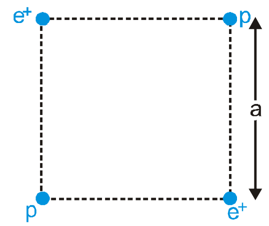
SOLVED EXAMPLES

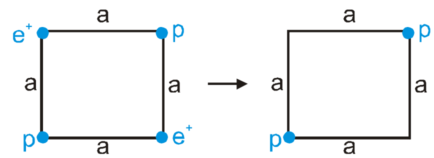
Ex. 1 Two positrons (e^+) and two protons (P) are kept on four corners of a square of side a as shown in figure. The mass of proton is much larger than the mass of positron. Let q denotes the charge on the proton as well as the positron then the kinetic energies of one of the positrons and one of the protons respectively after a very long time will be–



(A) $\frac{q^2}{4\pi\epsilon_0 a}\left(1+\frac{1}{2\sqrt{2}}\right), \frac{q^2}{4\pi\epsilon_0 a}\left(1+\frac{1}{2\sqrt{2}}\right)$ **(B)** $\frac{q^2}{2\pi\epsilon_0 a}, \frac{q^2}{4\sqrt{2}\pi\epsilon_0 a}$

(C) $\frac{q^2}{4\pi\epsilon_0 a}, \frac{q^2}{4\pi\epsilon_0 a}$ **(D)** $\frac{q^2}{2\pi\epsilon_0 a}\left(1+\frac{1}{4\sqrt{2}}\right), \frac{q^2}{8\sqrt{2}\pi\epsilon_0 a}$

Sol. As mass of proton >>> mass of positron so initial acceleration of positron is much larger than proton. Therefore positron reach far away in very short time as compare to proton.

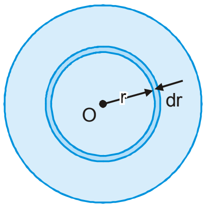


$$2K_{e^+} = \left(\frac{4kq^2}{a}+\frac{2kq^2}{a\sqrt{2}}\right)-\frac{kq^2}{a\sqrt{2}} \Rightarrow K_{e^+} = \frac{q^2}{2\pi\epsilon_0 a}\left(1+\frac{1}{4\sqrt{2}}\right) \text{ and } 2K_p = \frac{kq^2}{a\sqrt{2}}-0 \Rightarrow K_p = \frac{q^2}{8\sqrt{2}\pi\epsilon_0 a}$$

Ex. 2 For a spherically symmetrical charge distribution, electric field at a distance r from the centre of sphere is $\vec{E} = kr^7\hat{r}$, where k is a constant. What will be the volume charge density at a distance r from the centre of sphere ?

(A) $\rho = 9k\varepsilon_0 r^6$ **(B)** $\rho = 5k\varepsilon_0 r^3$ **(C)** $\rho = 3k\varepsilon_0 r^4$ **(D)** $\rho = 9k\varepsilon_0 r^0$

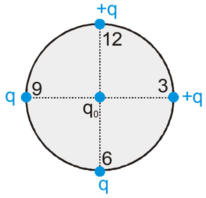
Sol. By using Gauss law $\oint \vec{E}\cdot d\vec{S} = \frac{q}{\epsilon_0} \Rightarrow (E)(4\pi r^2) = \frac{\int \rho(4\pi r^2 dr)}{\epsilon_0}$



(Note : Check dimensionally that $\rho \propto r^6$)

$$(kr^7)(4\pi r^2) = \frac{\int \rho(4\pi r^2 dr)}{\epsilon_0} \Rightarrow \cdot k\varepsilon_0 r^9 = \int \rho r^2 dr$$

Ex. 3 Four charges are placed at the circumference of a dial clock as shown in figure. If the clock has only hour hand, then the resultant force on a charge q_0 placed at the centre, points in the direction which shows the time as :–



(A) 1:30 **(B)** 7:30

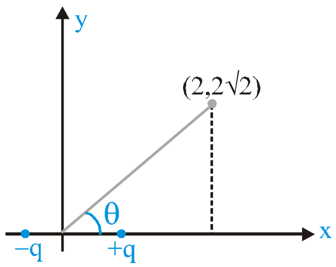
(C) 4:30 **(D)** 10:30

Sol. **(B)**

Ex. 4 A small electric dipole is placed at origin with its dipole moment directed along positive x-axis. The direction of electric field at point $(2, 2\sqrt{2}, 0)$ is

(A) along z-axis **(B)** along y-axis **(C)** along negative y-axis **(D)** along negative z-axis

Sol.



$\tan\theta = \frac{y}{x} = \sqrt{2}; \cot\theta = \frac{1}{\sqrt{2}}$ Also $\tan\alpha = \frac{\tan\theta}{2} = \frac{1}{\sqrt{2}} = \cot\theta \Rightarrow \theta + \alpha = 90°$ i.e., $\vec{E}$ is along positive y-axis.

Ex. 5 Uniform electric field of magnitude 100 V/m in space is directed along the line y= 3 + x. Find the potential difference between point A (3, 1) & B (1,3).

(A) 100 V **(B)** $200\sqrt{2}$V **(C)** 200 V **(D)** zero

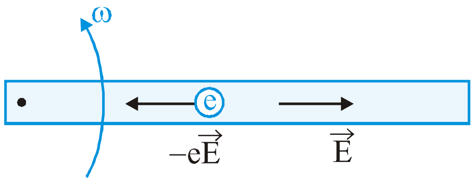
Sol. Slope of line AB $= \frac{3-1}{1-3} = -1$ which is perpendicular to direction of electric field.

Ex. 6 A metallic rod of length l rotates at angular velocity ω about an axis passing through one end and perpendiuclar to the rod. If mass of electron is m and its charge is –e then the magnitude of potential difference between its two ends is

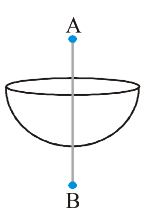
(A) $\frac{m\omega^2\ell^2}{(2e)}$ **(B)** $\frac{m\omega^2\ell^2}{e}$ **(C)** $\frac{m\omega^2\ell}{e}$ **(D)** None of these

Sol. When rod rotates the centripetal acceleration of electron comes from electric field $E = \frac{mr\omega^2}{e}$

Thus, $\Delta V = -\int \vec{E}.d\vec{r} = -\int_0^{\ell} \frac{mr\omega^2}{e} dr = \frac{m\omega^2\ell^2}{2e}$

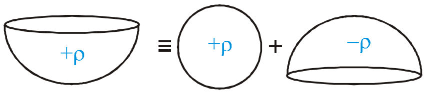


Ex. 7 The diagram shows a uniformly charged hemisphere of radius R. It has volume charge density ρ. If the electric field at a point 2R distance above its centre is E then what is the electric field at the point which is 2R below its centre?



(A) $\frac{\rho R}{6\varepsilon_0} + E$ **(B)** $\frac{\rho R}{12\varepsilon_0} - E$ **(C)** $\frac{-\rho R}{6\varepsilon_0} + E$ **(D)** $\frac{\rho R}{24\varepsilon_0} + E$

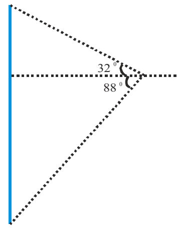
Sol.



Apply principle of superposition

Electric field due to a uniformly charged sphere = $\frac{\rho R}{12\varepsilon_0}$; $E_{resultant} = \frac{\rho R}{12\,\epsilon_0} - E$

Ex. 8 Consider a finite charged rod. Electric field at Point P (shown) makes an angle θ with horizontal dotted line then angle θ is :-

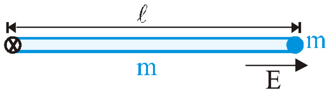


(A) 60° **(B)** 28° **(C)** 44° **(D)** information insufficient

Sol. Required angle = $\frac{\theta_2 - \theta_1}{2} = \frac{88^0 - 32^0}{2} = \frac{56^0}{2} = 28^0$

Ex. 9 to 11

A thin homogeneous rod of mass m and length ℓ is free to rotate in vertical plane about a horizontal axle pivoted at one end of the rod. A small ball of mass m and charge q is attached to the opposite end of this rod. The whole system is positioned in a constant horizontal electric field of magnitude $E = \frac{mg}{2q}$. The rod is released from shown position from rest.



9. What is the angular acceleration of the rod at the instant of releasing the rod?

(A) $\frac{8g}{9\ell}$ **(B)** $\frac{3g}{2\ell}$ **(C)** $\frac{9g}{8\ell}$ **(D)** $\frac{2g}{9\ell}$

10. What is the acceleration of the small ball at the instant of releasing the rod?

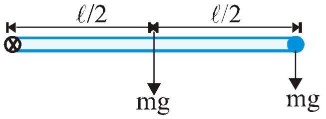
(A) $\frac{8g}{9}$ **(B)** $\frac{9g}{8}$ **(C)** $\frac{7g}{8}$ **(D)** $\frac{8g}{7}$

11. What is the speed of ball when rod becomes vertical?

(A) $\sqrt{\frac{2g\ell}{3}}$ **(B)** $\sqrt{\frac{3g\ell}{4}}$ **(C)** $\sqrt{\frac{3g\ell}{2}}$ **(D)** $\sqrt{\frac{4g\ell}{3}}$

Solution

9.



By taking torque about hinge $I\alpha = mg\left(\frac{\ell}{2}\right) + mg(\ell)$ when $I = \frac{m\ell^2}{3} + m\ell^2 \Rightarrow \alpha = \frac{9g}{8\ell}$

10. Acceleration of ball = $\alpha\ell = \left(\frac{9g}{8\ell}\right)\ell = \frac{9}{8}g$

11. From work energy theorem $\frac{1}{2}I\omega^2 = mg\left(\frac{\ell}{2}\right) + mg\ell - qE\ell$

$\frac{1}{2}\left(\frac{4}{3}m\ell^2\right)\omega^2 = \frac{3}{2}mg\ell - \frac{mg\ell}{2} \Rightarrow \frac{2}{3}m\ell^2\omega^2 = mg\ell \Rightarrow \omega = \sqrt{\frac{3g}{2\ell}}$ Speed of ball $= \omega\ell = \sqrt{\frac{3g\ell}{2}}$

Ex. 12 The electric potential in a region is given by the relation $V(x) = 4 + 5x^2$. If a dipole is placed at position (–1,0) with dipole moment $\vec{p}$ pointing along positive Y-direction, then

(A) Net force on the dipole is zero.

(B) Net torque on the dipole is zero

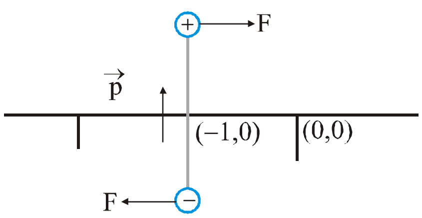
(C) Net torque on the dipole is not zero and it is in clockwise direction

(D) Net torque on the dipole is not zero and it is in anticlockwise direction

Sol. $V(x) = 4 + 5x^2 \Rightarrow \vec{E} = 10x\hat{i}$

∴ Net force will be zero and torque not zero

and rotation will be along clockwise direction



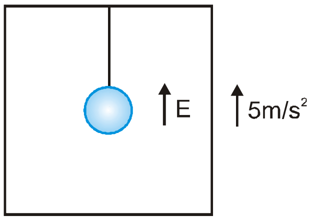
Ex. 13 A simple pendulum is suspended in a lift which is going up with an acceleration of 5 m/s^2. An electric field of magnitude 5 N/C and directed vertically upward is also present in the lift. The charge of the bob is 1 μC and mass is 1 mg. Taking $g = \pi^2$ and length of the simple pendulum 1m, find the time period of the simple pendulum (in sec).

Sol. $T = 2\pi\sqrt{\frac{\ell}{g_{eff}}}$

$g_{eff} = g - \frac{qE}{M} + 5 = 15 - \frac{1 \times 5 \times 10^{-6}}{1 \times 10^{-6}}$

$g_{eff} = 10 = \pi^2$

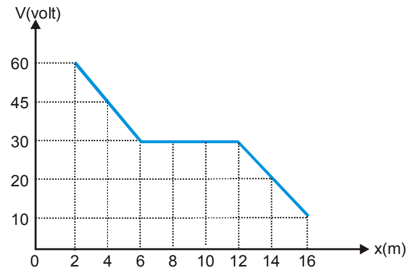
T = 2 sec



Ex. 14 The energy density u is plotted against the distance r from the centre of a spherical charge distribution on a log-log scale. Find the magnitude of slope of obtianed straight line.

Sol. $u = \frac{1}{2}\epsilon_0 E^2 = \frac{1}{2}\epsilon_0\left(\frac{q}{4\pi\epsilon_0 r}\right)^2 = \frac{q^2}{32\pi^2\epsilon_0 r^2} \Rightarrow \log u = \log\left(\frac{q^2}{32\pi^2\epsilon_0 r^2}\right) = \log k - 2\log r$

Ex.15 The variation of potential with distance x from a fixed point is shown in figure. Find the magnitude of the electric field (in V/m) at x =13m.



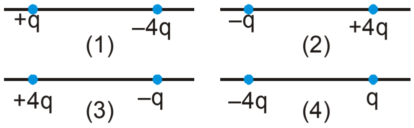
Sol. $E = -\dfrac{dV}{dx} = \dfrac{20}{4} = 5$ volt/meter

Ex. 16 An electric field is given by $\vec{E} = \left(y\hat{i} + x\hat{j}\right)\dfrac{N}{C}$. Find the work done (in J) in moving a 1C charge from $\vec{r}_A = \left(2\hat{i} + 2\hat{j}\right)$ m to $\vec{r}_B = \left(4\hat{i} + \hat{j}\right)$ m.

Sol. A= (2,2) and B = (4, 1); $W_{A\to B} = q\left(V_B - V_A\right) = q\int_A^B dV = -\int_A^B q\vec{E}.d\vec{r}$

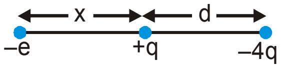
$$= q\int_A^B \left(y\hat{i} + x\hat{j}\right).\left(dx\hat{i} + dy\hat{j}\right) = q\int_A^B \left(ydx + xdy\right) = -q\int_{(2,2)}^{(4,1)} d\left(xy\right) = -q\left[xy\right]_{(2,2)}^{(4,1)} = -q\left[4-4\right] = 0$$

Ex. 17 The figure shows four situations in which charges as indicated (q>0) are fixed on an axis. How many situations is there a point to the left of the charges where an electron would be in equilibrium?



Sol. **For (1)**

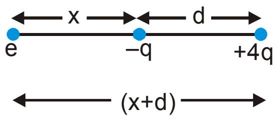
Let the electron be held at a distance x from +q charge.



For equilibrium $\dfrac{q(-e)}{4\pi \in_0 x^2} = \dfrac{(-e)(-4q)}{4\pi \in_0 (x+d)^2}$

We can find value of x for which $F_{net} = 0$ which means that electron will be in equilibrium.

