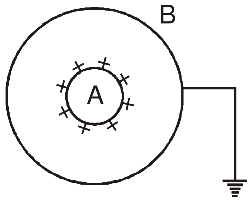
(B) All points on the conductor will have the same potential

(C) All points on its surface will have the same charge density.

(D) All points near its surface and outside it will have the same electric intensity.

Sol.

12. A and B are two conducting concentric spherical shells. A is given a charge Q while B is uncharged. If now B is earthed as shown in figure. Then :



(A) The charge appearing on inner surface of B is –Q

(B) The field inside the outside A is zero.

(C) The field between A and B is not zero.

(D) The charge appearing on outer surface of B is zero.

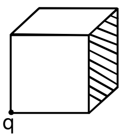
Sol.

Exercise - III (SUBJECTIVE PROBLEMS)

1. What do you predict by the given statement about the nature of charge (positive or negative) enclosed by the close surface. "In a close surface lines which are leaving the surface are double then the lines which are entering in it."

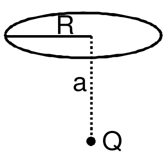
Sol.

2. The length of each side of a cubical closed surface is l. If charge q is situated on one of the vertices of the cube, then find the flux passing through shaded face of the cube.



Sol.

3. A point charge Q is located on the axis of a disc of radius R at a distance a from the plane of the disc. If one fourth (1/4th) of the flux from the charge passes through the disc, then find the relation between a & R.



Sol.

4. A charge Q is uniformly distributed over a rod of length l. Consider a hypothetical cube of edge l with the centre of the cube at one end of the rod. Find the minimum possible flux of the electric field through the entire surface of the cube.

Sol.

5. A very long uniformly charged thread oriented along the axis of a circle of radius R rests on its centre with one of the ends. The charge on the thread per unit length is equal to λ. Find the flux of the vector E through the circle area.

Sol.

6. A particle of mass m and charge –q moves along a diameter of a uniformly charged sphere of radius R and carrying a total charge +Q. Find the frequency of S.H.M. of the particle if the amplitude does not exceed R.

Sol.

7. There are 27 drops of a conducting fluid. Each has radius r and they are charged to a potential V_0. They are then combined to form a bigger drop. Find its potential.

Sol.

8. There are two concentric metal shells of radii r_1 and r_2 (> r_1). If initially the outer shell has a charge q and the inner shell is having zero charge. Now inner shell is grounded. Find :

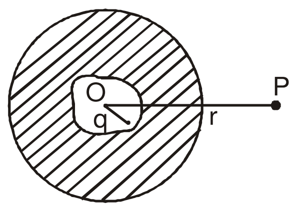
(i) Charge on the inner surface of outer shell.

(ii) Final charges on each sphere.

(iii) Charge flown through wire in the ground.

Sol.

9. A point charge 'q' is within an electrically neutral conducting shell whose other surface has spherical shape. Find potential V at point P lying outiside shell at a distance 'r' from centre O of outer sphere.

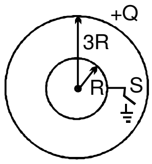


Sol.

10. Consider two concentric conducting spheres of radii a & b (b > a). Inside sphere has a positive charge q_1. What charge should be given to the outer sphere so that potential of the inner sphere becomes zero? How does the potential varies between the two spheres & outside ?

Sol.

11. Two thin conducting shells of radii R and 3R are shown in figure. The outer shell carries a charge +Q and the inner shell is neutral. The inner shell is earthed with the help of switch S. Find the charge attained by the inner shell.

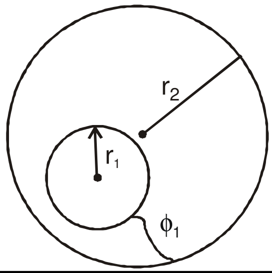


Sol.

12. Consider three identical metal spheres A, B and C. Spheres A carries charge +6q and sphere B carries charge –3q. Sphere C carries no charge. Spheres A and B are touched together and then separated. Sphere C is then touched to sphere A and separated from it. Finally the sphere C is touched to sphere B and separated from it. Find the final charge on the sphere C.

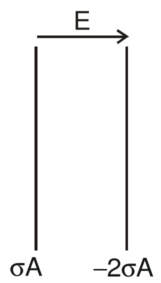
Sol.

13. A metal sphere of radius r_1 charged to a potential V_1 is than placed in a thin-walled uncharged conducting spherical shell of radius r_2. Determine the potential acquired by the spherical shell after it has been connected for a short time to the spher by a conductor.



Sol.

14. Two thin conducting plates (very large) parallel to each other carrying total charges σA and $-2\sigma A$ respectively (where A is the area of each plate), are placed in a uniform external electric field E as shown. Find the surface charge on each surface.

