PHYSICS

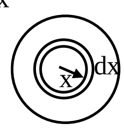
Q.1 The electric field inside a sphere which carries a charge density proportional to the distance from the origin $\rho = \propto r$ ($\propto$ is a constant) is:

(A) $\frac{\propto r^3}{4\varepsilon_0}$ (B) $\frac{\propto r^2}{4\varepsilon_0}$

(C) $\frac{\propto r^2}{3\varepsilon_0}$ (D) None of these

[B]

Sol. We can consider all the charge inside the sphere to be concentrated at the centre of sphere, consider an elementary shell of radius x and thickness dx



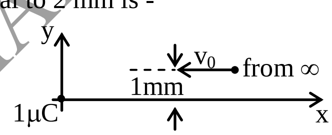
$$E = \frac{k\int dq}{r^2} = \frac{k\int_0^r 4\pi x^2 dx(\propto x)}{r^2} = \frac{\propto r^2}{4\varepsilon_0}$$

Q.2 At a point in space, the electric field points towards north. In the region surrounding this point, the rate of change of potential will be zero along –

(A) North
(B) South
(C) North-South
(D) East-West **[D]**

Sol. $E_{east-west = 0} \Rightarrow \left(\frac{dv}{dr}\right)_{east-west} = 0$

Q.3 A particle of mass 1 kg and charge 1 μC is projected towards another point charge 1 μC fixed at origin as shown in figure. The minimum initial velocity of projection required for the particle to move along a trajectory having minimum distance from fixed charge equal to 2 mm is -



(A) $\sqrt{\frac{2}{3}}$ m/s (B) $3\sqrt{2}$ m/s

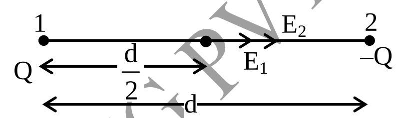
(C) $\sqrt{\frac{3}{2}}$ m/s (D) $2\sqrt{3}$ m/s **[D]**

Q.4 Two unlike charges of the same magnitude Q are placed at a distance d. The intensity of the electric field at the middle point in the line joining the two charge is -

(A) zero (B) $\frac{8Q}{4\pi\varepsilon_0 d^2}$

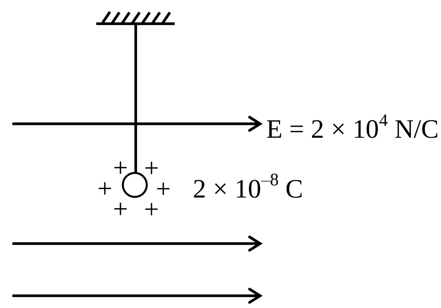
(C) $\frac{6Q}{4\pi\varepsilon_0 d^2}$ (D) $\frac{4Q}{4\pi\varepsilon_0 d^2}$ **[B]**

Sol.



$$E_{Net} = E_1 + E_2 = \frac{kQ}{\left(\frac{d}{2}\right)^2} + \frac{kQ}{\left(\frac{d}{2}\right)^2} = \frac{8Q}{4\pi\varepsilon_0 d^2}$$

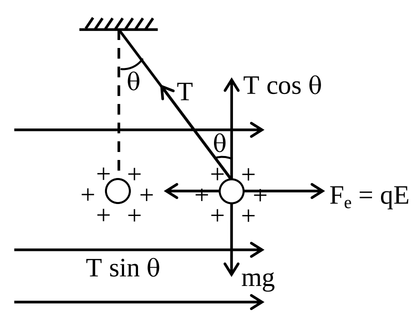
Q.5 Calculate the tension in the thread during equilibrium condition -



(A) 8.8 N (B) 8.8×10^2 N

(C) 8.8×10^{-4} N (D) 8.8×10^{-3} N **[C]**

Sol.



during equilibrium

T cos θ = mg

$T \sin \theta = qE$

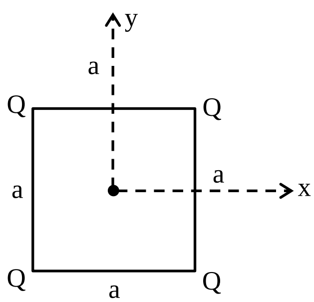
$T = \sqrt{(mg)^2 + (qE)^2}$

$T = \sqrt{(80 \times 10 \times 10^{-6})^2 + (2 \times 10^{-8} \times 2 \times 10^4)^2}$

$T = \sqrt{64 \times 10^{-8} + 16 \times 10^{-8}}$

$T = \sqrt{80 \times 10^{-8}} = 8.8 \times 10^{-4}$ N

Q.6 A charge –q is placed at (0, 0, – z) where z << a. On releasing –q from this position -



(A) –q will move towards z = – ∞

(B) –q will move towards z = ∞

(C) –q will move to and fro about the origin

(D) –q will remain stationary at (0, 0, – z) **[C]**

Sol. –q will experience a restoring force and will perform SHM

Q.7 Two small identical spheres having charges + 10μC and –90μC attract each other with a force of F newton. If they are kept in contact and then separated by the same distance, the new force between them is -

(A) F/6 (B) 16F

(C) 16F/9 (D) 9F **[C]**

Sol. $F = \frac{k(10)(90)}{r^2}$ ....(i)

charge on each when contact is made

$q_1' = q_2' = \frac{10 + (-90)}{2} = -40\mu C$

$\therefore$ New force $F' = \frac{k(40)(40)}{r^2}$

$\therefore \frac{F'}{F} = \frac{40 \times 40}{10 \times 90} = \frac{16}{9}$

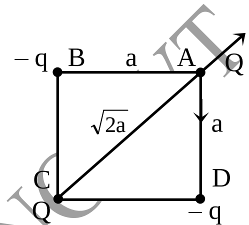
$\therefore \boxed{F' = \frac{16}{9} F}$

Q.8 A charge Q is placed at each of the opposite corners of a square. A charge q is placed at each of the other two corners. If the net electrical force on Q is zero, then Q/ q equals – **[AIEEE-2009]**

(A) $-2\sqrt{2}$ (B) – 1

(C) 1 (D) $-\frac{1}{\sqrt{2}}$ **[A]**

Sol.



Since net force on charge Q is zero (Placed at corner A).

$$\frac{KQ^2}{(\sqrt{2}a)^2} + \left[\sqrt{2}\ \frac{kQq}{a^2}\right] = 0$$

$$\Rightarrow \quad \frac{kQ^2}{2a^2} = \frac{-\sqrt{2}kQq}{a^2}$$

$$\Rightarrow \quad \frac{Q}{q} = -2\sqrt{2}$$

So option (1) is correct.