For (2) :



For equilibrium $\dfrac{(-e)(-q)}{4\pi \in_0 x^2} = \dfrac{(-e)4q}{4\pi \in_0 (x+d)^2}$

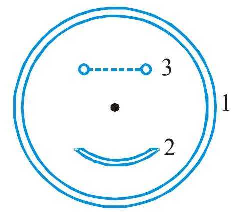
We can find value of x for which $F_{net} = 0$ which means that electron will be in equilibrium.

In case **(3)** and **(4)** the electron will not remain at rest, since it experiences a net non–zero force.

OR

Equilibrium is always found near the smaller charge

Ex. 18 The arrangement shown consists of three elements.



(i) A thin rod of charge –3.0 μC that forms a full circle of radius 6.0 cm.

(ii) A second thin rod of charge 2.0 μC that forms a circular arc of radius 4.0 cm and concentric with the full circle, subtending an angle of 90° at the centre of the full circle.

(iii) An electric dipole with a dipole moment that is perpendicular to a radial line and has magnitude 1.28×10^{-21} C-m.

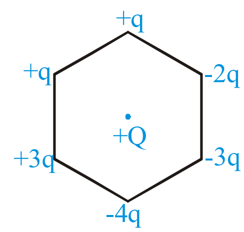
Find the net electric potential in volts at the centre.

Sol. Potential due to dipole at the centre of the circle is zero.

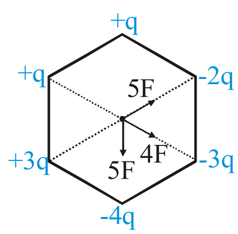
Potentials due to charge on circle = $V_1 = \dfrac{K.(-3\times10^{-6})}{6\times10^{-2}}$

Potential due to arc $V_2 = \dfrac{K.(2\times10^{-6})}{4\times10^{-2}}$ Net potential = $V_1 + V_2 = 0$

Ex. 19 Six charges are kept at the vertices of a regular hexagon as shown in the figure. If magnitude of force applied by +Q on +q charge is F, then net electric force on the +Q is nF. Find the value of n.



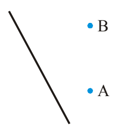
Sol.



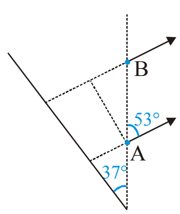
$F_{net} = 9F$

Ex. 20 An infinite plane of charge with $\sigma = 2\in_0 \dfrac{C}{m^2}$ is tilted at a 37° angle to the vertical direction as shown below.

Find the potential difference, $V_A - V_B$ in volts, between points A and B at 5 m distance apart. (where B is vertically above A).

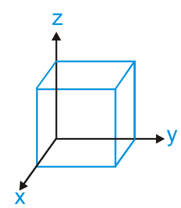


Sol.

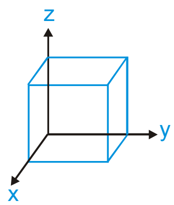


$E = \dfrac{\sigma}{2\varepsilon_0} = 1\ \text{N/C} \ \therefore V_B - V_A = -\int \vec{E}.d\vec{\ell} = \left(\dfrac{\sigma}{2\in_0}\right)(5\cos 53°) = 3V$

Ex. 21 Electric field in a region is given by $\vec{E} = -4x\hat{i} + 6y\hat{j}$. The charge enclosed in the cube of side 1m oriented as shown in the diagram is given by $\alpha\in_0$. Find the value of α.



Sol.



$\phi = (6y)\text{Area} - (4x)\text{Area} = 6\times1\times(1)^2 - 4\times1\times(1)^2 = 2$ therefore $\dfrac{q}{\varepsilon_0} = 2 \Rightarrow q = 2\varepsilon_0$

Exercise # 1

[Single Correct Choice Type Questions]

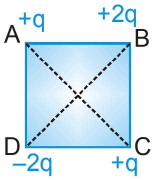
1. Two point charges + 9e and +e are kept 16 cm. apart from each other. Where should a third charge q be placed between them so that the system is in equilibrium state :

(A) 24 cm from + 9e **(B)** 12 cm from +9e **(C)** 24 cm from + e **(D)** 12 cm from + e

2. Using mass (M), length (L), time (T) and current (A) as fundamental quantities, the dimension of permittivity is :

(A) $ML^{-2}T^2A$ **(B)** $M^{-1}L^{-3}T^4A^2$ **(C)** $MLT^{-2}A$ **(D)** $ML^2T^{-1}A^2$

3. Four charges are arranged at the corners of a square ABCD as shown in the figure. The force on the charge kept at the centre O will be :



(A) perpendicular to side AB **(B)** along the diagonal BD
(C) along the diagonal AC **(D)** zero

4. Two equal negative charges –q are fixed at point (0, –a) and (0, a) on y–axis. A positive charge Q is released from rest at the point (2a, 0) on the x–axis. The charge Q will :

(A) execute simple harmonic motion about the origin
(B) move to the origin and remain at rest
(C) move to infinity
(D) execute oscillatory but not simple harmonic motion

5. When charge is given to a soap bubble, it shows :

(A) an increase in size **(B)** sometimes an increase and sometimes a decrease in size
(C) no change in size **(D)** none of these

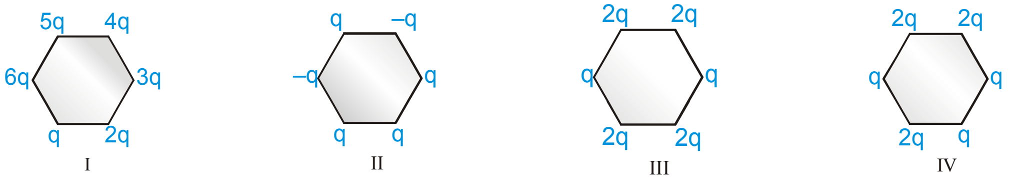
6. An electron of mass m_e, initially at rest, moves through a certain distance in a uniform electric field in time t_1. A proton of mass m_p, also, initially at rest, takes time t_2 to move through an equal distance in this uniform electric field. Neglecting the effect of gravity, the ratio t_2/t_1 is nearly equal to :

(A) 1 **(B)** $(m_p/m_e)^{1/2}$ **(C)** $(m_e/m_p)^{1/2}$ **(D)** 1836

7. Two infinite linear charges are placed parallel to each other at a distance 0.1 m from each other. If the linear charge density on each is 5 μC/m, then the force acting on a unit length of each linear charge will be :

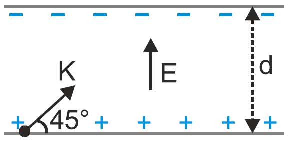
(A) 2.5 N/m **(B)** 3.25 N/m **(C)** 4.5 N/m **(D)** 7.5 N/m

8. Figures below show regular hexagon, the charges are placed at the vertices. In which of the following cases the electric field at the centre is zero.



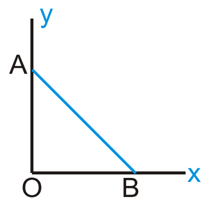
(A) IV **(B)** III **(C)** I **(D)** II

9. An electron is projected as in figure with kinetic energy K, at an angle $\theta = 45°$ between two charged plates. The magnitude of the electric field so that the electron just fails to strike the upper plate, should be greater than:



(A) $\frac{K}{qd}$ **(B)** $\frac{2K}{qd}$ **(C)** $\frac{K}{2qd}$ **(D)** Infinite

10. As per this diagram a point charge +q is placed at the origin O. Work done in taking another point charge –Q from the point A (0, a) to another point B (a,0) along the straight path AB is :

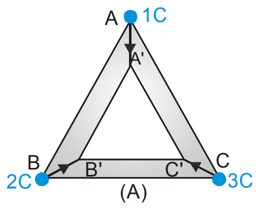


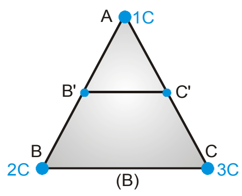
(A) $\left(\frac{-qQ}{4\pi \epsilon_0}\frac{1}{a^2}\right)\sqrt{2}\,a$ **(B)** zero **(C)** $\left(\frac{qQ}{4\pi \epsilon_0}\frac{1}{a^2}\right)\frac{1}{\sqrt{2}}$ **(D)** $\left(\frac{qQ}{4\pi \epsilon_0}\frac{1}{a^2}\right)\sqrt{2}\,a$

11. A point charge 50 μC is located in the XY plane at the point of position vector $\vec{r}_0 = (2\hat{i} + 3\hat{j})$ meter. What is the electric field at the point of position vector $\vec{r} = (8\hat{i} - 5\hat{j})$ meter:

(A) 1200 V/m **(B)** 0.04 V/m **(C)** 900 V/m **(D)** 4500 V/m

12. Three point charges 1C, 2C and 3C are placed at the corners of an equilateral triangle of side 1m. The work required to move these charges to the corners of a smaller equilateral triangle of side 0.5m in two different ways as in fig. **(A)** and fig. **(B)** are W_a and W_b then:





(A) $W_a > W_b$ **(B)** $W_a < W_b$ **(C)** $W_a = W_b$ **(D)** $W_a = 0$ and $W_b = 0$

13. Two identical particles of mass m carry a charge Q each. Initially one is at rest on a smooth horizontal plane and the other is projected along the plane directly towards first particle from a large distance with speed v. The closest distance of approach be :

(A) $\frac{1}{4\pi\varepsilon_0}\frac{Q^2}{mv}$ **(B)** $\frac{1}{4\pi\varepsilon_0}\frac{4Q^2}{mv^2}$ **(C)** $\frac{1}{4\pi\varepsilon_0}\frac{2Q^2}{mv^2}$ **(D)** $\frac{1}{4\pi\varepsilon_0}\frac{3Q^2}{mv^2}$

14. Two identical thin rings, each of radius R meter are coaxially placed at distance R meter apart. If Q_1 and Q_2 coulomb are respectively the charges uniformly spread on the two rings, the work done in moving a charge q from the centre of one ring to that of the other is :

(A) zero **(B)** $\frac{q(Q_1 - Q_2)(\sqrt{2}-1)}{(4\sqrt{2}\pi \in_0 R)}$ **(C)** $\frac{q\sqrt{2}(Q_1 + Q_2)}{4\pi \in_0 R}$ **(D)** $\frac{q(Q_1 - Q_2)(\sqrt{2}+1)}{(4\sqrt{2}\pi \in_0 R)}$

15. An alpha particle of energy 5 MeV is scattered through 180° by a fixed uranium nucleus. The distance of closest approach is of the order :

(A) 1 Å **(B)** 10^{-10} cm **(C)** 10^{-12} cm **(D)** 10^{-15} cm

16. In a regular polygon of n sides, each corner is at a distance r from the center. Identical charges are placed at (n–1) corners. At the centre, the intensity is E and the potential is V. The ratio V/E has magnitude :

(A) nr **(B)** (n–1)r **(C)** (n–1) /r **(D)** r (n–1)/n

17. A charge 3 coulomb experiences a force 300 N when placed in a uniform electric field. The potential difference between two points separated by a distance of 10 cm along the field line is :

(A) 10 V **(B)** 90 V **(C)** 1000 V **(D)** 9000 V

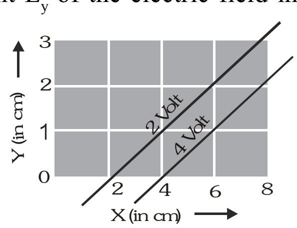
18. The equation of an equipotential line in an electric field is y=2x, then the electric field strength vector at (1, 2) may be :

(A) $4\tilde{i} + 3\tilde{j}$ **(B)** $4\tilde{i} + 8\tilde{j}$ **(C)** $8\tilde{i} + 4\tilde{j}$ **(D)** $-8\tilde{i} + 4\tilde{j}$

19. Uniform electric field of magnitude 100 V/m in space is directed along the line y=3 +x. Find the potential difference between point A (3,1) & B (1,3) :

(A) 100 V **(B)** 200 $\sqrt{2}$ V **(C)** 200V **(D)** 0

20. The figure below shows two equipotential lines in XY plane for an electric field. The scales are marked. The X–component E_x and Y–component E_y of the electric field in the space between these equipotential lines are respectively



(A) +100 V/m, –200 V/m **(B)** +200 V/m, +100 V/m
(C) –100 V/m, +200 V/m **(D)** –200 V/m, –100 V/m

21. In a certain region of space, the potential is given by $V=k(2x^2 - y^2 + z^2)$. The electric field at the point (1, 1, 1) has magnitude :

(A) $k\sqrt{6}$ **(B)** $2k\sqrt{6}$ **(C)** $2k\sqrt{3}$ **(D)** $4k\sqrt{3}$

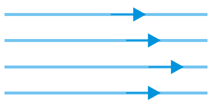
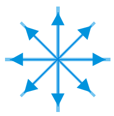
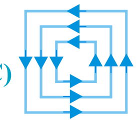
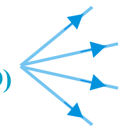
22. Two point charges + q and –q are held fixed at (–d, 0) and (d, 0) respectively of a x–y co–ordinate system. Then which of the following statement is incorrect :

(A) The electric field E at all points on the x–axis has the same direction
(B) No work has to be done in bringing a test charge from ∞ to the origin
(C) Electric field at all point on y–axis is parallel to x–axis
(D) The dipole moment is 2 qd along the –ve x–axis

23. A non–conducting ring of radius 0.5 m carries a total charge 1.11×10^{-10} C distributed non–uniformly on its circumference producing an electric field E every where in space. The value of the integral $\int_{\ell=\infty}^{\ell=0} -\vec{E}\cdot\vec{d}\ell$ (ℓ= 0 being centre of the ring) in volt is :

(A) +2 **(B)** –1 **(C)** –2 **(D)** zero

24. Which one of the following pattern of electric line of force can't possible :

(A)  **(B)**  **(C)**  **(D)** 

25. The work done in rotating an electric dipole of dipole moment p in an electric field E through an angle θ from the direction of electric field, is :

(A) pE (1 – cosθ) **(B)** pE **(C)** zero **(D)** – pE cosθ

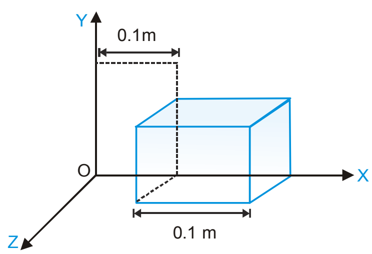
26. A sphere of radius R and charge Q is placed inside an imaginary sphere of radius 2R whose centre coincides with the given sphere. The flux related to imaginary sphere is :

(A) $\frac{Q}{\epsilon_0}$ **(B)** $\frac{Q}{2\,\epsilon_0}$ **(C)** $\frac{4Q}{\epsilon_0}$ **(D)** $\frac{2Q}{\epsilon_0}$

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

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

28. Due to a charge inside a cube the electric field is $E_x = 600\ x^{1/2}$, $E_y = 0$, $E_z = 0$. The charge inside the cube is (approximately) :

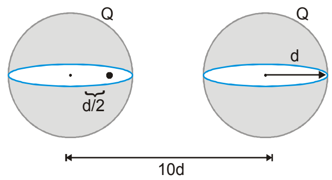


(A) 600 μC **(B)** 60 μC **(C)** 7 μμC **(D)** 6 μμC

29. 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 (b > a). What is the electric field at a distance R (a < R < b) from the centre ?