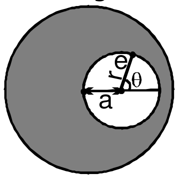


Sol.

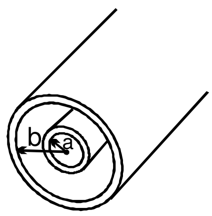
Exercise - IV (TOUGH SUBJECTIVE PROBLEMS)

1. A positive charge Q is uniformly distributed throughout the volume of a dielectric sphere of radius R. A point mass having charge +q and mass m is fired towards the centre of the sphere with velocity v from a point at distance r (r > R) from the centre of the sphere. Find the minimum velocity v so that it can penetrate R/2 distance of the sphere. Neglect any resistance other than electric interaction. Charge on the small mass remains constant throughout the motion.

2. A cavity of radius r is present inside a solid dielectric sphere of radius R, having a volume charge density of ρ. The distance between the centres of the sphere and the cavity is a. An electron e is kept inside the cavity at an angle θ = 45° as shown. How long will it take to touch the sphere again ?



3. Figure shows a section through two long thin concentric cylinders of radii a & b with a < b. The cylinders have equal and opposite charges per unit length λ. Find the electric field at a distance r from the axis for -

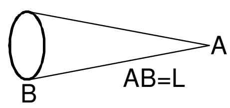


(A) r < a (B) a < r < b (C) r > b

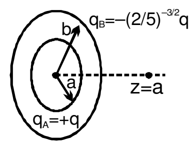
4. A solid non conducting sphere of radius R has a non-uniform charge distribution of volume charge density, $\rho = \rho_0 \frac{r}{R}$, where ρ_0 is a constant and r is the distance from the centre of the sphere. Show that -
(a) the total charge on the sphere is $Q = \pi\rho_0 R^3$ and
(b) the electric field inside the sphere has a magnitude given by, $E = \frac{KQr^2}{R^4}$.

5. An electron beam after being accelerated from rest through a potential difference of 500 V in vacuum is allowed to impinge normally on a fixed surface. If the incident current is 100 μA, determine the force exerted on the surface assuming that it brings the electrons to rest. ($e = 1.6 \times 10^{-19}$ C; $m = 9.0 \times 10^{-31}$ kg)

6. A cone made of insulating material has a total charge Q spread uniformly over its sloping surface. Calculate the energy required to take a test charge q from infinity to apex A of cone. The slant length is L.



7. Two concentric rings, one of radius 'a' and the other of radius 'b' have the charges +q and $-(2/5)^{-3/2}$ q respectively as shown in the figure. Find the ratio b/a if a charge particle placed on the axis at z = a is in equilibrium.



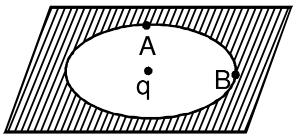
Exercise - V (JEE-PROBLEMS)

1. The magnitude of electric field $\vec{E}$ in the annular region of charged cylindrical capacitor
(A) Is same throughout **[IIT-96,2]**
(B) Is higher near the outer cylinder than near the inner cylinder
(C) Varies as (1/r) where r is the distance from the axis
(D) Varies as $(1/r^2)$ where r is the distance from the axis
Sol.

2. A conducting sphere S_1 of radius r is attached to an insulating handle. Another conducting sphere S_2 of radius R is mounted on an insulating stand. S_2 is initially uncharged. S_1 is given a charge Q, brought into contact with S_2 & removed, S_1 is recharged such that the charge on it is again Q & it is again brought into contact with S_2 & removed. This procedure is repeated n times. **[IIT-98]**
(a) Find the electrostatic energy of S_2 after n such contacts with S_1
(b) What is the limiting value of this energy as $n \to \infty$?

Sol.

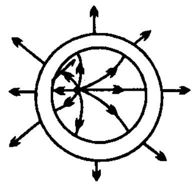
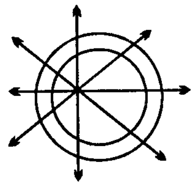
3. A n ellipsoidal cavity is carved within a perfect conductor. A positive charge q is placed at the center of the cavity. The points A & B are on the cavity surface as shown in the figure. Then **[IIT-99,3]**

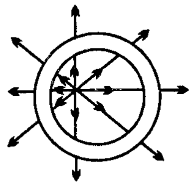
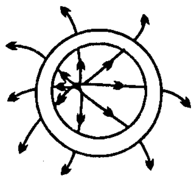


(A) electric field near A in the cavity = electric field near B in the cavity
(B) charge density at A = charge density at B
(C) potential at A = potential at B
(D) total electric field flux through the surface of the cavity is q/ε_0
Sol.