Q.9 Two points P and Q are maintained at the potentials of 10V and –4V, respectively. The work done in moving 100 electrons from P to Q is . **[AIEEE-2009]**

(A) -9.60×10^{-17} J

(B) 9.60×10^{-17} J

(C) -2.24×10^{-16} J

(D) 2.24×10^{-16} J **[D]**

Sol. $W = q(\Delta V)$

$= q(V_f - V_i)$

$= -100 \times 1.6 \times 10^{-19}(-4 - 10)$

$= 1.6 \times 14 \times 10^{-17}$

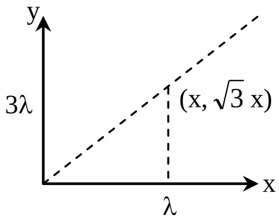
$= 2.24 \times 10^{-4}$ J

Q.10 Two uniformly long charged wires with linear densities λ and 3λ are placed along X and Y axis respectively. Determined the slope of electric field at any point on the line $y = \sqrt{3}\,x$.

(A) $3\sqrt{3}$ (B) $\frac{\sqrt{3}}{3\sqrt{2}}$

(C) $\frac{1}{3\sqrt{3}}$ (D) $\sqrt{3}$ **[C]**

Sol.



$$\vec{E} = \frac{3\lambda}{2\pi \epsilon_0 x}\,\hat{i} + \frac{\lambda}{2\pi \epsilon_0 x\sqrt{3}}\,\hat{j}$$

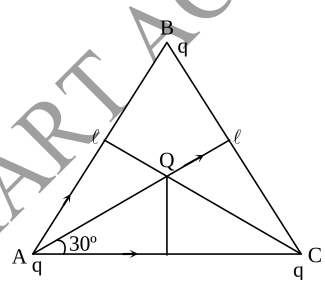
$$\text{Slope} = \frac{E_y}{E_x} = \frac{1}{\sqrt{3}} \div 3 = \frac{1}{3\sqrt{3}}$$

Q.11 Three charges each of +q, are placed at the vertices of an equilateral triangle. The charge needed at the centre of the triangle for the charges to be in equilibrium is –

(A) $\frac{-q}{\sqrt{3}}$ (B) $-\sqrt{3}q$

(C) $\sqrt{3}q$ (D) $-\sqrt{3}q$ **[A]**

Sol.



$$F = \sqrt{F_{AB}^2 + F_{AC}^2 + (2F_{AB}, F_{AC})\cos 30^\circ}$$

$$= \frac{q^2}{\ell^2}\sqrt{1+1+1} = \frac{\sqrt{3}q^2}{\ell^2}$$

$$F_{center} = \frac{q.Q.e}{\ell^2}$$

$$F + F_{center} = 0$$

$$= \frac{\sqrt{3}q^2}{\ell^2} + \frac{3qQ}{\ell^2} = 0$$

$$= \frac{3qQ}{\ell^2} = -\frac{\sqrt{3}q^2}{\ell^2}$$

$$\therefore \quad Q = -\frac{q}{\sqrt{3}} = -\frac{\sqrt{3}q^2}{\ell^2}$$

Q.12 The electric field and electric potential at a point are E and V respectively, then –

(A) If E = 0, V must be zero

(B) If V = 0, E must be zero

(C) If $E \neq 0$, V may be zero

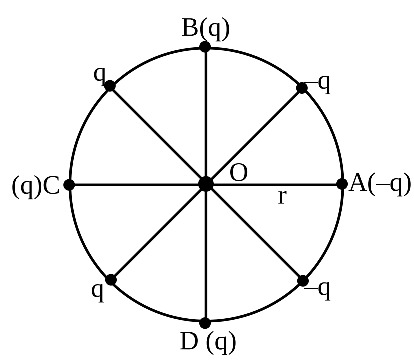
(D) If $V \neq 0$, E cannot be zero **[C]**

Q. 13 Electric charges are distributed in a small volume. The flux of the electric field through a spherical surface of radius 20 cm surrounding the total charge is 50 V-m. The flux over a concentric sphere of radius 40 cm will be –

(A) 25 V-m (B) 50 V-m

(C) 100 V-m (D) 200 V-m **[B]**

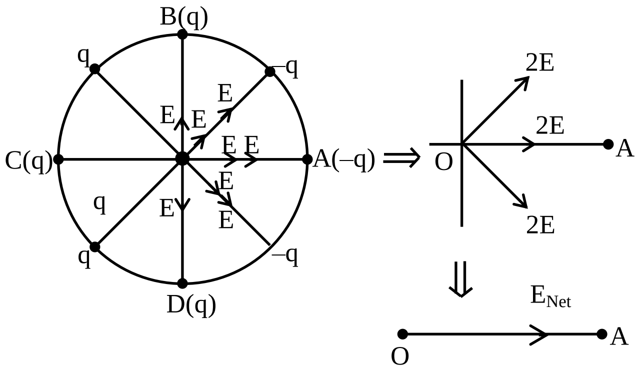
Q. 14 Some point charges are placed on the circumference of circle at equal distance. (See fig.) The direction of electric field at centre O will be along -



(A) OA (B) OB

(C) OC (D) OD **[A]**

Sol. Since magnitude of each charges are same and situated at equal distance from centre O so all charge will produce same magnitude of electric field at centre.



Q. 15 20 J of work has to be done against an existing electric field to take a charge of – 0.1 C from A to B, then potential difference $V_B – V_A$ is –

(A) 20 V (B) 120 V

(C) – 80 V (D) – 200 V **[D]**

Q. 16 A non-conducting sheet of large surface area and thickness d = 10 cm contains uniform charge distribution of density 17.7×10^{-9} C/m^3. Electric field intensity at a point inside the plate, at a distance x = 2 cm from one of the outer surfaces is

(A) 30 V/m (B) 60 V/m

(C) 120 V/m (D) 180 V/m **[B]**

Q. 17 A uniform electric field $\vec{E} = a\hat{i} + b\hat{j}$, intersects a surface of area A. What is the flux through this area if the surface lies in the yz plane –

(A) aA (B) 0

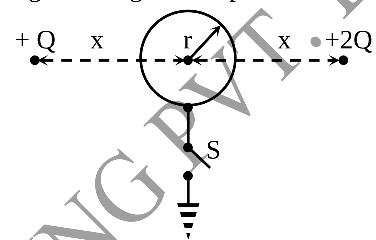
(C) bA (D) $A\sqrt{a^2 + b^2}$ **[A]**

Q. 18 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) $\frac{R}{2}$

(C) $\frac{R}{3}$ (D) 2R **[C]**

Q. 19 Two particles having positive charges + Q and + 2Q are fixed at equal distance x from centre of an conducting sphere having zero net charge and radius r as shown. Initially the switch S is open. After the switch S is closed, the net charge flowing out of sphere is -



(A) $\frac{Qr}{x}$ (B) $\frac{2Qr}{x}$

(C) $\frac{3Qr}{x}$ (D) $\frac{6Qr}{x}$ **[C]**

Sol. Initially the potential at centre of sphere is

$$V_C = \frac{1}{4\pi\varepsilon_0}\frac{Q}{x} + \frac{1}{4\pi\varepsilon_0}\frac{2Q}{x} = \frac{1}{4\pi\varepsilon_0}\frac{3Q}{x}$$