(A) $\frac{4Q}{2\pi\varepsilon_0 R^2}$ **(B)** $\frac{3Q}{4\pi\varepsilon_0 R^2}$ **(C)** $\frac{3Q}{2\pi\varepsilon_0 R^2}$ **(D)** $\frac{Q}{2\pi\varepsilon_0 R}$

30. Two spherical, nonconducting, and very thin shells of uniformly distributed positive charge Q and radius d are located at 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) $\frac{362qQ}{361\pi\varepsilon_0 d^2}$ to the left

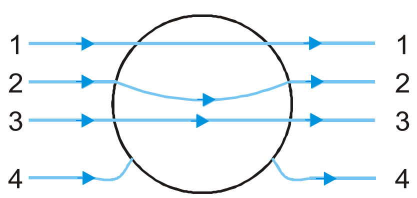
(D) $\frac{360qQ}{361\pi\varepsilon_0 d^2}$ to the right

31. A cube of metal is given a charge (+ Q), which of the following statements is true :
(A) Potential at the surface of cube is zero
(B) Potential within the cube is zero
(C) Electric field is normal to the surface of the cube
(D) Electric field varies within the cube

32. A hollow metal sphere of radius 5 cm is charged such that the potential on its surface is 10V. The potential at the distance 3 cm from the centre of the sphere is :
(A) zero
(B) 10 V
(C) same as at a point 5 cm away from the surface
(D) same as at a point 25 cm away from the surface

33. A solid conducting sphere having a charge Q is surrounded by an uncharged concentric conducting hollow spherical shell. Let the potential difference between the surface of the solid sphere and that of the outer surface of the hollow shell be V. If the shell is now given a charge of –3Q, the new potential difference between the same two surfaces is :
(A) V (B) 2V (C) 4V (D) –2V

34. A metallic solid sphere is placed in a uniform electric field. The lines of force follow the path(s) shown in figure as :



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

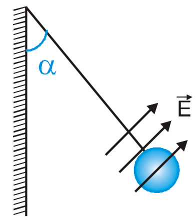
Exercise # 2

Part # I **[Multiple Correct Choice Type Questions]**

1. A charged particle having some mass is resting in equilibrium at a height H above the centre of a uniformly charged non–conducting horizontal ring of radius R. The force of gravity acts downwards.; The equilibrium of the particle will be stable :

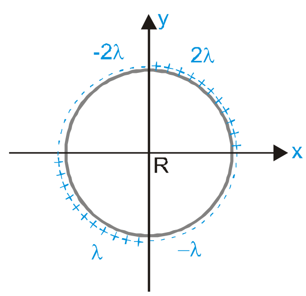
(A) for all values of H **(B)** only if $H > \frac{R}{\sqrt{2}}$ **(C)** only if $H < \frac{R}{\sqrt{2}}$ **(D)** only if $H = \frac{R}{\sqrt{2}}$

2. A charged cork of mass m suspended by a light string is placed in uniform electric field of strength $E = (\hat{i} + \hat{j}) \times 10^5 \ NC^{-1}$ as shown in the figure. If in equilibrium position tension in the string is $\frac{2mg}{(1+\sqrt{3})}$ then angle 'α' with the vertical is



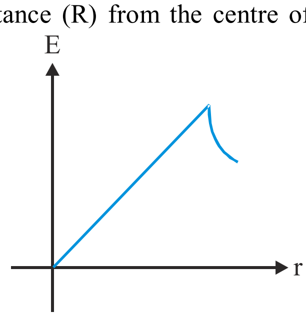
(A) 60^0 **(B)** 30^0 **(C)** 45^0 **(D)** 18^0

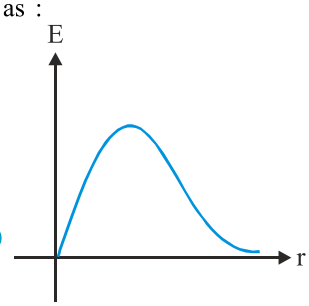
3. The charge per unit length of the four quadrant of the ring is 2λ, – 2λ, λ and –λ respectively. The electric field at the centre is :

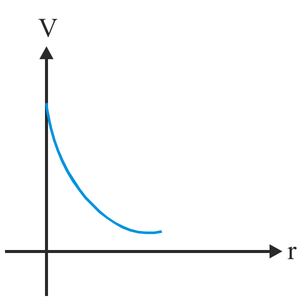


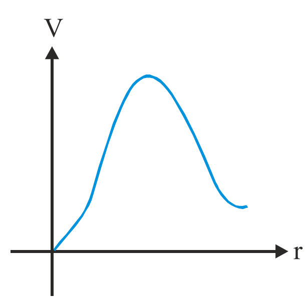
(A) $\frac{-\lambda}{2\pi\varepsilon_0 R}\hat{i}$ **(B)** $\frac{\lambda}{2\pi\varepsilon_0 R}\hat{j}$ **(C)** $\frac{\sqrt{2}\lambda}{4\pi\varepsilon_0 R}\hat{i}$ **(D)** None

4. A circular ring carries a uniformly distributed positive charge. The electric field (E) and potential (V) varies with distance (R) from the centre of the ring along its axis as :

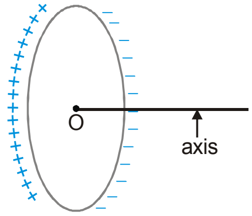
(A)


(B)


(C)


(D)


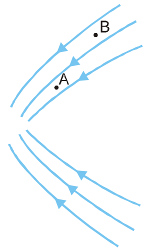
5. The figure shows a nonconducting ring which has positive and negative charge non uniformly distributed on it such that the total charge is zero. Which of the following statements is true?



(A) The potential at all the points on the axis will be zero.
(B) The electric field at all the points on the axis will be zero.
(C) The direction of electric field at all points on the axis will be along the axis.
(D) If the ring is placed inside a uniform external electric field then net torque and force acting on the ring would be zero.

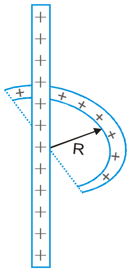
6. An electric charge 10^{-8} C is placed at the point (4m, 7m, 2m). At the point (1m, 3m, 2m), the electric :
(A) potential will be 18 V
(B) field has no Y–component
(C) field will be along Z–axis
(D) potential will be 1.8 V

7. Which of the following is true for the figure showing electric lines of force ? (E is electrical field, V is potential)



(A) $E_A > E_B$
(B) $E_B > E_A$
(C) $V_A > V_B$
(D) $V_B > V_A$

8. Find the force experienced by the semicircular rod charged with a charge q, placed as shown in figure. Radius of the wire is R and the infinite line of charge with linear charge density λ is passing through its centre and perpendicular to the plane of rod.



(A) $\frac{-\lambda q}{2\pi^2\varepsilon_0 R}$
(B) $\frac{\lambda q}{\pi^2\varepsilon_0 R}$
(C) $\frac{\lambda q}{4\pi^2\varepsilon_0 R}$
(D) $\frac{\lambda q}{4\pi\varepsilon_0 R}$

9. Two point charges Q and –Q/4 are separated by a distance x. Then :

(A) potential is zero at a point on the axis which is at a distance x/3 on the right side of the charge –Q/4
(B) potential is zero at a point on the axis which is at a distance x/5 on the left side of the charge –Q/4
(C) electric field is zero at a point on the axis which is at a distance x on the right side of the charge–Q/4
(D) there exist two points on the axis where electric field is zero

10. In a uniform electric field, the potential is 10V at the origin of coordinates, and 8V at each of the points (1, 0, 0), (0, 1, 0) and (0, 0, 1). The potential at the point (1, 1, 1) will be :

(A) 0 **(B)** 4V **(C)** 8V **(D)** 10V

11. Two positively charged particles X and Y are initially far away from each other and at rest. X begins to move towards Y with some initial velocity. The total momentum and energy of the system are p and E :

(A) If Y is fixed, both p and E are conserved

(B) If Y is fixed, E is conserved, but not p

(C) If both are free to move, p is conserved but not E

(D) If both are free, E is conserved, but not p

12. Two particles X and Y, of equal mass and with unequal positive charges, are free to move and are initially far away from each other. With Y at rest, X begins to move towards it with initial velocity u. After a long time, finally :

(A) X will stop, Y will move with velocity u

(B) X and Y will both move with velocities u/2 each

(C) X will stop, Y will move with velocity < u

(D) both will move with velocities < u/2

13. Potential at a point A is 3 volt and at a point B is 7 volt, an electron is moving towards A from B :

(A) It must have some K.E. at B to reach A

(B) It need not have any K.E. at B to reach A

(C) To reach A it must have more than or equal to 4 eV KE at B

(D) When it will reach A, it will have K.E. more than or at least equal to 4 eV if it was released from rest at B

14. Four charges of $1\mu C$, $2\mu C$, $3\mu C$, and $-6\mu C$ are placed one at each corner of the square of side 1m. The square lies in the x–y plane with its centre at the origin.

(A) The electric potential is zero at the origin.

(B) The electric potential is zero everywhere along the x–axis only if the sides of the sqaure are parallel to x and y axis.

(C) The electric potential is zero everywhere along the z–axis for any orientation of the square in the x–y plane.

(D) The electric potential is not zero along the z–axis except at the origin.

15. A particle of mass m and charge q is thrown in a region where uniform gravitational field and electric field are present. The path of particle :

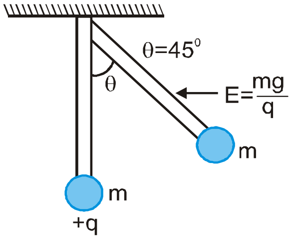
(A) may be a straight line **(B)** may be a circle

(C) may be a parabola **(D)** may be a hyperbola

16. A particle of charge $1\mu C$ & mass 1 gm moving with a velocity of 4 m/s is subjected to a uniform electric field of magnitude 300 V/m for 10 sec. Then it's final speed cannot be :

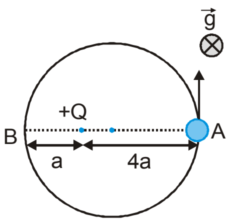
(A) 0.5 m/s **(B)** 4 m/s **(C)** 3 m/s **(D)** 6 m/s

17. A horizontal electric feild (E = (mg)/q) exists as shown in figure and a mass m attached at the end of a light rod. If mass m is released from the position shown in figure find the angular velocity of the rod when it passes through the bottom most position :



(A) $\sqrt{\frac{g}{\ell}}$ **(B)** $\sqrt{\frac{2g}{\ell}}$ **(C)** $\sqrt{\frac{3g}{\ell}}$ **(D)** $\sqrt{\frac{5g}{\ell}}$

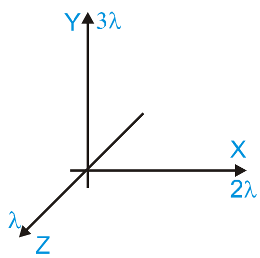
19. The diagram shows a small bead of mass m carrying charge q. The bead can freely move on the smooth fixed ring placed on a smooth horizontal plane. In the same plane a charge + Q has also been fixed as shown. The potential at the point A due to +Q is V. The velocity with which the bead should proejcted from the point A so that it can complete a circle should be greater than :



(A) $\sqrt{\frac{6qV}{m}}$ **(B)** $\sqrt{\frac{qV}{m}}$

(C) $\sqrt{\frac{3qV}{m}}$ **(D)** None of these

18. The diagram shows three infinitely long uniform line charges placed on the X,Y and Z axis. The work done in moving a unit positive charge from (1, 1, 1) to (0, 1, 1) is equal to:



(A) $\frac{(\lambda \ell n2)}{2\pi\varepsilon_0}$ **(B)** $\frac{(\lambda \ell n2)}{\pi\varepsilon_0}$ **(C)** $\frac{(3\lambda \ell n2)}{2\pi\varepsilon_0}$ **(D)** None

20. A proton and a deuteron are initially at rest and are accelerated through the same potential difference which of the following is false concerning the final properties of the two particles?

(A) They have different speeds **(B)** They have same momentum

(C) They have same kinetic energy **(D)** They have been subjected to same force

21. The electric potential decreases uniformly from V to –V along X–axis in a coordinate system as we moves from a point $(-x_0, 0)$ to $(x_0, 0)$, then the electric field at the origin :

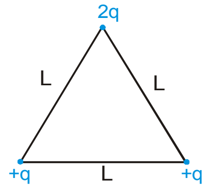
(A) must be equal to $\frac{V}{x_0}$ **(B)** may be equal to $\frac{V}{x_0}$

(C) must be greater than $\frac{V}{x_0}$ **(D)** may be less than $\frac{V}{x_0}$

22. The dipole moment of a system of charge +q distributed uniformly on an arc of radius R subtending an angle $\pi/2$ at its centre where another charge –q is placed is

(A) $\frac{2\sqrt{2}qR}{\pi}$ **(B)** $\frac{\sqrt{2}qR}{\pi}$ **(C)** $\frac{qR}{\pi}$ **(D)** $\frac{2qR}{\pi}$

23. Three points charges are placed at the corners of an equilateral triangle of side L as shown in the figure:



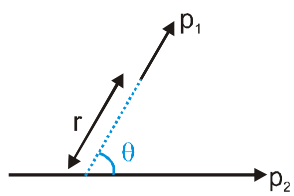
(A) The potential at the centroid of the triangle is zero.
(B) The electric field at the centroid of the triangle is zero.
(C) The dipole moment of the system is $\sqrt{2}$ qL
(D) The dipole moment of the system is $\sqrt{3}$ qL

24. Point P lies on the axis of a dipole. If the dipole is rotated by 90° anticlock wise, the electric field vector $\vec{E}$ at P will rotate by :
(A) 90° clockwise **(B)** 180° clockwise **(C)** 90° anticlock wise **(D)** 180° anticlockwise

25. An electric dipole is kept on the axis of a uniformly charged ring at distance $R/\sqrt{2}$ from the centre of the ring. The direction of the dipole moment is along the axis. The dipole moment is P, charge of the ring is Q and radius of the ring is R. The force on the dipole is nearly :

(A) $\frac{4kPQ}{3\sqrt{3}R^2}$ **(B)** $\frac{4kPQ}{3\sqrt{3}R^3}$ **(C)** $\frac{2kPQ}{3\sqrt{3}R^3}$ **(D)** zero

26. Two short electric dipoles are placed as shown. The energy of electric interaction between these dipoles will be



(A) $\frac{2Kp_1p_2\cos\theta}{r^3}$ **(B)** $\frac{-2Kp_1p_2\cos\theta}{r^3}$ **(C)** $\frac{-2Kp_1p_2\sin\theta}{r^3}$ **(D)** $\frac{-4Kp_1p_2\cos\theta}{r^3}$

27. An electric dipole is placed at the centre of a sphere. Mark the correct answer :
(A) The flux of the electric field passing through the sphere is zero
(B) The electric field is zero at every point of the sphere
(C) The electric potential is zero everywhere on the sphere
(D) The electric potential is zero on a circle on the surface

28. 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 $\phi\neq 0$

29. At distance of 5 cm and 10 cm outwards from the surface of a uniformly charged solid sphere, the potentials are 100 V and 75 V respectively. Then :

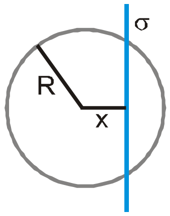
(A) potential at its surface is 150 V

(B) the charge on the sphere is (5/3) x 10^{-10}C

(C) the electric field on the surface is 1500 V/m

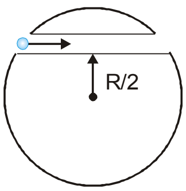
(D) the electric potential at its centre is 225 V

30. An infinite, uniformly charged sheet with surface charge denisty 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)** $\frac{2\pi\left(R^2 - x^2\right)\sigma}{\varepsilon_0}$ **(C)** $\frac{\pi\left(R - x\right)^2 \sigma}{\varepsilon_0}$ **(D)** $\frac{\pi\left(R^2 - x^2\right)\sigma}{\varepsilon_0}$

31. 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 non conducting sphere. The minimum velocity with which the point charge should be projected such that it can it reach the opposite end of the tunnel, is equal to :



(A) $\left[\frac{\rho R^2}{4m\varepsilon_0}\right]^{1/2}$ **(B)** $\left[\frac{\rho R^2}{24m\varepsilon_0}\right]^{1/2}$ **(C)** $\left[\frac{\rho R^2}{6m\varepsilon_0}\right]^{1/2}$

(D) zero because the initial and the final points are at same potential

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

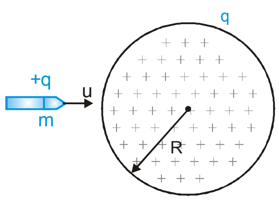
(A) Total charge contained in any spherical volume with its centre at origin is negative.