(ii)A non-conducting disc of radius a and uniform positive surface charge density σ is placed on the ground, with its axis vertical. A particle of mass m & positive charge q is dropped, along the axis of the disc, from a height H with zero initial velocity. The particle has $\frac{q}{m} = \frac{4\varepsilon_0 g}{\sigma}$ **[IIT-99]**
(i) Find the value of H if the particle just reaches the disc.
(ii) Sketch the potential energy of the particle as a function of its height and find its equilibrium position.
Sol.

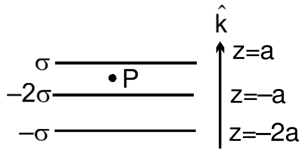
4. A point charge 'q' is placed at a point inside a hollow conducting sphere. Which of the following electric force pattern is correct ?

(A)  (B) 

(C)  (D) 

Sol.

5. Three large parallel plates have uniform surface charge densities as shown in the figure. What is the electric field at P. **[JEE' 2005 (Scr)]**



(A) $-\frac{4\sigma}{\epsilon_0}\hat{k}$ (B) $\frac{4\sigma}{\epsilon_0}\hat{k}$

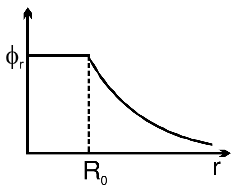
(C) $-\frac{2\sigma}{\epsilon_0}\hat{k}$ (D) $\frac{2\sigma}{\epsilon_0}\hat{k}$

Sol.

6. A conducting liquid bubble of radius a and thickness t (t<<a) is charged to potential V. If the bubble collapses to a droplet, find the potential on the droplet. **[JEE2005]**

Sol.

7. The electrostatic potential (ϕ_r) of a spherical symmetric system, kept at origin, is shown in the adjacent figure, and given as **[JEE 2006]**



$$\phi = \frac{q}{4\pi \in_0 r}(r \geq R_0)$$

$$\phi_r = \frac{q}{4\pi \in_0 R_0}(r \leq R_0)$$

Which of the following option(s) is / are correct ?

(A) For spherical region $r \leq R_0$, total electrostatic energy stored is zero.

(B) Within $r = 2R_0$, total charge is q.

(C) There will be no charge anywhere except at $r = R_0$.

(D) Electric field is discontinuous at $r = R_0$

Sol.

8. A long, hollow conducting cylinder is kept coaxially inside another long, hollow conducting cylinder of larger radius. Both the cylinders are initially electrically neutral. **[JEE 2007]**

(A) A potential difference appears between the two cylinders when a charge density is given to the inner cylinder

(B) A potential difference appears between the two cylinders when a charge density is given to the outer cylinder

(C) No potential difference appears between the two cylinders when a uniform line charge is kept along the axis of the cylinder

(D) No potential difference appears between the two cylinders when same charge density is given to both the cylinders.

Sol.

9. Consider a neutral conducting sphere. A positive point charge is placed outside the sphere. The net charge on the sphere is then, **[JEE 2007]**

(A) negative and distributed uniformly over the surface of the sphere

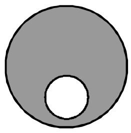
(B) negative and appears only at the point on the sphere closest to the point charge

(C) negative and distributed non-uniformly over the entire surface of the sphere

(D) Zero

Sol.

10. A spherical portion has been removed from a solid sphere having a charge distributed uniformly in its volume as shown in the figure. The electric field inside the emptied space is - **[JEE 2007]**



(A) zero everywhere (B) non-zero and uniform
(C) non-uniform (D) zero only at its center

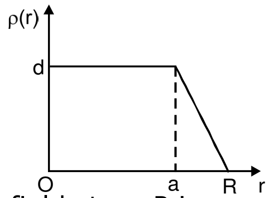
Sol.

11. STATEMENT-1
For practical purposes, the earth is used as a refrence at zero potential in electrical circuits. **[JEE 2008]**
and
STATEMENT-2
The electrical potential of a sphere of radius R with charge Q uniformly distributed on the surface is given by $\frac{Q}{4\pi\varepsilon_0 R}$.

(A) STATEMENT-1 is True, STATEMENT-2 is True; STATEMENT-2 **is** a correct explanation for STATEMENT-1
(B) STATEMENT-1 is True, STATEMENT-2 is True' STATEMENT-2 **is NOT** a correct explanation for STATEMENT-1
(C) STATEMENT-1 is True, STATEMENT-2 is False
(D) STATEMENT-1 is False, STATEMENT-2 is True

Sol.

Paragraph for Question No. 12 to 14
The nuclear charge (Ze) is non-uniformly distributed within a nucleus of radius R. The charge density ρ (r) [charge per unit volume] is dependent only on the radial distance r from the centre of the nucleus as shown in figure The electric field is only along the radial direction. **[JEE 2008]**
Figure :



12. The electric field at r = R is
(A) independent of a
(B) directly proportional to a
(C) directly proportional to a^2
(D) inversely proportional to a

Sol.