After the sphere grounded, potential at centre becomes zero. Let the net charge on sphere finally be q.

$$\therefore \frac{1}{4\pi\varepsilon_0}\frac{q}{r} + \frac{1}{4\pi\varepsilon_0}\frac{3Q}{x} = 0 \text{ or } q = \frac{3Qr}{x}$$

$\therefore$ The charge flowing out of sphere is $\frac{3Qr}{x}$

Q.20 Four equal positive charges each +Q are placed at corners of a square of side length L. A charge particle having negative charge $–q_1$ is placed at centre of square and the system of these five charges becomes in equilibrium –

(A) The presence of $–q_1$ charge makes the electric potential energy of system negative

(B) The presence of $– q_1$ charge cannot makes the electric potential energy negative

(C) The presence of – q_1 charge makes the electric potential energy zero

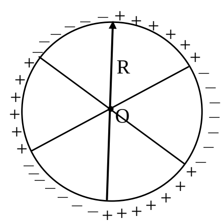
(D) All of the above can possible **[C]**

Q.21 A charged soap bubble having surface charge density σ and radius r. If pressure inside soap bubble and pressure outside it is same then the surface tension for soap bubble is-

(A) $T = \frac{\sigma^2 R}{8\varepsilon_0}$ (B) $T = \frac{\sigma^2 R}{4\varepsilon_0}$

(C) $T = \frac{\sigma^2 R}{2\varepsilon_0}$ (D) $T = \frac{\sigma^2 R}{\varepsilon_0}$ **[A]**

Q.22 A ring of radius R is marked in six equal parts and these parts are charged uniformly with a charge of magnitude Q but positive and negative alternately as shown. Then the electric field at centre of ring will be –



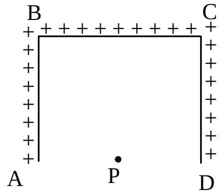
(A) $\frac{k\lambda}{r}$ where $\lambda = \frac{3Q}{\pi R}$

(B) $\frac{2k\lambda}{r}$ where $\lambda = \frac{3Q}{\pi R}$

(C) $\frac{3k\lambda}{r}$ where $\lambda = \frac{3Q}{\pi R}$

(D) None of these **[D]**

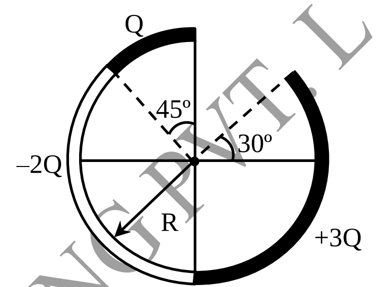
Q.23 Three wires AB, BC, CD of equal length ℓ are charged uniformly with linear charge density λ and are placed as shown. P is a point which lies at a distance ℓ from the wire BC on its perpendicular bisector. Then the electric field at P is –



(A) $\frac{2k\lambda}{\sqrt{5}\ell}(2\sqrt{5}-1)$ (B) $\frac{2k\lambda}{\sqrt{5}\ell}(\sqrt{5}-1)$

(C) $\frac{k\lambda}{\sqrt{5}\ell}(2\sqrt{5}-3)$ (D) None of these **[A]**

Q. 24 Figure shows three circular arcs, each of radius R and total charge as indicated. The net electric potential at the centre of curvature is -



(A) $\frac{Q}{2\pi\varepsilon_0 R}$ (B) $\frac{Q}{4\pi\varepsilon_0 R}$

(C) $\frac{2Q}{\pi\varepsilon_0 R}$ (D) $\frac{Q}{\pi\varepsilon_0 R}$ **[A]**

Sol. $V = V_1 + V_2 + V_3$

$$= \frac{1}{4\pi\varepsilon_0}.\frac{Q}{R} + \frac{1}{4\pi\varepsilon_0}\left[\frac{-2Q}{R}\right] + \frac{1}{4\pi\varepsilon_0}\left[\frac{3Q}{R}\right]$$

$$= \frac{1}{4\pi\varepsilon_0}.\left[\frac{2Q}{R}\right]$$

Q. 25 The electric potential decreases uniformly from 120 V to 80 V as one moves on the x-axis from x = – 1 cm to x = +1 cm. Then the electric field at origin -

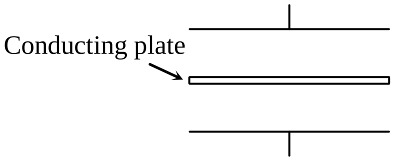
(A) may be equal to 20 V/cm
(B) may be equal to 30 V/cm
(C) may be equal to 100 V/cm
(D) All of the above are possible **[D]**

Q.26 Consider a solid cube of uniform charge density of insulating material. What is the ratio of the electrostatic potential at a corner to that at the centre. (Take the potential to be zero at infinity, as usual)

(A) $\frac{1}{1}$ (B) $\frac{1}{2}$

(C) $\frac{1}{4}$ (D) $\frac{1}{9}$ **[B]**

Q.27 A thin conducting plate is inserted in half way between the plates of a parallel plates capacitor of capacitance C.

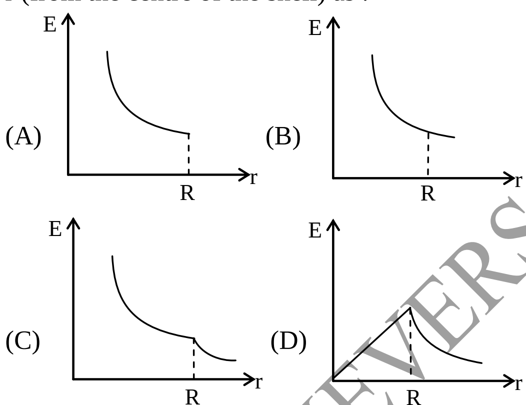


What does the value of capacitance, if both the plate of capacitor is connected by conducting wire ?

(A) C (B) 2C

(C) 3C (D) 4C **[D]**

Q.28 A conducting shell of radius R carries charge –Q. A point charge +Q is placed at the centre of shell. The electric field E varies with distance r (from the centre of the shell) as :



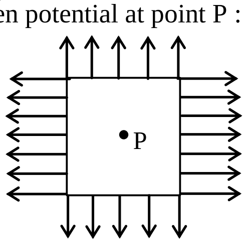
Sol. **[A]**

Using gauss theorem,

$E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q}{r^2}$ for $r \leq R$ and $E = 0$ for $r \geq R$

$\therefore$ correct graph is (A)

***Q.29** Electric lines of force are as shown in the figure . Then potential at point P :



(A) is zero (B) is not zero

(C) may be zero also (D) is not defined

Sol. **[C]**

The dotted lines may be surface boundary of a conductor. Electric lines of force do not enter a conductor. Potential of a conductor is constant but not necessarily zero.