(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 equals 3 × 10^{-13} C.

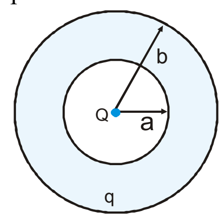
(D) Total charge contained in a spherical volume of radius 3 cm with its centre at origin has magnitude 3 × 10^{-9} C.

33. 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 value of u so that it can penetrate through the sphere. (Neglect all resistnace forces or friction acting on bullet except electrostatic forces)



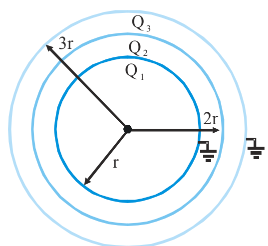
(A) $\frac{q}{\sqrt{2\pi\varepsilon_0 mR}}$ **(B)** $\frac{q}{\sqrt{4\pi\varepsilon_0 mR}}$ **(C)** $\frac{q}{\sqrt{8\pi\varepsilon_0 mR}}$ **(D)** $\frac{\sqrt{3}q}{\sqrt{4\pi\varepsilon_0 mR}}$

34. 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. 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

35. Three concentric conducting spherical shells have radius r, 2r and 3r and Q_1, Q_2 and Q_3 are final charges respectively. Innermost and outermost shells are already earthed as shown in figure. choose the wrong statement.



(A) $Q_1 + Q_3 = -Q_2$ **(B)** $Q_1 = \frac{-Q_2}{4}$ **(C)** $\frac{Q_3}{Q_1} = 3$ **(D)** $\frac{Q_3}{Q_2} = \frac{-1}{3}$

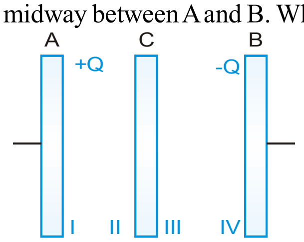
36. There are four concentric shells A, B, C and D of radii a, 2a, 3a and 4a respectively. Shells B and D are given charges +q and –q respectively. Shell C is now earthed. The potential difference $V_A - V_C$ is :

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

37. In the previous question 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 where $\left(K = \frac{1}{4\pi\varepsilon_0}\right)$

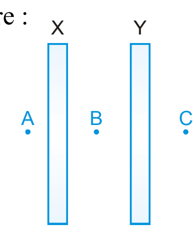
(A) 0 **(B)** $\frac{KQ}{a}$ **(C)** $K\frac{Q-q}{R}$ **(D)** $K\frac{Q-q}{b}$

38. Plates A and B constitutes an isolated, charge parallel plate capacitor. The inner surfaces (I and IV) of A and B have charges + Q and –Q respectively. A third plate C with charge + Q is now introduced midway between A and B. Which of the following statements is not correct?



(A) The surface I and II will have equal and opposite charges
(B) The surfaces III and IV will have equal and opposite charges
(C) The charge on surace III will be greater than Q
(D) The potential difference between A and C will be equal to the potential difference between C and B

39. X and Y are large, parallel conducting plates closed to each other. Each face has an area A. X is given a charge Q. Y is without any charge. Points A, B and C are as shown in figure :

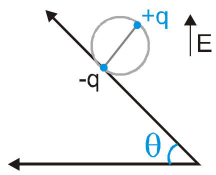


(A) The field at B is $\frac{Q}{2\varepsilon_0 A}$

(B) The field at B is $\frac{Q}{\varepsilon_0 A}$

(C) The fields at A, B and C are of the same magnitude
(D) The field at A and C are of the same magnitude, but in opposite directions

40. A wheel having mass m has charges +q and –q on diametrically opposite points. It remains in equilibrium on a rough inclined plane in the presence of uniform vertical electric field E. The value of E is :



(A) $\frac{mg}{q}$ (B) $\frac{mg}{2q}$ (C) $\frac{mg\tan\theta}{2q}$ (D) None

Part # II [Assertion & Reason Type Questions]

These questions contains, Statement 1 (assertion) and Statement 2 (reason).

(A) Statement-1 is true, Statement-2 is true ; Statement-2 is 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.

1. **Statement–1 :** Mass of ion is slightly differed from its element.
Statement–2 : Ion is formed, when some electrons are removed or added so the mass changes

2. **Statement–1 :** Charge is invariant.
Statement–2 : Charge does not depends on speed or frame of reference.

3. **Statement–1 :** Charge is quantized
Statement–2 : Charge, which is less than 1 C is not possible

4. **Statement–1 :** If a point charge q is placed in front of an infinite grounded conducting plane surface, the point charge will experience a force.
Statement–2 : This force is due to the induced charge on the conducting surface which is at zero potential

5. **Statement–1 :** In electrostatic electric lines of force can never be closed loops, as a line can never start and end on the same charge.
Statement–2 : The number of electric lines of force originating or terminating on a charge is proportional to the magnitude of charge.

6. **Statement–1 :** When charges are shared between two bodies, there occurs no loss of charge, but there does occur a loss of energy.
Statement–2 : In case of sharing of charges conservation of energy fails.

7. **Statement–1 :** The particles such as photon or neutrino which have no (rest) mass can never have a charge.
Statement–2 : Charge can not exist without mass.

8. **Statement–1 :** When two charged spheres are touched, then total charge is always devides equally.
Statement–2 : Flow of charge take place untill potential equals.

9. **Statement–1 :** Induced charge does not contribute to electric field or potential at a given point.
Statement–2 : A point charge q_0 is kept outside a solid metallic sphere, the electric field inside the sphere is zero.

10. **Statement–1 :** Electric field intensity at surface of uniformly charge spherical shell is E. If shell is punchered at a point then intensity at punchered point become E/2.
Statement–2 : Electric field intensity due to spherical charge distribution can be found out by using Gauss law.

11. **Statement–1 :** A conducting sphere charged upto 50V is placed at the centre of a conducting shell charged upto 100V and connected by a wire. All the charge of the shell flows to the sphere.

Statement–2 : The positive charge always flows from higher to lower potential.

12. **Statement–1 :** When a charged particle is placed in the cavity in a conducting sphere, the induced charge on the outer surface of the sphere is found to be uniformly distributed.

Statement–2 : Conducting surface is equipotential surface.

13. **Statement–1 :** A metallic shield in form of a hollow shell may be built to block an electric field.

Statement–2 : In a hollow spherical shield, the electric field inside it is zero at every point.

14. **Statement–1 :** If two concentric conducting sphere which are connected by a conducting wire. No charge can exist on inner sphere.

Statement–2 : When charge on outer sphere will exist then potential of inner shell and outer shell will be same.

15. **Statement–1 :** Electric field E at a point P is zero if potential at that point is zero.

Statement–2 : Potential difference between two points in space is zero if electric field at all points in space is zero.

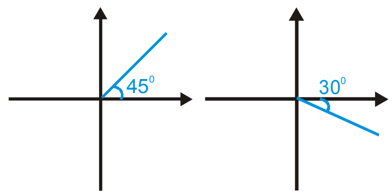
16. **Statement–1 :** A hollow metallic sphere of inner radius a and outer radius b has charge q at the centre. A negatively charged particle moves from inner surface to outer surface. Then total work done will be zero.

Statement–2 : Potential is constant inside the metallic sphere.

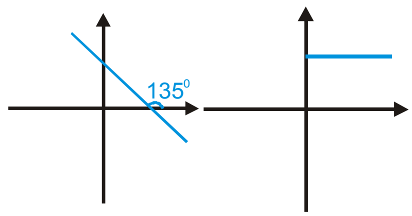
Exercise # 3 Part # I [Matrix Match Type Questions]

1. Column–I shows graphs of electric potential V versus x and y in a certain region for four situations. Column–II shows the range of angle which the electric field vector makes with poisitive x–direction

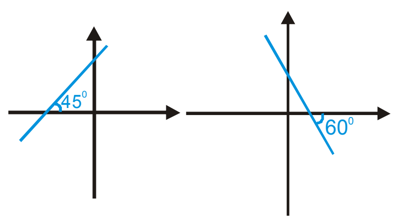
Column–I : V versus x, V versus y **Column–II : Range of angle**

(A) 

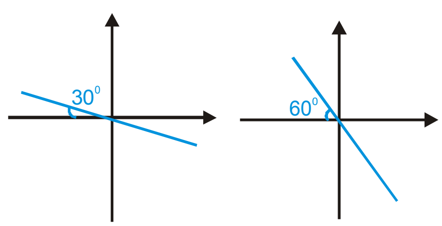
(P) $0^0 \le \theta < 45^0$

(B) 

(Q) $45^0 \le \theta < 90^0$

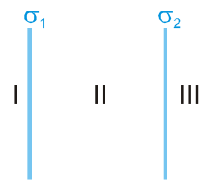
(C) 

(R) $90^0 \le \theta < 135^0$

(D) 

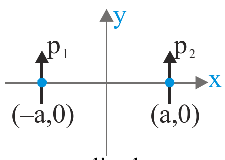
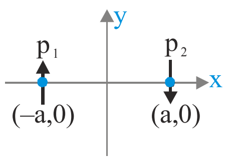
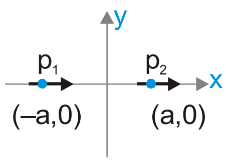
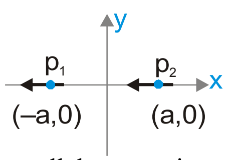
(S) $135^0 \le \theta < 180^0$

2. Two parallel metallic plates have surface charge densities σ_1 and σ_2 as shown in figure.

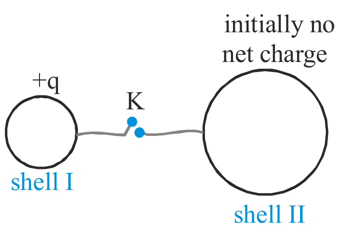
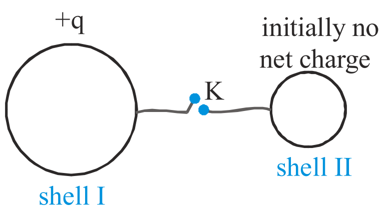


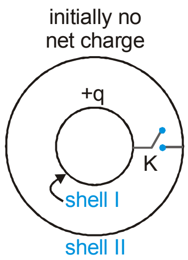
	Column–I		Column–II
(A)	If $\sigma_1 + \sigma_2 = 0$	**(P)**	Electric field in region III is towards right
(B)	If $\sigma_1 + \sigma_2 > 0$	**(Q)**	Electric field in region I is zero
(C)	If $\sigma_1 + \sigma_2 < 0$	**(R)**	Electric field in region I is towards right
		(S)	Nothing can be said

3. In each situation of column–I, two electric dipoles having dipole moments $\vec{p}_1$ and $\vec{p}_2$ of same magnitude (that is, $p_1 = p_2$) are placed on x–axis symmetrically about origin in different orientations as shown. In column–II certain inferences are drawn for these two dipoles. Then match the different orientations of dipole in column–I with the corresponding results in column–II.

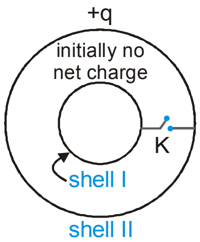
Column I	Column II
(A)  ($\vec{p}_1$ and $\vec{p}_2$ are perpendicular to x–axis as shown)	**(P)** The torque on one dipole due to other is zero
(B)  ($\vec{p}_1$ and $\vec{p}_2$ are perpendicular to x–axis as shown)	**(Q)** The potential energy of one dipole in electric field of other dipole is negative
(C)  ($\vec{p}_1$ and $\vec{p}_2$ are parallel to x–axis as shown)	**(R)** There is one straight line in x-y plane (not at infinity) which is equipotential
(D)  ($\vec{p}_1$ and $\vec{p}_2$ are parallel to x–axis as shown)	**(S)** Electric field at origin is zero.

4. Column–I gives certain situations involving two thin conducting shells connected by a conducting wire via a key K. In all situations one sphere has net charge +q and other sphere has no net charge. After the key K is pressed, column–II gives some resulting effect.

Column I	Column II
(A) 	**(P)** Charge flows through connecting wire
(B) 	**(Q)** Potential energy of system of spheres decreases

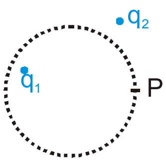
(C) 

(R) No heat is produced

(D) 

(S) The sphere I has no charge after equilibrium is reached

5. In the figure shown P is a point on the surface of an imaginary sphere.

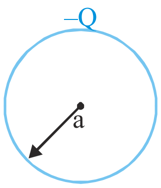


Column–I		Column–II	
(A)	Electric field at point P	**(P)**	due to q_1 only
(B)	Electric flux through a small area at P	**(Q)**	due to q_2 only
(C)	Electric flux through whole sphere	**(R)**	due to both q_1 and q_2

6. In each situation of column–I, some charge distributions are given with all details explained. The electrostatic potential energy and its nature is given situation in column–II.