13. For a = 0, the value of d (maximum value of ρ as shown in the figure) is
(A) $\frac{3Ze}{4\pi R^3}$ (B) $\frac{3Ze}{\pi R^3}$ (C) $\frac{4Ze}{3\pi R^3}$ (D) $\frac{Ze}{3\pi R^3}$

Sol.

14. The electric field within the nucleus is generally observed to be linearly dependent on r. This implies.
(A) a = 0 (B) $a = \frac{R}{2}$ (C) a = R (D) $a = \frac{2R}{3}$

Sol.

15. Three concentric metallic spherical shells of radii R, $2R$, $3R$, are given charge Q_1 , Q_2 , Q_3 , respectively. It is found that the surface charge densities on the outer surfaces of the shells are equal. Then, the ratio of the charges given to the shells $Q_1 : Q_2 : Q_3$, is

(A) 1 : 2 : 3 (B) 1 : 3 : 5

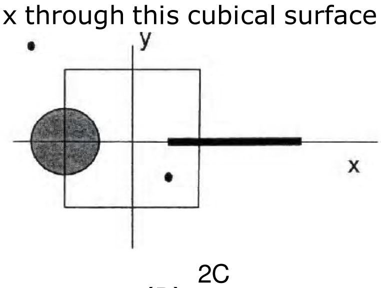
(C) 1 : 4 : 9 (D) 1 : 8 : 18 **[JEE 2009]**

Sol.

16. A solid sphere of radius R has a charge Q distributed in its volume with a charge dinsity $\rho = Kr^a$, where K and a are constants and r is the distance from its centre. If the electric field at $r = \frac{R}{2}$ is $\frac{1}{8}$ times that at $r = R$, find the value of a. **[JEE 2009]**

Sol.

17. A disk of radius $a / 4$ having a uniformly distributed charge 6 C is placed in the x–y plane with its centre at $(-a / 2, 0, 0)$. A rod of length a carrying a uniformly distributed charge 8 C is place on the x-axis from $x = a / 4$ to $x = 5a / 4$. Two point charges –7 C and 3 C are placed at $(a / 4, -a / 4, 0)$ and $(-3a / 4, 3a / 4, 0)$, respectively. Consider a cubical surface formed by six surfaces $x = \pm a / 2$, $y = \pm a / 2$, $z = \pm a / 2$. The electric flux through this cubical surface is

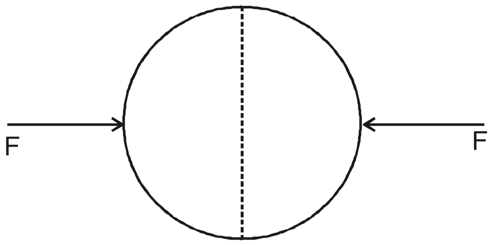


(A) $\frac{-2C}{\varepsilon_0}$ (B) $\frac{2C}{\varepsilon_0}$

(C) $\frac{10C}{\varepsilon_0}$ (D) $\frac{12C}{\varepsilon_0}$ **[JEE 2009]**

Sol.

18. A uniformly charged thin spherical shell of radius R carries uniform surface charge density of σ per unit area. It is made of two hemispherical shells, held together by pressing them with force F (see figure). F is proportional to

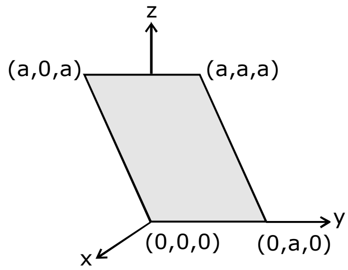


(A) $\frac{1}{\varepsilon_0}\sigma^2 R^2$ (B) $\frac{1}{\varepsilon_0}\sigma^2 R$

(C) $\frac{1}{\varepsilon_0}\frac{\sigma^2}{R}$ (D) $\frac{1}{\varepsilon_0}\frac{\sigma^2}{R^2}$ **[JEE 2010]**

Sol.

19. Consider an electric field $\vec{E} = E_0\,\hat{x}$, where E_0 is a constant. The flux through the shaded area (as shown in the figure) due to this field is **[JEE 2011]**



(A) $2E_0a^2$ (B) $\sqrt{2}\,E_0a^2$ (C) E_0a^2 (D) $\frac{E_0a^2}{\sqrt{2}}$

Sol.

20. A spherical metal shell A of radius R_A and a solid metal sphere B of radius R_B ($<R_A$) are kept far apart and each is given charge '+Q'. Now they are connected by a thin metal wire. Then **[JEE 2011]**

(A) $E_A^{inside} = 0$ (B) $Q_A > Q_B$

(C) $\frac{\sigma_A}{\sigma_B} = \frac{R_B}{R_A}$ (D) $E_A^{on\,surface} < E_B^{on\,surface}$