It may be zero also. So, Point P may be inside a conductor (solid or hollow).

Q. 30 An insulating solid sphere of radius 'R' is charged in a non-uniform manner such that volume charge density $\rho = \frac{A}{r}$, where A is a positive constant and r the distance from centre. Electric field strength at any inside point at distance r_1 is -

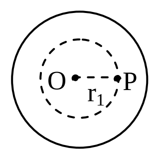
(A) $\frac{1}{4\pi\varepsilon_0} \frac{4\pi A}{r_1}$ (B) $\frac{1}{4\pi\varepsilon_0} \frac{A}{r_1}$

(C) $\frac{A}{\pi\varepsilon_0}$ (D) $\frac{A}{2\varepsilon_0}$

Sol. **[D]**

P is any inside point at distance r_1 from O. we take a spherical surface of radius r_1 as Gaussian –surface of radius r_1 as Gaussian-surface.

$$\oint_s \vec{E}.\vec{ds} = \frac{q_{in}}{\varepsilon_0}$$



By symmetry, E at all points on the surface is same and angle between $\vec{E}$ and $\vec{ds}$ is zero everywhere.

$$\therefore \oint_s \vec{E}.\vec{ds} = Es = \frac{q_{in}}{\varepsilon_0} \text{ or } E\,4\pi r^2{}_1 = \frac{q_{in}}{\varepsilon_0} \quad .....(i)$$

q_{in} : The sphere can be regarded as consisting of a large number of spherical shells.Consider a shell of inner and outer radii r and r +dr. Its volume will be $dV = 4\pi r^2$ dr. Charge in the shell,

$$dq = \rho dV = \frac{A}{r} 4\pi r^2 dr$$

Total charge enclosed by Gaussian-surface,

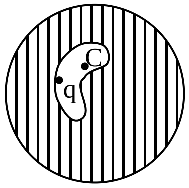
$$q_{in} = \int dq = \int_0^{r_1} rdr = 4\pi A = \frac{r_1^2}{2}$$

$$q_{in} = 4pA \int_0^{r_1} rdr = 4\pi A \frac{r_1^2}{2}$$

From Eq. (1) $E 4\pi r_1^2 = 4\pi A \frac{r_1^2}{2} / \varepsilon_0$

$\therefore E = \dfrac{A}{2\varepsilon_0}$

Q.31 The figure shows a charge q placed inside a cavity in an uncharged conductor. Now if an external electric field is switched on then :



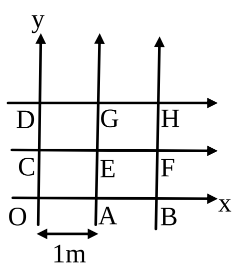
(A) only induced charge on outer surface will redistribute.
(B) only induced charge on inner surface will redistribute
(C) Both induced charge on outer and inner surface will redistribute.
(D) force on charge q placed inside the cavity will change

Sol. **[A]**

The distribution of charge on the outer surface, depends only on the charges outside, and it distributes itself such that the net electric field inside the outer surface due to the charge on outer surface and all the outer charges is zero. Similarly the distribution of charge on the inner surface, depends only on the charges inside the inner surface, and it distributes itself such that the net, electric field outside the inner surface due to the charge on inner surface and all the inner charges is zero.

Also the force on charge inside the cavity is due to the charge on the inner surface. Hence answer is option (A).

Q.32 The grid (each square of 1m × 1m), represents a region in space containing a uniform electric field. If potentials at point O, A, B, C, D, E, F, G, H are respectively 0, –1, –2, 1, 2, 0, –1, 1 and 0 volts. find the electric field intensity.

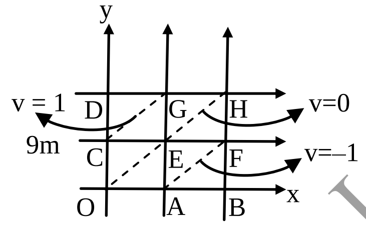


(A) $(\hat{i} + \hat{j})$V/m (B) $(\hat{i} - \hat{j})$V/m

(C) $(-\hat{i} + \hat{j})$V/m (D) $(-\hat{i} - \hat{j})$V/m

Sol. **[B]**

OEH is an equipotential surface, the uniform E.F. must be perpendicular to it pointing from higher to lower potential as shown.



Hence $E = \left(\dfrac{\hat{i} - \hat{j}}{\sqrt{2}}\right)$

$E = \dfrac{(v_E - v_B)}{EB} = \dfrac{0-(-2)}{\sqrt{2}} = \sqrt{2}$

$\therefore \vec{E} = E.\vec{E} = \sqrt{2}\,\dfrac{(\hat{i} - \hat{j})}{\sqrt{2}} = \hat{i} - \hat{j}$

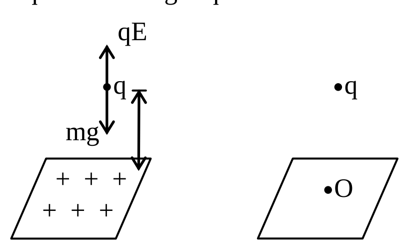
Q. 33 A small charged ball is hovering in the state of equilibrium at a height h over a large horizontal. uniformly charged dielectric plate. What would be the acceleration of the ball if a disc of radius r = 0.00lh is removed from the plate directly underneath the ball ?

(A) $\dfrac{g}{2}\left(\dfrac{r}{h}\right)^2$ (B) $\dfrac{g}{2}\left(\dfrac{h}{r}\right)^2$

(C) $\dfrac{g}{4}\left(\dfrac{r}{h}\right)^2$ (D) $\dfrac{g}{4}\left(\dfrac{h}{r}\right)^2$

Sol. **[A]**

Equilibrium mg = qE



Now 6 × πr^2 charged disc is removed as r is very less we can treat disc as a point charge

$\therefore$ unbalanced acceleration = $\dfrac{Q}{4\pi t h^2} \times \dfrac{q}{m}$

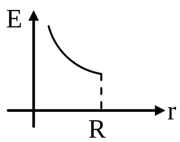
$Q = 6 \times \pi r^2$

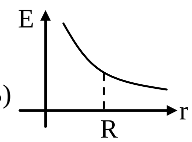
$$q = \frac{mg}{E}$$

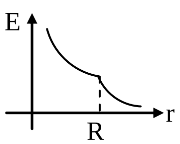
putting in acceleration expression

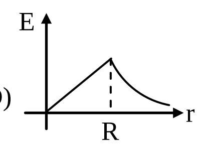
$$a = \frac{g}{2}\left(\frac{r}{h}\right)^2$$

Q.34 A conducting shell of radius R carries charge – Q. A point charge +Q is placed at the centre. The electric field E varies with distance r (from the center of the shell) as-

(A)


(B)


(C)


(D)