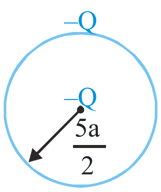
Column I | **Column II**

(A) A thin shell of radius a and having a charge –Q uniformly distributed over its surface as shown



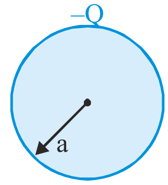
(P) $\dfrac{1}{8\pi \epsilon_0}\dfrac{Q^2}{a}$ in magnitude

(B) A thin shell of radius $\dfrac{5a}{2}$ and having a charge –Q uniformly distributed over its surface and a point charge –Q placed at its centre as shown



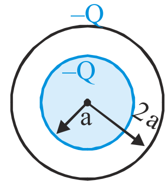
(Q) $\dfrac{3}{20\pi \epsilon_0}\dfrac{Q^2}{a}$ in magnitude

(C) A solid sphere of radius a and having a charge –Q uniformly distributed throughout its volume as shown



(R) $\frac{2}{5\pi \in_0}\frac{Q^2}{a}$ in magnitude

(D) A solid sphere of radius a and having a charge –Q uniformly distributed throughout its volume. The solid sphere is surrounded by a concentric thin uniformly charged spherical shell of radius 2a and carrying charge –Q as shown



(S) Positive in sign

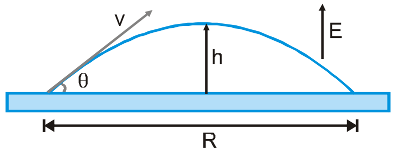
7. A spherical metallic conductor has a spherical cavity. A positive charge is placed inside the cavity at its centre. Another positive charge is placed outside it. The conductor is initially electrically neutral.

Column I (Cause)	Column II (Effect)
(A) If outside charge is shifted to other position	**(P)** Distribution of charge on inner surface of cavity changes
(B) If inside charge is shifted to other position within cavity	**(Q)** Distribution of charge on outer surface of conductor changes
(C) If magnitude of charge inside cavity is increased	**(R)** Electric potential at the centre of conductor changes due to charges present on outer surface of conductor
(D) If conductor is earthed	**(S)** Force on the charge placed inside cavity changes

Part # II [Comprehension Type Questions]

Comprehension # 1

A very large, charged plate floats in deep space. Due to the charge on the plate, a constant electric field E exists everywhere above the plate. An object with mass m and charge q is shot upward from the plate with a velocity v and at an angle θ. It follows the path shown reaching a height h and a range R. Assume the effects of gravity to be negligible.



1. Which of the following must be true concerning the object ?
(A) q must be positive **(B)** q must be negative **(C)** m must be large **(D)** m must be small

2. Which of the following is true concerning all objects that follow the path shown when propelled with a velocity v at an angle θ ?
(A) They must have the same mass
(B) They must have the same charge
(C) They must have the same mass and the same charge
(D) Their mass to charge ratios must be the same

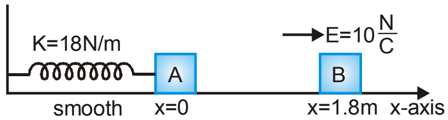
3. Suppose E is 10N/C, m is 1kg, q is –1C, v is 100 m/s and θ is 30°. What is h ?
(A) 25m **(B)** 45m **(C)** 80m **(D)** 125m

4. Which of the following will result in an increase in R ?
(A) Increasing both q and m by a factor of 2
(B) Decreasing both q and m by a factor of 2
(C) Increasing q by a factor of 2 while decreasing m by a factor of 2
(D) Decreasing q by a factor of 2 while increasing m by a factor of 2

5. Which of the following is true concerning the flight of the projectile shown ?
(A) Increasing the mass m decreases the maximum height h
(B) Increasing the charge q increases the maximum height h
(C) Increasing the mass m decreases the downward acceleration
(D) Increasing the charge q decreases the downward acceleration

Comprehension # 2

Electrostatic force on a charged particle is given by $\vec{F} = q\vec{E}$. If q is positive $\vec{F} \uparrow\uparrow \vec{E}$ and if q negative $\vec{F} \uparrow\downarrow \vec{E}$.
In the figure $m_A = m_B = 1$kg. Block A is neutral while $q_B = -1$C. Sizes of A and B are negligible. B is released from rest at a distance 1.8 m from A. Initially spring is neither compressed nor elongated.



1. If collision between A and B is perfectly inelastic, what is velocity of combined mass just after collision ?
(A) 6m/s **(B)** 3m/s **(C)** 9m/s **(D)** 12m/s

2. Equilibrium position of the combined mass is at x = ...m.

(A) $-\frac{2}{9}$ **(B)** $-\frac{1}{3}$ **(C)** $-\frac{5}{9}$ **(D)** $-\frac{7}{9}$

3. The amplitude of oscillation of the combined mass will be :–

(A) $\frac{2}{3}$m **(B)** $\frac{\sqrt{124}}{3}$m **(C)** $\frac{\sqrt{72}}{9}$m **(D)** $\frac{\sqrt{106}}{9}$m

Comprehension # 3

In a certain experiment to measure the ratio of charge and mass of elementary charged particles, a surprising result was obtained in which two particles moved in such a way that the distance between them remained constant always. It was also noticed that, this two particle system was isolated from all other particles and no force was acting on this system except the force between these two masses. After careful observation followed by intensive calculation it was deduced that velocity of these two particles was always opposite in direction and magnitude of velocity was 10^3 m/s and 2×10^3 m/s for first and second particle respectively and masses of these particles were 2×10^{-30} kg and 10^{-30} kg respectively. Distance between them came out to be 12 Å. (1 Å = 10^{-10} m)

1. Acceleration of the first particle was–
(A) zero **(B)** 4×10^{16} m/s^2 **(C)** 2×10^{16} m/s^2 **(D)** 2.5×10^{15} m/s^2

2. Acceleration of second particle was–
(A) 5×10^{15} m/s^2 **(B)** 4×10^{16} m/s^2 **(C)** 2×10^{16} m/s^2 **(D)** Zero

3. If the first particle is stopped for a moment and then released. The velocity of centre of mass of the system just after the release will be–

(A) $\frac{1}{3} \times 10^{-30}$ m/s **(B)** $\frac{1}{3} \times 10^3$ m/s **(C)** $\frac{2}{3} \times 10^3$ m/s **(D)** None of these

4. Path of the two particles was–
(A) Intersecting straight lines **(B)** Parabolic
(C) Circular **(D)** Straight line w.r.t. each other

5. Angular velocity of the first particle was–
(A) 2.5×10^{12} rad/s **(B)** 4×10^{12} rad/s **(C)** 4×10^{13} rad/s **(D)** zero

Comprehension # 4

Electric potential on the axis of a charged ring of radius R at distance x is given by :

$$V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{\sqrt{R^2 + x^2}} \text{ (q = charge on the ring)}$$

Electric potential is a physical quantity measured for unit positive charge and the potential energy is the quantity measured for whole charge.

If only conservative forces (e.g., electrostatic) act on a system, mechanical energy remains conserved.

An insulated ring having a charge $q_1 = 2 \times 10^{-5}$ C is uniformly distributed over it has radius 4m. Another particle having charge $q_2 = 4 \times 10^{-4}$C is released from rest along its axis at distance x = 3m from its centre. Mass of both ring and the particle is 1kg each. Neglect gravitational effects. Ring is free to move.

1. Maximum speed of particle will be :–
(A) 4.4 m/s **(B)** 3.1 m/s **(C)** 5.2 m/s **(D)** 6.1 m/s

2. If ring is not free to move then maximum speed of particle will be

(A) $\frac{2}{\sqrt{5}}$ ms^{-1} **(B)** $\frac{4}{5}$ ms^{-1} **(C)** $\frac{\sqrt{2}}{5}$ ms^{-1} **(D)** None of these

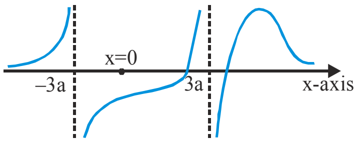
Comprehension # 5

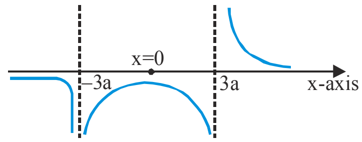
Electric potential is a scalar quantity. Due to a point charge q at distance r, the potential is given by $V = \frac{q}{4\pi \in_0 r}$.

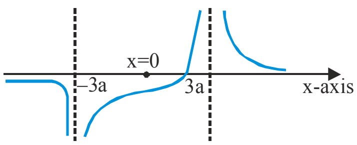
A point charge q is placed at (3a, 0) and another charge –2q is placed at (–3a 0).

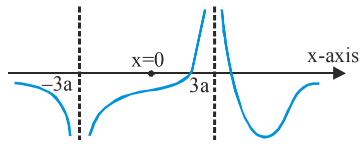
1. At how many points on the x–axis, (at finite distance) electric potential will be zero ?
(A) 1 **(B)** 2 **(C)** 3 **(D)** 4

2. If we plot a graph of potential (V) on x–axis it will be like :

(A)


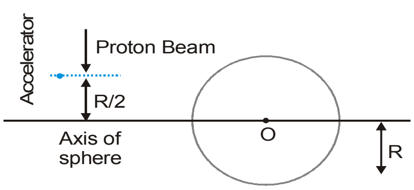
(B)


(C)


(D)


Comprehension # 6

An accelerator produces a narrow beam of protons, each having an initial speed of v_0. The beam is directed towards an initially uncharged distant metal sphere of radius R and centered at point O. The initial path of the beam is parallel to the axis of the sphere at a distance of (R/2) from the axis, as indicated in the diagram.

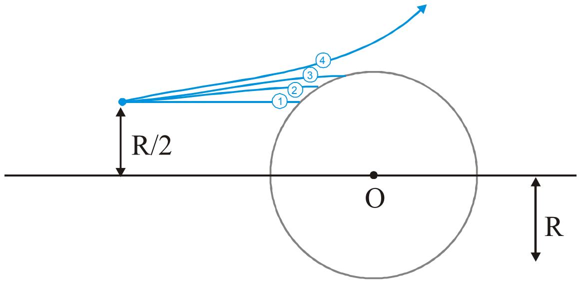


The protons in the beam that collide with the sphere will cause it to become charged. The subsequent potential field at the accelerator due to the sphere can be neglected. The angular momentum of a particle is defined in a similar way to the moment of a force. It is defined as the moment of its linear momentum; linear momentum replacing the force. We may assume the angular momentum of a proton about point O to be conserved. Assume the mass of the proton as m_p and the charge on it as e. Given that the potential of the sphere increases with time and eventually reaches a constant value.

1. The total energy (E) of a proton in the beam travelling with speed v at a distance of r $(r \geq R)$ from point O. Assuming that the sphere has acquired an electrostatic charge Q is

(A) $\frac{eQ}{4\pi\varepsilon_0 r}$ **(B)** less than $\frac{eQ}{4\pi\varepsilon_0 r}$ **(C)** greater than $\frac{eQ}{4\pi\varepsilon_0 r}$ **(D)** zero

2. After a long time, when the potential of the sphere reaches a constant value, the trajectory of proton is correctly sketched as



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

3. Once the potential of the sphere has reached its final, constant value, the minimum speed v of a proton along its trajectory path is given by

(A) v_0 **(B)** $v_0/2$ **(C)** $2v_0$ **(D)** None of these

4. The limiting electric potential of the sphere is

(A) $\frac{3m_p v_0^2}{8e}$ **(B)** $\frac{3m_p v_0^2}{4e}$ **(C)** $\frac{3m_p v_0^2}{2e}$ **(D)** None of these

5. If the initial kinetic energy of a proton is 2.56 keV, then the final potential of the sphere is

(A) 2.56 kV **(B)** 1.92 kV **(C)** greater than 2.56 kV **(D)** needs more information

Comprehension # 7

Van-de graff generator is a man made high voltage generator used to generate a potential difference of order of 10^6V. Which can be further utilised to accelerate the charged particles for executing nuclear reaction. For example we can accelerate α-particles to make bombardment on N_2 to convert it into O_2.
The maximum charge which can be held by a conductor depends on dielectric strength of the surrounding medium. For example : The dielectric strength of air is 3MV/m i.e. It is the maximum value of electric field, above which the surrounding air get ionsided & become conducting.

1. What maximum charge can be built on surface of dome having radius 20cm, if it is surrounded by air.

(A) 13 μC **(B)** 12 μC **(C)** 10 μC **(D)** 1.5 μC

2. The 660V rails on a subway can kill a person upon contact. A 1000 V Van de Graaff genertor, however, will only give a mild shock. Which of the following best explains this paradox ?

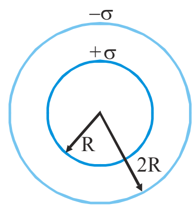
(A) The generator provides more energy per charge, but since it has few charges it transfers a lesser amount of energy
(B) The generator provides more energy, but since there is little energy per charge the current is small
(C) Most of the energy provided by the generator is dissipated in the air because air presents a smaller resistance then the human body
(D) Most of the energy flows directly to the ground without going through the human body since the generator is grounded

3. Why is the potential of the dome limited by the dielectric strength of the air ?

(A) Once the potential of the dome reaches the dielectric strength of the air, charge from the belt is repelled by the charge on the dome
(B) Once the potential of the dome reaches the dielectric strength of the air, the air heats the metal of the dome, and it is no longer a good conductor
(C) Once the air molecules become ionized, charged on the dome can leak into the air
(D) Once the air molecules become ionized, they no longer conduct electricity

Comprehension # 8

When two concentric shells are connected by a thin conducting wire, whole of the charge of inner shell transfers to the outer shell and potential difference between them becomes zero. Surface charge densities of two thin concentric spherical shells are σ and –σ respectively. Their radii are R and 2R. Now they are connected by a thin wire.



1. Potential on either of the shells will be :–

(A) $-\frac{3\sigma R}{2\varepsilon_0}$ **(B)** $-\frac{2\sigma R}{2\varepsilon_0}$ **(C)** $-\frac{\sigma R}{2\varepsilon_0}$ **(D)** zero

2. Suppose electric field at a distance r (> 2R) was E_1 before connecting the two shells and E_2 after connecting the two shells, then $\left|\frac{E_2}{E_1}\right|$ is :–

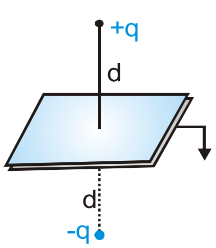
(A) zero **(B)** 1 **(C)** 2 **(D)** ½

3. Suppose electric field at a distance $r = \frac{3R}{2}$ was E_1 before connecting the two shells and E_2 after connecting the two shells, then $\left|\frac{E_2}{E_1}\right|$ is :–

(A) zero **(B)** 1 **(C)** 9/8 **(C)** 8/9

Comprehension # 9

The method of electrical images is used to solve the electrostatic problems, where charge distribution is not specified completely. The method consists of replacement of given charge distribution by a simplified charge distribution or a single point charge or a number of point charges provided the original boundary conditions are still satisfied. For example consider a system containing a point charge q placed at a distance d of from an infinite earthed conducting plane. The boundary conditions are :



(i) Potential is zero at infinity **(ii)** Potential is zero at each point on the conducting plane

If we replaced the conducting plane by a point charge (–q) placed at a distance 'd' opposite to conducting plane. The charge (–q) is called the electrical image.