Sol. **[A]**

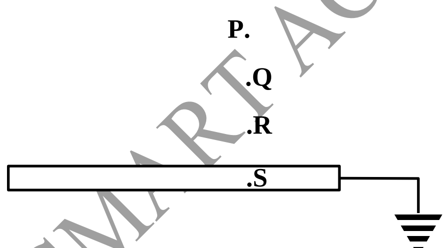
Using Gauss theorem

$$E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Q}{r^2} \text{ for } r \le R$$

and E = 0 for $r \ge R$

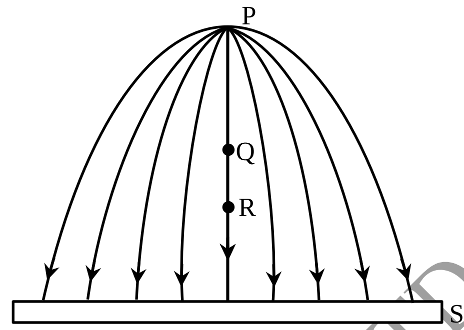
$\therefore$ The correct graph is (a).

Q.35 A positive point charge is placed at P in front of an earthed metal sheet S. Q & R are two points between P & S as shown in figure. If the electric field strength at Q & R are respectively E_Q & E_R and potential at Q & R are respectively V_Q & V_R. Then-



(A) $E_Q > E_R$ (B) $E_Q < E_R$
(C) $V_Q > V_R$ (D) $V_Q < V_R$

Sol. **[C]**



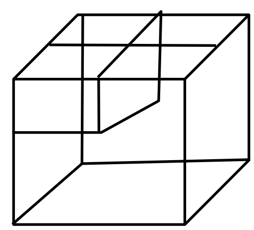
As we are are moving away from P toward sheet S spacing between electric lines of force is increasing. $\therefore$ $E_R < E_Q$ In direction of electric field potential decreases. $\therefore$ $V_R < V_Q$

Q.36 Consider a solid cube of uniform charge density of insulating material. What is the ratio of the electrostatic potential at a corner to that at the centre. (Take the potential to be zero at infinity, as usual)

(A) $\frac{1}{1}$ (B) $\frac{1}{2}$
(C) $\frac{1}{4}$ (D) $\frac{1}{9}$

Sol. **[B]**

ρ- charge density of the cube



V_ℓ^{corner} = potential at the corner of a cube of side ℓ.

V_ℓ^{centre} = potential at the centre of a cube of side ℓ.

$V_{\ell/2}^{centre}$ = potential at the centre of a cube of side $\frac{\ell}{2}$.

$V_{\ell/2}^{corner}$ = potential at the corner of a cube of side $\frac{\ell}{2}$.

By dimensional analysis $V_\ell^{corner} \propto \frac{Q}{\ell} = \rho\ell^2$

$V_\ell^{corner} = 4\, V_{\ell/2}^{corner}$

But by super position $V_\ell^{centre} = 8\, V_{\ell/2}^{corner}$ because the centre of the larger cube lies at a corner of the eight smaller cubes of which it is made

Therefore $\frac{V_\ell^{corner}}{V_\ell^{centre}} = \frac{4V_{\ell/2}^{coner}}{8V_{\ell/2}^{centre}} = \frac{1}{2}$

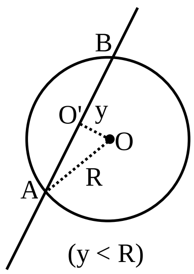
Q.37 A uniformly charged and infinitely long line having a linear charge density 'λ' is placed at a normal distance y from a point O. Consider a sphere of radius R with O as centre and R > y. Electric flux through the surface of the sphere is-

(A) zero (B) $\frac{2\lambda R}{\varepsilon_0}$

(C) $\frac{2\lambda\sqrt{R^2 - y^2}}{\varepsilon_0}$ (D) $\frac{\lambda\sqrt{R^2 + y^2}}{\varepsilon_0}$

Sol. **[C]**

Electric flux $\oint_S \vec{E}.\vec{dS} = \frac{q_{in}}{\varepsilon_0}$ q_{in} is the charge enclosed by the Gaussian-surface which, in the present case, is the surface of given sphere. As shown, length AB of the line lies inside the sphere.



(y < R)

In ΔOO'A $R^2 = y^2 + (O'A)^2$

∴ $O'A = \sqrt{R^2 - y^2}$

and $AB = 2\sqrt{R^2 - y^2}$

Charge on length AB = $2\sqrt{R^2 - y^2} \times \lambda$

∴ electric flux = $\oint_S \vec{E}.\vec{dS} = \frac{2\lambda\sqrt{R^2 - y^2}}{\varepsilon_0}$

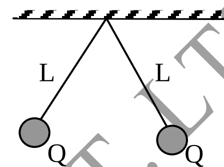
Q.38 Two identical small balls, each of mass m and having charge q are suspended by two light inelastic insulating threads each of length ℓ from the same fixed point support. If the distance (d) between two balls is very less than ℓ, then d is equal to-

(A) $\left(\frac{2k\ell q^2}{mg}\right)^{1/3}$ (B) $\left(\frac{2k\ell q^2}{mg}\right)^{2/3}$

(C) $\left(\frac{k\ell q^2}{2mg}\right)^{2/3}$ (D) none of these

[A]

Q.39 Two small balls having equal positive charge Q on each are suspended by two insulating strings at equal length L metre, from a hook fixed to a stand. The whole set-up is taken in a satellite into space where there is no gravity. Then the angle θ between two strings and tension in each string is –



(A) 0, $\frac{kq^2}{L^2}$ (B) π, $\frac{kq^2}{2L^2}$

(C) π, $\frac{kq^2}{4L^2}$ (D) $\frac{\pi}{2}$, $\frac{kq^2}{2L^2}$ **[C]**

Q.40 Two balls A and B having equal charges are placed at a fixed distance experience a force F. A similar uncharged ball after touching one of them is placed at the middle point between the two balls. The force experienced by this ball is –

(A) F/2 (B) F

(C) 2F (D) 4F **[B]**

Q.41 Two point charges placed at a distance r in air exert a force F on each other. The value of distance R at which they experience force 4F when placed in a medium of dielectric constant K = 16 is -

(A) r (B) r/8

(C) r/4 (D) r/2 **[B]**

Q.42 Three charge +4q, Q and q are placed in a straight line of length ℓ at point distance 0, $\ell/2$ and ℓ respectively. What should be the value of Q in order to make the net force on q to be zero ?

(A) – q (B) –2 q

(C) –q/2 (D) 4q **[A]**

Q.43 A proton and an electron are placed in a uniform electric field.