Now system consists of two charges +q an –q at separation 2d. If charge +q moves to a distance 'y' from the boundary of conducting plane (now absent), the electrical image –q also moves to the same distance 'y' from the boundary of conducting plane, so that the new distance between +q and –q is 2y.

1. The force between point charge +q and earthed conducting plane is

(A) $\frac{1}{4\pi \epsilon_0}\frac{q^2}{d^2}$ (repulsive) **(B)** $\frac{1}{4\pi \epsilon_0}\frac{q^2}{d^2}$ (attractive)

(C) $\frac{1}{4\pi \epsilon_0}\frac{q^2}{4d^2}$ (repulsive) **(D)** $\frac{1}{4\pi \epsilon_0}\frac{q^2}{4d^2}$ (attractive)

2. The potential energy of system of charge +q placed at a distance d from the earthed conducting plane is

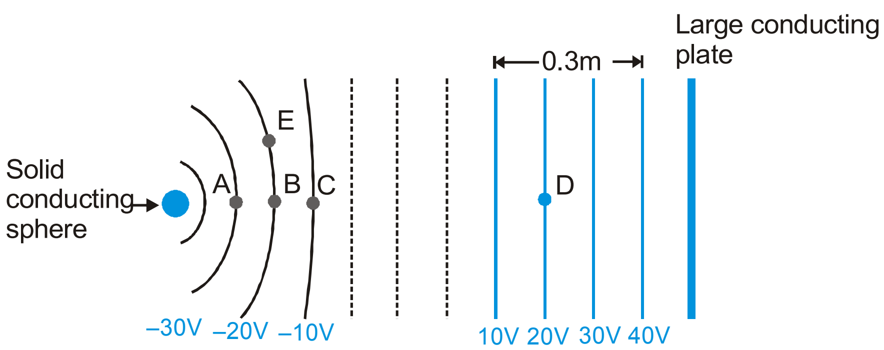
(A) $\frac{1}{4\pi \epsilon_0}\frac{q^2}{d^2}$ **(B)** $-\frac{1}{4\pi \epsilon_0}\frac{q^2}{2d^2}$ **(C)** $\frac{1}{4\pi \epsilon_0}\frac{q^2}{2d}$ **(D)** $-\frac{1}{4\pi \epsilon_0}\frac{q^2}{4d}$

3. The work done in carrying charge q from distance d to distance y from earthed conducting plane is

(A) zero **(B)** $\frac{1}{4\pi \epsilon_0}\frac{q^2}{2}\left[\frac{1}{y}-\frac{1}{d}\right]$ **(C)** $\frac{1}{4\pi \epsilon_0}\frac{q^2}{4}\left[\frac{1}{d}-\frac{1}{y}\right]$ **(D)** $\frac{1}{4\pi \epsilon_0}q^2\left[\frac{1}{y}-\frac{1}{d}\right]$

Comprehension # 10

The sketch below shows cross–sections of equipotential surfaces between two charged conductors that are shown in solid black. Some points one the equipotential surfaces near the conductors are marked as A, B, C,............ The arrangement lies in air. [Take $\epsilon_0 = 8.85 \times 10^{-12}$ $C^2/N\ m^2$]



1. Surface charge density of the plate is equal to–

(A) 8.85×10^{-10} C/m^2 **(B)** -8.85×10^{-10} C/m^2

(C) 17.7×10^{-10} C/m^2 **(D)** -17.7×10^{-10} C/m^2

2. A positive charge is placed at B. When it is released–

(A) no force will be exerted on it **(B)** it will move towards A

(C) it will move towards C **(D)** it will move towards E

3. How much work is required to slowly move a –1 μC charge from E to D ?

(A) 2×10^{-5} J **(B)** -2×10^{-5} J **(C)** 4×10^{-5} J **(D)** -4×10^{-5} J

Exercise # 4 [Subjective Type Questions]

1. Two equal point charges $Q = +\sqrt{2}\ \mu C$ are placed at each of the two opposite corners of a square and equal point charges q at each of the other two corners. What must be the value of q so that the resultant force on Q is zero ?

2. Three particles, each of mass 1 g and carrying a charge q, are suspended from a common point by insulated massless strings, each 100 cm long. If the particles are in equilibrium and are located at the corners of an equilateral triangle of side length 3 cm, calculate the charge q on each particle. (Take $g = 10\ m/s^2$).

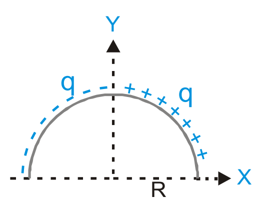
3. A point charge q is situated at a distance d from one end of a thin non–conducting rod of length L having a charge Q (uniformly distributed along its length) as shown in figure. Find the magnitude of electric force between the two.

4. An infinite number of charges, each equal to $Q = 10\ \mu C$ are placed along the x–axis at x = 1, 3, 9 ....m. Calculate the magnitude of electric field at x = 0 if the consecutive charges have opposite signs.

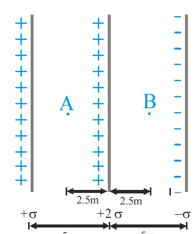
5. A thin circular wire of radius r has a charge Q. If a point charge q is placed at the centre of the ring, then find the increase in tension in the wire.

6. A clock face has negative charges –q, –2q, –3q, ..., –12q fixed at the position of the corresponding numerals on the dial. The clock hands do not disturb the net field due to point charges. At what time does the hour hand, point in the same direction of electric field at the centre of the dial.

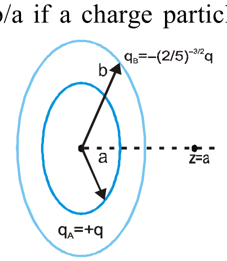
7. Find the electric field at centre of semicircular ring shown in figure.



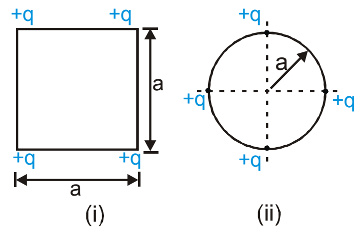
8. The figure shows three infinite non–conducting plates of charge perpendicular to the plane of the paper with charge per unit area $+\sigma$, $+2\sigma$ and $-\sigma$. Find the ratio of the net electric field at that point A to that at point B.



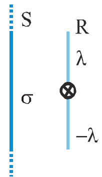
9. Two concentric rings, one of radius 'a' and the other of radius 'b' have the charges +q and $-(2/5)^{-3/2}$ q respectively as shown in the figure. Find the ratio b/a if a charge particle placed on the axis at z=a is in equilibrium.



10. Consider the configuration of a system of four charges each of value +q. Find the work done by external agent in changing the configuration of the system from figure **(i)** to figure. **(ii)**.



11. In the figure shown S is a large nonconducting sheet of uniform charge density σ. A rod R of length ℓ and mass 'm' is parallel to the sheet and hinged at its mid point. The linear charge densities on the upper and lower half of the rod are shown in the figure. Find the angular acceleration of the rod just after it is released.



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.

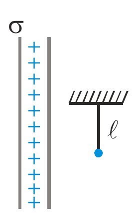
13. Three charges 0.1 coulomb each are placed on the corners of an equilateral triangle of side 1m. If the energy is supplied to this system at the rate of 1kW, how much time would be required to move one of the charges onto the midpoint of the line joining the other two?

14. Two identical particles of mass m carry charge Q each. Initially one is at rest on a smooth horizontal plane and the other is projected along the plane directly towards the first from a large distance with an initial speed v. Find the closest distance of approach.

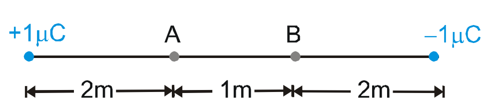
15. A charge +Q is uniformly distributed over a thin ring with radius R. A negative point charge –Q and mass m starts from rest at a point far away from the centre of the ring and moves towards the centre. Find the velocity of this particle at the moment it passes through the centre of the ring.

16. Three point charges q, 2q and 8q are to be placed on a 9cm long straight line. Find the positions where the charges should be placed such that the potential energy of this system is minimum. In this situation, what is the electric field at the position of the charge q due to the other two charges ?

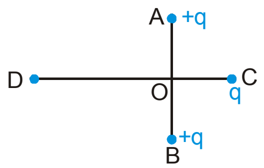
17. A simple pendulum of length ℓ and bob mass m is hanging in front of a large nonconducting sheet having surface charge density σ. If suddenly a charge +q is given to the bob & it is released from the position shown in figure. Find the maximum angle through which the string is deflected from vertical.



18. Positive and negative charges of $1\mu C$ each are placed at two points as shown in the figure. Find the potential difference between A and B-



19. Two fixe, equal, positive charges, each of magnitude $q = 5 \times 10^{-5}$ C are located at points A and B separated by a distance of 6 m. An equal and opposite charge moves towards them along the line COD, the perpendicular bisector of the line AB. The moving charge, when it reaches the point C at a distance of 4 m from O, has a kinetic energy of 4 J. Calculate the distance of the farthest point D which the negative charge will reach before returning towards C.



20. A point charge +q & mass 100 g experiences a force of 100 N at a point at a distance 20 cm from a long infinite uniformly charged wire. If it is released find its speed when it is at a distance 40 cm from wire.

21. Two fixed charges –2Q and Q are located at the points with coordinates (–3a, 0) and (+3a, 0) respectively in the x–y plane.

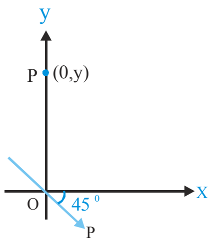
(i) Show that all points in the x–y plane where the electric potential due to the two charges is zero, lie on a circle. Find its radius and the location of its centre

(ii) Give the expression V(x) at a general point on the x–axis and sketch the function V(x) on the whole x–axis.

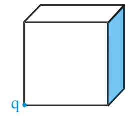
(iii) If a particle of charge +q starts form rest at the centre of the circle, show by a short quantitative argument that the particle eventually crosses the circle. Find its speed when it does so.

22. Two point dipoles $p\tilde{k}$ and $\frac{P}{2}\tilde{k}$ are located at (0, 0, 0) and (1m, 0, 2m) respectively. Find the resultant electric field due to the two dipoles at the point (1m, 0, 0).

23. A dipole is placed at origin of coordinate system as shown in figure,find the electric field at point P (0, y).

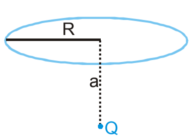


24. The length of each side of a cubical closed surface is ℓ. If charge q is situated on one of the vertices of the cube, then find the flux passing through shaded face of the cube.



25. Show that, for a given dipole, V & E cannot have the same magnitude at distances less than 2 m from the dipole. Suppose that the distance is $\sqrt{5}$ m, determine the directions along which V & E are equal in magnitude.

26. 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.



27. 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.

28. 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.

29. Three concentric spherical metallic shells, A, B and C of radii a, b and c (a < b < c) have surface charge densities σ, $-\sigma$ and σ respectively.

(i) Find the potential of the three shells A, B and C.

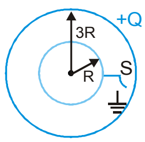
(ii) If the shells A and C are at the same potential, obtain the relation between the radii a, b and c.

30. A charge Q is distributed over two concentric hollow spheres of radii r and R (R> r) such that the surface densities are equal. Find the potential at the common centre.

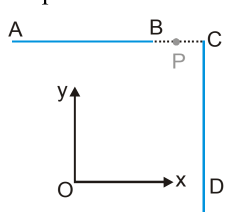
31. A spherical balloon of radius R charged uniformly on its surface with surface density σ. Find work done against electric forces in expanding it upto radius 2R.

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

33. 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.



34. Two wires AB & CD, each 1m length, carry a total charge of 0.2 microcoulomb each and are placed as shown in figure. The ends B & C are separated 1m distance. Determine the value of electric intensity at the point P in the vector form. Note that P is the mid point of BC.

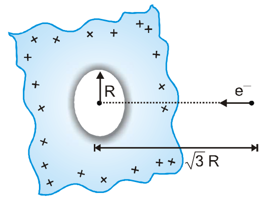


35. 2 small balls having the same mass & charge & located on the same vertical at heights h_1 & h_2 are thrown in the same direction along the horizontal at the same velocity v. The 1st ball touches the ground at a distance ℓ from the initial vertical. At what height will the 2nd ball be at this instant? The air drag & the charges induced should be neglected.

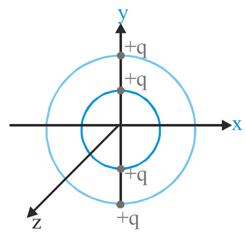
36. A circular ring of radius R with uniform positive charge density λ per unit length is fixed in the Y–Z plane with its centre at the origin O. A particle of mass m and positive charge q is projected from the point P $\left(\sqrt{3}R,0,0\right)$ on the positive X–axis directly towards O, with initial velocity v. Find the smallest value of the speed v such that the particle does not return to P.

37. Two identical balls of charges q_1 & q_2 initially have equal velocity of the same magnitude and direction. After a uniform electric field is applied for some time, the direction of the velocity of the first ball changes by 60^0 and the magnitude is reduced by half. The direction of the velocity of the second ball changes there by 90^0. In what proportion will the velocity of the second ball changes?

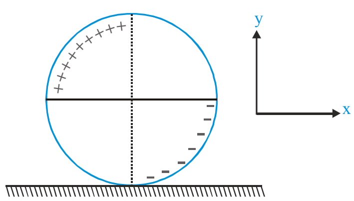
38. An infinite dielectric sheet having charge density σ has a hole of radius R in it. An electron is released on the axis of the hole at a distance $\sqrt{3}$ R from the centre. What will be the velocity which it crosses the plane of sheet. (e = charge on electron and m= mass of electron).



39. Two concentric rings of radii r and 2r are placed with centre at origin. Two charges +q each are fixed at the diametrically opposite points of the rings as shown in figure. Smaller ring is now rotated by an angle 90^0 about Z–axis then it is again rotated by 90^0 about Y–axis. Find the work done by electrostatic forces in each step. If finally larger ring is rotated by 90^0 about X–axis, find the total work required to perform all three steps.

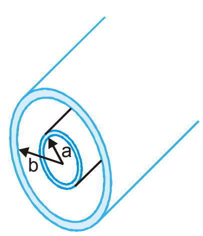


40. A nonconducting ring of mass m and radius R is charged as shown. The charged density i.e. charged per unit length is λ. It is then placed on a rough nonconducting horizontal surface plane. At time t = 0, a uniform electric field $\vec{E} = E_0\hat{i}$ is switched on and the ring start rolling without sliding. Determine the friction force (magnitude and direction) acting on the ring, when it start moving.