(A) The electric forces acting on them will be equal
(B) The magnitudes of the forces will be equal
(C) Their accelerations will be equal
(D) The magnitudes of acceleration will be equal **[B]**

Q.44 A charged water drop of radius 0.1 μm is in equilibrium in an electric field. If charge on it is equal to charge on an electron, then intensity of electric field will be : (g = 10 m/s^2 and density of water = 1000 kg/m^3)
(A) 1.61 N/C (B) 26.2 N/C
(C) 262 N/C (C) 1610 N/C **[C]**

Q.45 Four charges q, 2q, – 4q and 2q are placed in order at the four corners of a square of side b. The net field at the centre of the square is –

(A) $\frac{q}{2\pi\varepsilon_0 b^2}$ from + q to – 4q

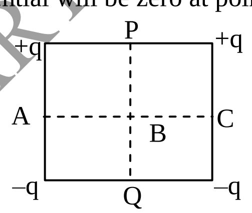
(B) $\frac{5q}{2\pi\varepsilon_0 b^2}$ from + q to – 4q

(C) $\frac{10q}{2\pi\varepsilon_0 b^2}$ from + q to – 4q

(D) $\frac{20q}{2\pi\varepsilon_0 b^2}$ from – 4q to + q **[B]**

Q.46 Point charges q, – q, 2Q and Q are placed in order at the corners A, B, C, D, of a square of side 2b. If the field at the midpoint CD is zero, then $\frac{q}{Q}$ is -
(A) 1 (B) 2
(C) $\frac{2\sqrt{2}}{5}$ (D) $\frac{5\sqrt{5}}{2}$ **[D]**

Q.47 Figure represents a square carrying charges +q, +q, –q, – q at its four corners as shown. Then the potential will be zero at points -



(A) A, B, C, P and Q
(B) A, B and C
(C) A, P, C and Q
(D) P, B and Q **[B]**

Q.48 At a certain distance from a point charge the electric field is 500 V/m and the potential is 3000 V. What is the distance ?
(A) 6 m (B) 12 m
(C) 36 m (D) 144 m **[A]**

Q.49 A charge of 5 C is given a displacement of 0.5 m, the work done in the process is 10 J. The potential difference between the two points will be -
(A) 2 V (B) 0.25 V
(C) 1 V (D) 25 V **[A]**

Q.50 A hollow charged metal sphere has radius r. If the potential difference between its surface and a point at a distance 3r from the centre is V, then electric field intensity at distance 3 r from the centre is -
(A) $\frac{V}{3r}$ (B) $\frac{V}{4r}$
(C) $\frac{V}{6r}$ (D) $\frac{V}{2r}$

Sol. **[C]** $V_A - V_B = \frac{KQ}{r} - \frac{KQ}{3r}$

$= \frac{KQ2}{3r}$, $V = \frac{2}{3}\frac{KQ}{r}$

Q.1 A particle that carries a negative charge '–q' is placed at rest in a uniform electric field. 10 N/C. It experiences a force and moves. In a certain time't', it is observed to acquire a velocity $10\hat{i} - 10\hat{j}$ m/s. The given electric field intersects a surface of area A m^2 in the x-z plane. Electric flux through the surface is –

Sol. **[7]**

Force on a charge –q in an electric field

$\vec{F} = -q\vec{E}$

This force acts in a direction opposite to $\vec{E}$. Therefore the particle, initially placed at rest, will move opposite to $\vec{E}$ under the action of force. Obviously, direction of $\vec{V}$ will be opposite to $\vec{E}$.

Now $\vec{V} = 10\hat{i} - 10\hat{j}$ m/s (given)

unit vector in the direction of $\vec{V}$,

$$\vec{V} = \frac{10\hat{i} - 10\hat{j}}{\sqrt{(10)^2 + (-10)^2}}$$

$$= \frac{10\hat{i} - 10\hat{j}}{10\sqrt{2}}$$

$$\therefore \ \vec{V} = \frac{i}{\sqrt{2}} - \frac{j}{\sqrt{2}}$$

So unit vector opposite to $\vec{V}$, i.e. in the direction of

$$\vec{E} = -\frac{\hat{i}}{\sqrt{2}} + \frac{\hat{j}}{\sqrt{2}}$$

Magnitude of $\vec{E}$ is 10 N/C (given)

Therefore $\vec{E} = 10\left[-\frac{\hat{i}}{\sqrt{2}} + \frac{\hat{j}}{\sqrt{2}}\right)$ ….(1)

The surface of area Am^2 has been placed in the x-z plane so that its area vector can be expressed as,

$\vec{A} = A\hat{j}$($\vec{A}$ being normal to x-z plane, will be along y-axis)

Electric flux, in case of a uniform electric field,

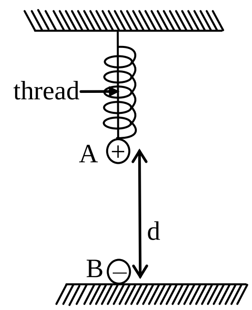
$$\phi = \vec{E}.\vec{A} = 10\left[-\frac{\hat{i}}{\sqrt{2}} + \frac{\hat{j}}{\sqrt{2}}\right].A\hat{j}$$

$$= \frac{10A}{\sqrt{2}} = 5\sqrt{2} \text{ A Nm}^2/\text{C}$$

Q.2 Point charges $q_1 = -4$ nC and $q_2 = +4$ nC are separated by 3 mm, forming an electric dipole. The dipole is placed in uniform electric field whose direction makes an angle of 30º with line connecting the charges. What is the magnitude of this field in N/C if the torque exerted on the dipole has magnitude 7.2×10^{-9} N-m.

[1200]

Q.3 As shown in figure sphere A of mass 5 kg and charge 100 μC is tied with a thread so that spring of spring constant 10^4 N/m is in its natural length while sphere B of same mass and charge – 100 μC is fixed just below A at seperation d = 50 cm then the maximum elongnation in spring in centimeters when the thread is burnt is (g = 10 m/s^2)........................



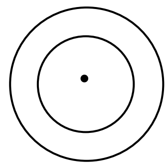
[0010]

Q.4 A non coducting sphere of radius R = 5 cm has its centre at origin O. It has a spherecial cavity of radius r = 1 cm whose centre is at (0, 3 cm). Solid meterial of sphere has uniform positive charge density $\rho = \frac{10^{-6}}{\pi}$ C/m^3. Then potential at point P(4 cm, 0) in volts is ………….. .

[0035]

Q.5 In the figure two conducting concentric spherical shells are shown. If the electric potential at the centre is 2000 V and the electric potential of the other shell is 1500 V. then the potential of the inner shell is......... **[2000 V]**

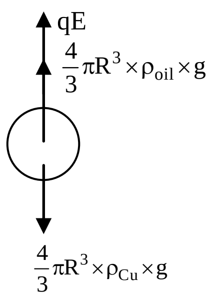
Sol.



Potential to centre is same as potential at the inner surface of the spherical shell.

Q.6 A copper ball of density 8.6 g/cm^3, 1 cm in diameter is immersed in oil of density 0.8 g/cm^3. What is the charge in μC on the ball, if it remains just suspended in an electric field of intensity 3600 V/m acting in upward direction. **[0034]**

Sol.