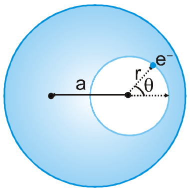
41. Small identical balls with equal charges are fixed at vertices of regular 2009 –gon with side a. At a certain instant, one of the balls is released & a sufficiently long time interval later, the ball adjacent to the first released ball is freed. The kinetic energies of the released balls are found to differ by K at a sufficiently long distance from the polygon. Determine the charge q of each part.

42. Figure shown 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 **(i)** r < a **(ii)** a < r < b **(iii)** r >b



43. The electric field in a region is given by $\vec{E} = \frac{E_0 x}{\ell}\vec{i}$. Find the charge contained inside a cubical volume bounded by the surfaces x = 0, x = a, y = 0, y = a, z = 0 and z = a. [Take $E_0 = 5 \times 10^3$ N/C, ℓ = 2cm and a = 1cm]

44. 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 angle $\theta = 45^0$ as shown. How long will it take to touch the sphere again?



45. 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 :

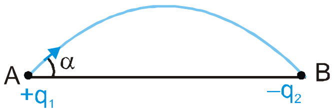
(i) The total charge on the sphere is $Q = \pi\rho_0 R^3$ and

(ii) The electric field inside the sphere has a magnitude given by, $E = \frac{KQr^2}{R^4}$.

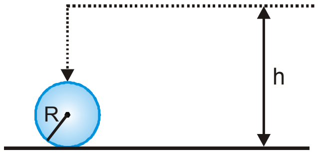
46. A positive charge Q is uniformly distributed throughout the volume of dielectric sphere of radius R. A point mass having charge +q and mass m is fired towards the centre of the sphere with velocity v from a point a distance r (r>R) from the centre of the sphere. Find the minimum velocity v so that 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.

47. Two small metallic balls of radii R_1 & R_2 are kept in vacuum at a large distance compared to the radii. Find the ratio between the charges on the two balls at which electrostatic energy of the system is minimum. What is the potential difference between the two balls? Total charge of balls is constant.

48. Two charges + q_1 & –q_2 are placed at A and B respectively. A line of force emerges from q_1 at angle α with line AB. At what angle will it terminate at –q_2?



49. Electrically charged drops of mercury fall from altitude h into a spherical metal vessel of radius R in the upper part of which there is a small opening. The mass of each drop is m & charge is Q. What is the number 'n' of last drop that can still enter the sphere.

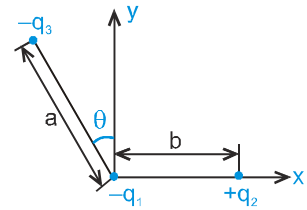


Exercise # 5 Part # I [Previous Year Questions] [AIEEE/JEE-MAIN]

1. 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 : **[AIEEE-2003]**

(1) $\frac{2Q}{4\pi\varepsilon_0 R}$ **(2)** $\frac{2Q}{4\pi\varepsilon_0 R}-\frac{2q}{4\pi\varepsilon_0 R}$ **(3)** $\frac{2Q}{4\pi\varepsilon_0 R}+\frac{q}{4\pi\varepsilon_0 R}$ **(4)** $\frac{(q+Q)}{4\pi\varepsilon_0 R}\frac{2}{R}$

2. 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 : **[AIEEE-2003]**



(1) $\frac{q_2}{b^2}-\frac{q_3}{a^2}\cos\theta$ **(2)** $\frac{q_2}{b^2}+\frac{q_3}{a^2}\sin\theta$

(3) $\frac{q_2}{b^2}+\frac{q_3}{a^2}\cos\theta$ **(4)** $\frac{q_2}{b^2}-\frac{q_3}{a^2}\sin\theta$

3. 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 : **[AIEEE-2003]**

(1) $(\phi_2-\phi_1)\varepsilon_0$ **(2)** $(\phi_1+\phi_2)/\varepsilon_0$ **(3)** $(\phi_2-\phi_1)/\varepsilon_0$ **(4)** $(\phi_1+\phi_2)\,\varepsilon_0$

4. Two spherical conductors B and C having equal radii and carrying equal charges 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 : **[AIEEE-2004]**

(1) $\frac{F}{4}$ **(2)** $\frac{3F}{4}$ **(3)** $\frac{F}{8}$ **(4)** $\frac{3F}{8}$

5. 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 were given a speed of '2v', the closest distance of approach would be : **[AIEEE-2004]**

(1) r **(2)** 2r **(3)** $\frac{r}{2}$ **(4)** $\frac{r}{4}$

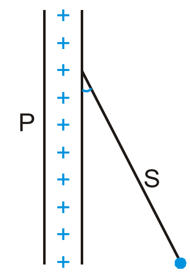
6. Four charges equal to –Q each are placed at the four corners of a square and a charge q is at its centre. If the system is in equilibrium, the value of q is: **[AIEEE-2004]**

(1) $-\frac{Q}{4}(1+2\sqrt{2})$ **(2)** $\frac{Q}{4}(1+2\sqrt{2})$ **(3)** $-\frac{Q}{2}(1+2\sqrt{2})$ **(4)** $\frac{Q}{2}(1+2\sqrt{2})$

7. 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 = 9.9×10^{-15} kg, g = 10m/s^2) **[AIEEE-2004]**

(1) 3.3×10^{-18} C **(2)** 3.2×10^{-18} C **(3)** 1.6×10^{-18} C **(4)** 4.8×10^{-18} C

8. 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: **[AIEEE-2005]**



(1) sin θ
(2) tanθ
(3) cosθ
(4) cot θ

9. Two point charges + 8 q 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: **[AIEEE-2005]**

(1) 8L **(2)** 4L **(3)** 2L **(4)** L/4

10. 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 centers of the two rings is: **[AIEEE-2005]**

(1) zero

(2) $\frac{q}{4\pi\varepsilon_0}\left[\frac{1}{R}-\frac{1}{\sqrt{R^2+d^2}}\right]$

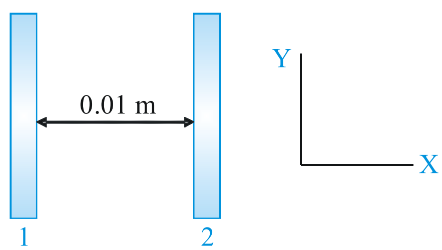
(3) $\frac{qR}{4\pi\varepsilon_0 d^2}$

(4) $\frac{q}{2\pi\varepsilon_0}\left[\frac{1}{R}-\frac{1}{\sqrt{R^2+d^2}}\right]$

11. An electric dipole is placed at an angle of 30° to a non-uniform electric field. The dipole will experience **[AIEEE-2006]**

(1) A torque as well as a translational force.
(2) A torque only.
(3) A translational force only in the direction of the field.
(4) A translational force only in a direction normal to the direction of the field.

12. Two insulating plates are both uniformly charged in such a way that the potential difference between them is $V_2 - V_1 = 20$ V. (i.e. plate 2 is at a higher potential). The plates are separated by d = 0.01 m and can be treated as infinitely large. An electron is released from rest on the inner surface of plate 1. What is its speed when it hits plate 2 ? ($e = 1.6 \times 10^{-19}$ C, $m_e = 9.11 \times 10^{-31}$ kg) **[AIEEE-2006]**



(1) 1.87×10^6 m/s **(2)** 32×10^{-19} m/s **(3)** 2.65×10^6 m/s **(4)** 7.02×10^{12} m/s

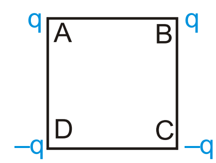
13. Two spherical conductors A and B of radii 1 mm and 2mm are separated by a distance of 5 cm and are uniformly charged. If the spheres are connected by a conducting wire then in equilibrium condition, the ratio of the magnitude of the electric fields at the surfaces of sphere A and B is **[AIEEE-2006]**

(1) 2 : 1 **(2)** 1 : 4 **(3)** 4 : 1 **(4)** 1 : 2

14. An electric charge $10^{-3}\mu$C is placed at the origin (0,0) of X–Y co-ordinate system. Two points A and B are situated at $(\sqrt{2},\sqrt{2})$ and (2,0) respectively. The potential difference between the points A and B will be **[AIEEE-2007]**

(1) 9 volt **(2)** zero **(3)** 2 volt **(4)** 4.5 volt

15. Charges are placed on the vertices of a square as shown. Let $\vec{E}$ be the electric field and V the potential at the centre. If the charges on A and B are interchanged with those on D and C respectively, then **[AIEEE-2007]**



(1) $\vec{E}$ remains unchanged, V changes **(2)** Both $\vec{E}$ and V change

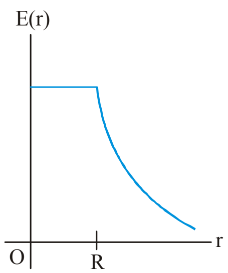
(3) $\vec{E}$ and V remain unchanged **(4)** $\vec{E}$ changes, V remains unchanged

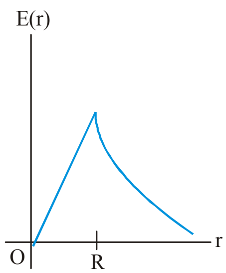
16. The potential at a point x (measured in μm) due to some charges situated on the x-axis is given by $V(x) = 20/(x^2 - 4)$ volts. The electric field E at x = 4 μm is given by : **[AIEEE-2007]**

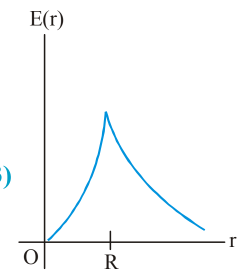
(1) 5/3 volt/μm and in the –ve x direction **(2)** 5/3 volt/μm and in the +ve x direction

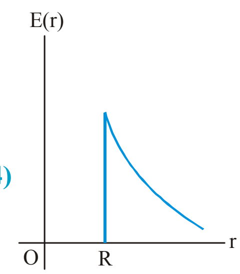
(3) 10/9 volt/μm and in the –ve x direction **(4)** 10/9 volt/μm and in the +ve x direction

17. A thin spherical shell of radius R has charge Q spread uniformly over its surface. Which of the following graphs most closely represents the electric field E (R) produced by the shell in the range $0 \leq r < \infty$, where r is the distance from the centre of the shell? **[AIEEE-2008]**

(1)


(2)


(3)


(4)


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

(1) 9.60×10^{-17} J **(2)** -2.24×10^{-16} J **(3)** 2.24×10^{-16} J **(4)** -9.60×10^{-17} J

19. 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]**

(1) –1 **(2)** 1 **(3)** $-\frac{1}{\sqrt{2}}$ **(4)** $-2\sqrt{2}$

20. **Statement 1 :** For a charged particle moving from point P to point Q, the net work done by an electrostatic field on the particle is independent of the path connecting point P to point Q. **[AIEEE-2009]**

Statement 2 : The net work done by a conservative force on an object moving along a closed loop is zero.

(1) Statement-1 is true, Statement-2 is true; Statement-2 is the correct explanation of Statement-1.

(2) Statement-1 is true, Statement-2 is true; Statement-2 is not the correct explanation of Statement-1.

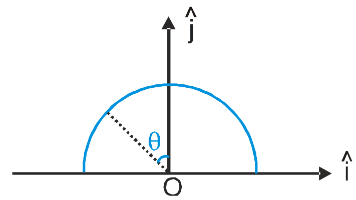
(3) Statement-1 is false, Statement-2 is true.

(4) Statement-1 is true, Statement-2 is false.

21. Let $\rho(R) = \frac{Q}{\pi R^4} r$ be the charge density distribution for a solid sphere of radius R and total charge Q. For a point 'P' inside the sphere at distance r_1 from the centre of sphere, the magnitude of electric field is: **[AIEEE-2009]**

(1) $\frac{Q}{4\pi\varepsilon_0 r_1^2}$ **(2)** $\frac{Q r_1^2}{4\pi\varepsilon_0 R^4}$ **(3)** $\frac{Q r_1^2}{3\pi\varepsilon_0 R^4}$ **(4)** 0

22. A thin semi-circular ring of radius r has a positive charge q distributed uniformly over it. The net field $\vec{E}$ at the centre O is : **[AIEEE-2010]**



(1) $\frac{q}{4\pi^2\varepsilon_0 r^2}\hat{j}$ **(2)** $-\frac{q}{4\pi^2\varepsilon_0 r^2}\hat{j}$

(3) $-\frac{q}{2\pi^2\varepsilon_0 r^2}\hat{j}$ **(4)** $\frac{q}{2\pi^2\varepsilon_0 r^2}\hat{j}$

23. Let there be a spherically symmetric charge distribution with charge density varying as $\rho(r) = \rho_0\left(\frac{5}{4} - \frac{r}{R}\right)$ upto r = R, and ρ(R) = 0 for r > R, where r is the distance from the origin. The electric field at a distance r (r < R) from the origin is given by **[AIEEE-2010]**

(1) $\frac{4\pi\rho_0 r}{3\varepsilon_0}\left(\frac{5}{3} - \frac{r}{R}\right)$ **(2)** $\frac{\rho_0 r}{4\varepsilon_0}\left(\frac{5}{3} - \frac{r}{R}\right)$ **(3)** $\frac{4\rho_0 r}{3\varepsilon_0}\left(\frac{5}{4} - \frac{r}{R}\right)$ **(4)** $\frac{\rho_0 r}{3\varepsilon_0}\left(\frac{5}{4} - \frac{r}{R}\right)$

24. Two identical charged spheres are suspended by strings of equal lengths. The strings make an angle of 30º with each other. When suspended in a liquid of density 0.8 g cm^{-3}, the angle remains the same. If density of the material of the sphere is 1.6 g cm^{-3}, the dielectric constant of the liquid is **[AIEEE-2010]**

(1) 4 **(2)** 3 **(3)** 2 **(4)** 1

25. The electrostatic potential inside a charged spherical ball is given by $\phi = ar^2 + b$ where r is the distance from the centre; a,b are constants. Then the charge density inside the ball is : **[AIEEE - 2011]**

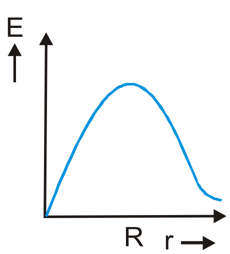
(1) $-24\pi a\varepsilon_0 r$ **(2)** $-6\pi a\varepsilon_0 r$ **(3)** $-24\pi a\varepsilon_0$ **(4)** $-6 a\varepsilon_0$

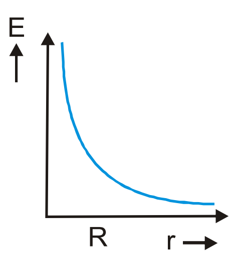
26. Two positive charges of magnitude 'q' are placed at the ends of a side (side 1) of a square of side '2a'. Two negative charges of the same magnitude are kept at the other corners. Starting from rest, if a charge Q moves from the middle of side 1 to the centre of square, its kinetic energy at the centre of square is : **[AIEEE - 2011]**

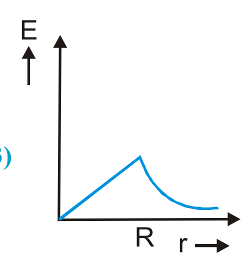
(1) zero **(2)** $\frac{1}{4\pi\varepsilon_0}\frac{2qQ}{a}\left(1 + \frac{1}{\sqrt{5}}\right)$

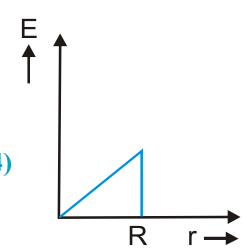
(3) $\frac{1}{4\pi\varepsilon_0}\frac{2qQ}{a}\left(1 - \frac{2}{\sqrt{5}}\right)$ **(4)** $\frac{1}{4\pi\varepsilon_0}\frac{2qQ}{a}\left(1 - \frac{1}{\sqrt{5}}\right)$

27. In a uniformly charged sphere of total charge Q and radius R, the electric field E is plotted as function of distance from the centre. The graph which would correspond to the above will be : **[AIEEE - 2012]**

(1)


(2)


(3)


(4)


28. This question has statement-1 and statement-2. Of the four choices given after the statements, choose the one that best describes the two statements. **[AIEEE - 2012]**

An insulating solid sphere of radius R has a unioformly positive charge density ρ. As a result of this uniform charge distribution there is a finite value of electric potential at the centre of the sphere, at the surface of the sphere and also at a point out side the sphere. The electric potential at infinite is zero.