For equilibrium

$$qE + \frac{4}{3}\pi R^3 \times \rho_{oil} \times g = \frac{4}{3}\pi R^3 \times \rho_{Cu} \times g$$

$$q = \frac{\frac{4}{3}\pi R^3(\rho_{Cu} - \rho_{oil})g}{E}$$

$$q = \frac{\frac{4}{3} \times 3.14 \times (0.5 \times 10^{-2})^3 (7.8) \times 10^3 \times 10}{3600}$$

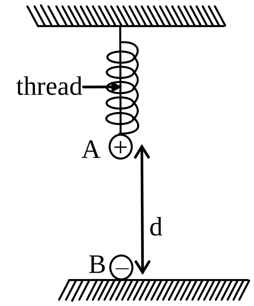
$$q = \frac{\frac{4}{3} \times 3.14 \times 7.8 \times 0.125 \times 10^{-2}}{3600}$$

$q = 3.4 \times 10^{-5}$ C

$= 34 \times 10^{-6}$ C

$= 34$ μC

Q.7 As shown in figure sphere A of mass 5 kg and charge 100 μC is tied with a thread so that spring of spring constant 10^4 N/m is in its natural length while sphere B of same mass and charge – 100 μC is fixed just below A at separation d = 50 cm then the maximum elongation in spring in centimeters when the thread is burnt is (g = 10 m/s^2).........................



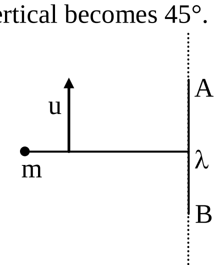
[0010]

Q.8 A non conducting sphere of radius R = 5 cm has its centre at origin O. It has a spherical cavity of radius r = 1 cm whose centre is at (0, 3 cm). Solid material of sphere has uniform positive charge density $\rho = \frac{10^{-6}}{\pi}$ C/m^3. Then potential at point P(4 cm, 0) in volts is …………… **[0035]**

Q.9 Three charges – q, + 2q and – q are placed at the vertices of an isosceles right angled triangle ABC, angle B being 90º and AB = BC = a. If q = 1.6 × 10^{-19} C and a = 1.5 × 10^{-10}m then energy required to dissociate the system of charges is x × 10^{-18} J, then the value of x is - **[0005]**

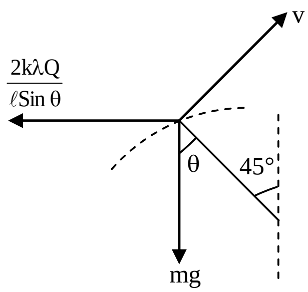
Q.10 AB is a vertical rigid infinite wire carrying a linear of density λ = 10 μC/m. A particle having mass

m = 2 gm and charge Q = 1μC is fixed to the wire by means of a light, insulating and inextensible string having length = $2\sqrt{2}$ m. Find the vertical velocity u in with which it should be projected under gravity from the shown position so that the string slacks when its angle with vertical becomes 45°.



[0006]

Sol.



Equation of circular motion

$$mg\cos\theta - \frac{2k\lambda Q\sin\theta}{\ell\sin\theta} = \frac{mv^2}{\ell} \quad ...(1)$$

Using work energy principle

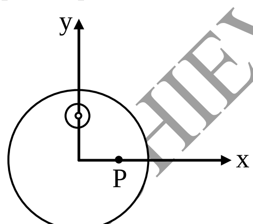
$$-mg\ell\cos\theta + \int_{\ell}^{\ell\sin\theta}\frac{2k\lambda Q dx}{x} = \frac{1}{2}m(v^2 - u^2) \quad ..(2)$$

By using (1) & (2)

u = 5.7 m/s

$\approx$ 6 m/s

Q.11 A non-conducting sphere of radius R = 5 cm has its centre at origin O of co-ordinate system. It has a spherical cavity of radius r = 1 cm having its centre at (0, 3 cm). Solid material of sphere has uniform positive charge density $\rho = \frac{10^{-6}}{\pi}$ coulomb m^{-3}. Calculate potential at point P (4 cm, 0). [in volt] **[0035]**



Sol. Assume given sphere is solid, potential V_1 at P is to be calculated. But in cavity there is no charge therefore potential V_2 due to charge assumed in cavity must be subtracted from V_1.

Charge on solid sphere = $\frac{4}{3}\pi R^3 \times \rho$

$= \frac{5}{3} \times 10^{-10}$ cb

Potential at P can be calculated say V_1

V_2 = Potential due to cavity sphere

$$= \frac{\frac{4}{3}\pi r^3 \rho}{4\pi\varepsilon_0 a} = 0.24\text{V}$$

Potential at P = $V_1 - V_2$ = 35.16 volt

Q.12 In a certain region of space, electric potential V is given by $V = ax^2 + ay^2 + 2az^2$ (where a is a constant of proper dimensions). Work done by electric field in bringing a 2μC charge from origin to (0,0,0.1m) is (-5×10^{-8})joule. Find the approximate value of a in V/m^2.

Sol. **[1]**

W by electric field = -5×10^{-8} J

W against electric field = $+ 5 \times 10^{-8}$ joule

$2 \times 10^{-6}\,[2 \times a \times (0.1)^2 - 0\,]$

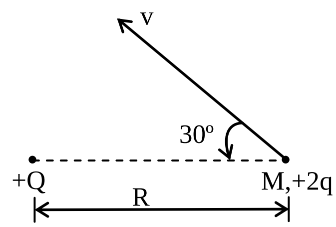
$= + 5 \times 10^{-5}$ joule

$4 \times 10^{-6} \times a \times \frac{1}{100} = 5 \times 10^{-8}$

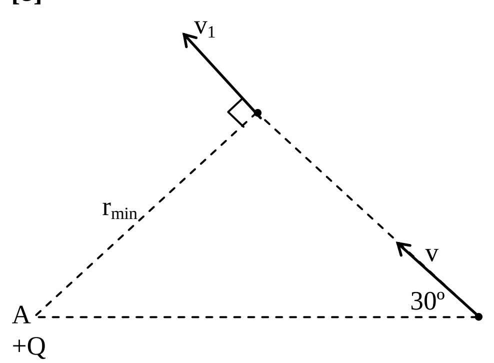
$4 \times 10^{-8} \times a = 5 \times 10^{-8}$

$a = \frac{5}{4} = 1.2\ V/m^2$

Q.13 In the diagram shown, the charge + Q is fixed. Another charge +2q, is projected from a distance R from the fixed charge. Minimum separation between two charges if the velocity becomes $\frac{1}{\sqrt{3}}$ times of the projected velocity at this moment is (assume gravity to be present) in cm (R = 10cm given)-



Sol. **[8]**



Angular momentum about A is conserved as $\tau_{external} = 0$

$mv\sin 30° \times R = v_1 \times m \times r_{min}$

$\frac{Rv}{2} = \frac{1}{\sqrt{3}} \times r_{min}$

$r_{min} = \frac{\sqrt{3}R}{2} = \frac{1.713 \times 10}{2} = 8.665 = 8$ cm

Q.14 A beam of charged particles accelerated using a potential difference of 5000 V falls to rest on a metal plate normally constituting a current of 500 μA. Find the force exerted by the beam on the plate ? (specific charge = 4×10^6 C kg^{-1} for each particle). (in μN). **[0025]**

Sol. Let m, q = mass and charge of each particle

V = accelerating voltage

v, p = velocity and momentum acquired by each particle

$\therefore \quad \frac{1}{2} mv^2 = qV$

or $\quad v = (2qV/m)^{1/2}$

$\therefore \quad p = mv = (2mqV)^{1/2}$

Number of particles reaching the plate per second

= N = i/q, where i = current

Momentum delivered to plate per second = force on plate

$$= Np = \frac{1}{q}(2mqV)^{1/2} = i\left(\frac{2V}{q/m}\right)^{1/2}$$

$$= 500 \times 10^{-6}\left[\frac{2 \times 5000}{4 \times 10^6}\right]^{\frac{1}{2}} \text{ N}$$

$$= 25 \times 10^{-6} \text{ N}$$

0	0	2	5

Q.15 A solid sphere of radius R has a charge Q distributed in its volume with a charge density $\rho = \kappa r^a$, where κ 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.

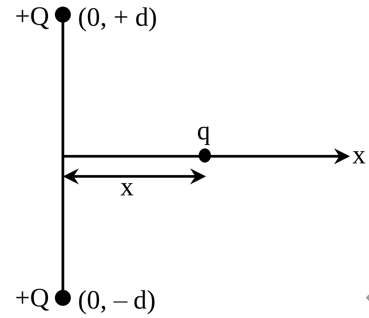
[IIT-2009]

Ans. 2

Q.16 Two equal point charges of same sign are fixed on y-axis, on the either sides of the origin equidistant from it, distance between them d. A third charge moves along x axis. Find the distance of third charge from either of the two fixed charges when force on third charge is maximum. [d = 10 cm] give answer in cm.

[0012]

Sol.



$$F_{net} = \frac{2KQq}{(d^2+x^2)}\left[\frac{x}{[d^2+x^2]^{1/2}}\right]$$

$$\frac{dF_{Net}}{dx} = 0$$

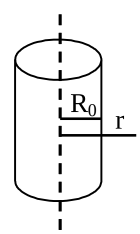
$$x = \frac{d}{\sqrt{2}}$$

Required distance $\sqrt{d^2 + \frac{d^2}{2}} = d\frac{\sqrt{3}}{2}$ = 10 × 1.2

= 12.2 cm

Q.17 A straight infinitely long cylinder of radius R_0 = 10 cm is uniformly charged with a surface charge density $\sigma = + 10^{-12}$ C/m^2. The cylinder serves as a source of electrons, with the velocity of the emitted electrons perpendicular to its surface. Electron velocity must be … × 10^5 m/s to ensure that electrons can move away, from the axis of the cylinder to a distance greater than $r = 10^3$ m.

Ans. [4] $\frac{1}{2} mv^2 = \frac{\lambda e}{2\pi \in_0} \log_n \frac{r}{R_0}$



$$v = \sqrt{\frac{\lambda e}{\pi \in_0 m} \log \frac{r}{R_0}}$$

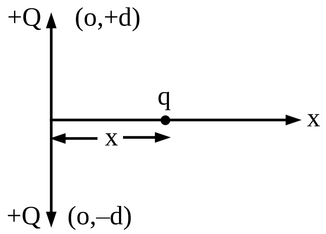
$$\sigma = \frac{Q}{2\pi R_0 \times L}$$

$$\lambda = \frac{Q}{L} = \sigma \times 2\pi R_0 \quad \therefore v = \sqrt{\frac{2\sigma e R_0}{\in_0 m} \log \frac{r}{R_0}}$$

3.7×10^5 m/s or 4×10^5 m/s

Q.18 Two equal point charges of same sign fixed are on y axis, to the two sides of the origin equidistant from it, distance being d. A third charge moves along x axis. Find the distance from either of the two fixed charges, when force is maximum. [d = $\frac{10}{\sqrt{3}}$ cm] Give answer in cm.

Sol. [5]



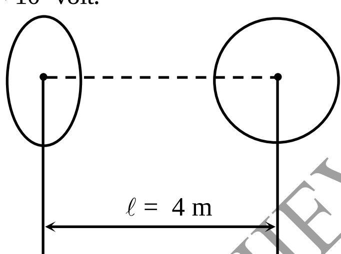
$$F_{Net} = \frac{2kQq}{(d^2+x^2)}\left[\frac{x}{[d^2+x^2]^{1/2}}\right]$$

$$\frac{dF_{Net}}{dx} = 0$$

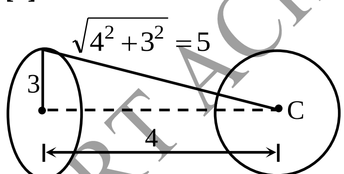
$$x = \frac{d}{\sqrt{2}}$$

Required distance $\sqrt{d^2+\frac{d^2}{2}} = \frac{d\sqrt{3}}{2}$

Q.19 A thin ring of radius R = 3m has been uniformly charged with an amount of 20 µC and placed in relation to a conducting sphere in such a way that the centre of the sphere O, lies on the rings axis at a distance of ℓ = 4m from the plane of the ring. The potential of the sphere is……….× 18 × 10^3 volt.



Sol. **[2]**



potential at C = $\frac{kQ}{\sqrt{4^2+3^2}} = \frac{kQ}{5}$

$$= \frac{9\times10^9\times20\times10^{-6}}{5}$$

$$= \frac{18\times10^4}{5} = 3.6\times10^4 \text{ volt}$$

Q.20 A charged dust particle of radius 5 × 10^{-7} m is located in a horizontal electric field having an intensity of 6.28 × 10^5 V/m. The surrounding medium is air with coefficient of viscosity η = 1.6 × 10^{-5} N-s/m^2. If the particle moves with a uniform horizontal speed 0.02 m/s, the number of electrons on it is……….× 10.

Sol. **[3]**

As dust particle is moving with uniform velocity along horizontal, the dust particle is in dynamic-equilibrium and as the forces acting on dust particle along horizontal are electric force (qE) and viscous force (6πηrν).

So, qE = 6πηrν or

neE = 6πηrν [as q = ηe]

and hence n = $\frac{6\pi\eta r\nu}{eE}$

$$= \frac{6\times3.14\times1.6\times10^{-5}\times5\times10^{-7}\times0.02}{(1.6\times10^{-19})(6.28\times10^5)}$$

$\simeq$ 30