Statement-1 : When a charge 'q' is taken from the centre to the surface of the sphere its potential energy changes by $\frac{q\rho}{3\varepsilon_0}$.

Statement-2 : The electric field at a distance r (r < R) from the centre of the sphere is $\frac{\rho r}{3\varepsilon_0}$

(1) Statement-1 is true, Statement-2 is true; Statement-2 is not the correct explanation of statement-1.

(2) Statement 1 is true Statement 2 is false.

(3) Statement 1 is false Statement 2 is true.

(4) Statement 1 is true, Statement 2 is true, Statement 2 is the correct explanation of Statement 1.

29. Two charges, each equal to q, are kept at x = – a and x = a on the x-axis. A particle of mass m and charge $q_0 = \frac{q}{2}$ is placed at the origin. If charge q_0 is given a small displacement (y <<a) along the y-axis, the net force acting on the particle is proportional to : **[JEE-Mains 2013]**

(1) y **(2)** –y **(3)** $\frac{1}{y}$ **(4)** $-\frac{1}{y}$

30. A charge Q is uniformly distributed over a long rod AB of length L as shown in the figure. The electric potential at the point O lying at distance L from the end A is : **[JEE-Mains 2013]**

(1) $\frac{Q}{8\pi \in_0 L}$ **(2)** $\frac{3Q}{4\pi \in_0 L}$ **(3)** $\frac{Q}{4\pi \in_0 L \ln 2}$ **(4)** $\frac{Q \ln 2}{4\pi \in_0 L}$

31. Assume that an electric field $\vec{E} = 30x^2\hat{i}$ exists in space. Then the potential difference $V_A - V_O$, where V_O is the potential at the origin and V_A the potential at x = 2 m is : **[JEE-Mains 2014]**

(1) – 80 J **(2)** 80 J **(3)** 120 J **(4)** – 120 J

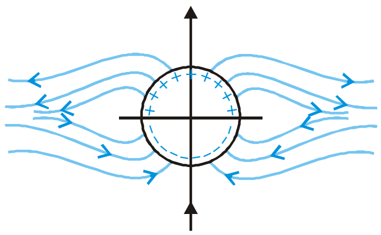
32. A uniformly charged solid sphere of radius R has potential V_0 9measured with respect to ∞) on its surface. For this sphere the equipotential surfaces with potentials $\frac{3V_0}{2}$, $\frac{5V_0}{4}$, $\frac{3V_0}{4}$ and $\frac{V_0}{4}$ have radius R_1, R_2, R_3 and R_4 respectively. Then **[JEE-Mains 2015]**

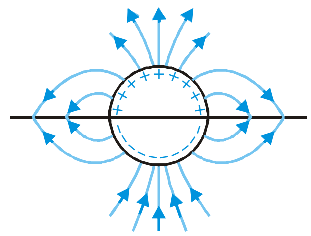
(1) $R_1 = 0$ and $R_2 < (R_4 - R_3)$ **(2)** $2R < R_4$

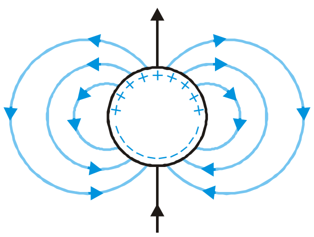
(3) $R_1 = 0$ and $R_2 > (R_4 - R_3)$ **(4)** $R_1 \neq 0$ and $(R_2 - R_1) > (R_4 - R_3)$

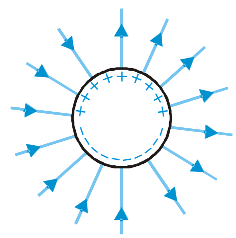
33. A long cylindrical shell carries positive surface charge σ in the upper half and negative surface charge $-\sigma$ in the lower half. The electric field lines around the cylinder will look like figure given in:

(figures are schematic and not drawn to scale) **[JEE-Mains 2015]**

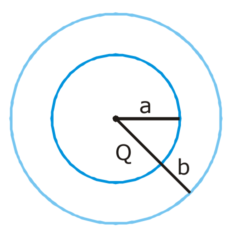
(1) 

(2) 

(3) 

(4) 

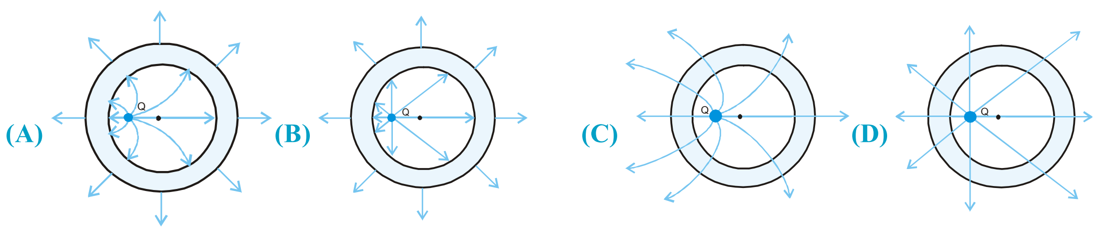
34. The region between two concentric spheres of radii 'a' and 'b', respectively (see figure), has volume charge density $\rho = \frac{A}{r}$, where A is a constant and r is the distance from the centre. At the centre of the spheres is a point charge Q. The value of A such that the electric field in the region between the spheres will be constant, is : **[JEE-Mains 2016]**



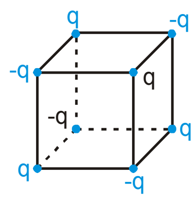
(1) $\frac{Q}{2\pi\left(b^2 - a^2\right)}$ (2) $\frac{2Q}{\pi\left(a^2 - b^2\right)}$ (3) $\frac{2Q}{\pi a^2}$ (4) $\frac{Q}{2\pi a^2}$

Part # II [Previous Year Questions][IIT-JEE ADVANCED]

1. A point charge 'q' is placed at a point inside a hollow conducting sphere. Which of the following electric force pattern is correct? **[JEE 2003]**

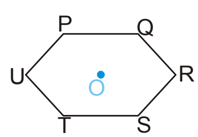


2. Eight charges each of magnitude ' q ', are placed at the vertices of a cube of side a. The nearest neighbours of any charge have opposite sign. Find the work required to dismantle the system . **[JEE 2003]**



3. A point positive charge Q is fixed at origin and a dipole P is placed at very large distance on x-axis with $\vec{P}$ pointing away from the origin . Find (A) the kinetic energy of the dipole when it is at a distance 'd' from origin and (B) at that moment , find the force on charge by dipole. **[JEE 2003]**

4. Six charges q,q,q, – q, –q and –q are to be arranged on the vertices of a regular hexagon PQRSTU such that the electric field at centre is double the field produced when only charge 'q' is placed at vertex R. The sequence of the charges from P to U is : **[JEE 2004]**



(A) q, –q, q, q, –q, –q **(B)** q, q, q, –q, –q, –q
(C) –q, q, q, –q, –q, q **(D)** –q, q, q, q, –q, –q

5. A $+q_1$ charge is at centre of an imaginary spherical Gaussion surface 'S' and $-q_1$ charge is placed nearby this $+q_1$ charge inside 'S'. A charge $+q_2$ is located outside this Gaussian surface. Then, electric field on Gaussian surface will be : **[JEE 2004]**
(A) due to $-q_1$ & q_2 **(B)** uniform **(C)** due to all charges **(D)** zero

6. Two uniformly charged infinitely large plane sheets S_1 and S_2 are held in air parallel to each other with separation d between them. The sheets have charge distributions per unit area σ_1 and σ_2 (Cm^{-2}), respectively, with $\sigma_1 > \sigma_2$. Find the work done by the electric field on a point charge Q that moves from S_1 towards S_2 along a line of length a (a > d) making an angle of $\pi/4$ with the normal to the sheets. Assume that the charge Q does not affect the charge distributions of the sheets. **[JEE 2004]**

7. Which of the following groups do not have same dimensions **[JEE 2005]**
(A) Young's modulus, pressure, stress
(B) Work, heat, energy
(C) Electromotive force, potential difference, voltage
(D) Electric dipole moment, electric flux, electric field

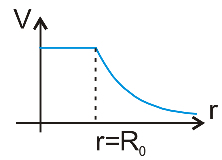
8. Three large parallel plates have uniform surface charge densities as shown in the figure. Find out electric field intensity at point P. **[JEE 2005]**

(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)** $\frac{2\sigma}{\epsilon_0}\hat{k}$

9. A bubble of conducting liquid is charged to potential V. It has radius a and thickness t << a. It collapses to form a droplet. Find potential of the droplet. **[JEE 2005]**

10. For spherical symmetrical charge distribution, variation of electric potential with distance from centre is given in diagram. Given that : **[JEE 2006]**

$V = \frac{q}{4\pi\varepsilon_0 R_0}$ for $r \le R_0$ and $V = \frac{q}{4\pi\varepsilon_0 r}$ for $r \ge R_0$.



Then which option(s) are correct :

(A) Total charge within $2R_0$ is q.

(B) Total electrostatic energy for $r \le R_0$ is zero.

(C) At $r = R_0$ electric field is dicontinuous.

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

11. 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 cylinders.

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

12. Consider a neutral conducting sphere. A positive point charge is placed outside the sphere. Then the net charge on the sphere is : **[JEE-2007]**

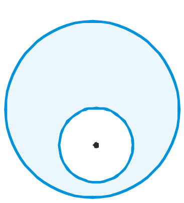
(A) negative and distributed uniformly over the surface of the sphere.

(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.

13. 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 every where **(B)** is not zero but uniform

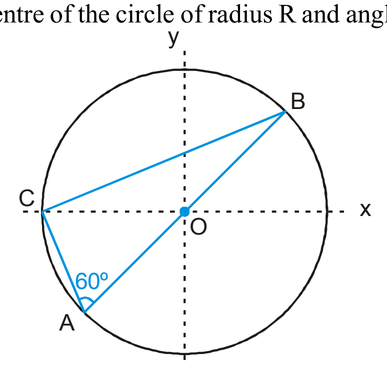
(C) nonuniform **(D)** is zero at centre only

14. Positive and negative point charges of equal magnitude are kept at $\left(0, 0, \frac{a}{2}\right)$ and $\left(0, 0, \frac{-a}{2}\right)$, respectively. The work done by the electric field when another positive point charge is moved from (–a, 0, 0) to (0, a, 0) is **[JEE-2007]**

(A) positive **(B)** negative **(C)** zero

(D) depends on the path connecting the initial and final positions.

15. Consider a system of three charges $\frac{q}{3}$, $\frac{q}{3}$ and $-\frac{2q}{3}$ placed at points A, B and C, respectively, as shown in the figure. Take O to be the centre of the circle of radius R and angle CAB = 60º. **[JEE-2008]**



(A) The electric field at point O is $\frac{q}{8\pi\varepsilon_0 R^2}$ directed along the negative x-axis.

(B) The potential energy of the system is zero.

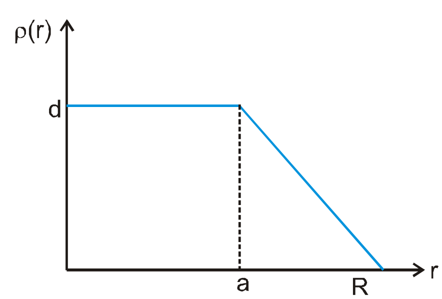
(C) The magnitude of the force between the charges at C and B is $\frac{q^2}{54\pi\varepsilon_0 R^2}$.

(D) The potential at point O is $\frac{q}{12\pi\varepsilon_0 R}$.

Paragraph for Question Nos. 16 to 18

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 :



16. 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

17. For a = 0, the value d (maximum value of ρ as shown in the figure) is :

(A) $\frac{3Ze^2}{4\pi R^3}$ **(B)** $\frac{3Ze}{\pi R^3}$ **(C)** $\frac{4Ze}{3\pi R^3}$ **(D)** $\frac{Ze}{3\pi R^3}$

18. 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)** $a = \frac{2R}{3}$

19. **STATEMENT-1** **[JEE -2008]**

For practical purposes, the earth is used as a reference at zero potential in electrical circuits.

STATEMENT-2

The electrical potential of a sphere of radius R with charge Q uniformly distributed on the surface is given by $\frac{Q}{4\pi\varepsilon_0 R}$.

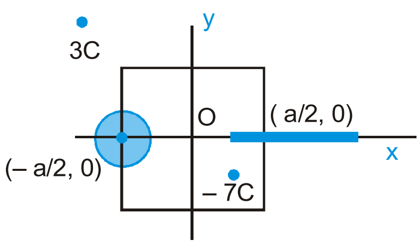
(A) STATEMENT -1 is True, STATEMENT -2 is True; STATEMENT -2 **is** a correct explanation for STATEMENT -1

(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.

20. A disk of radius a/4 having a uniformly distributed charge 6C 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 8C is placed on the x-axis from x = a/4 to x = 5a/4. Two point charges –7C and 3C are placed at (a/4, –a/4, 0) and (–3a/4, 3a/4, 0), respectively. Consider a cubical surface formed by six surfaces x = ± a/2, y = ± a/2, z = ±a/2.
The electric flux through this cubical surface is :
[JEE -2009]



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

(C) $\frac{10C}{\varepsilon_0}$ **(D)** $\frac{12C}{\varepsilon_0}$

21. Three concentric metallic spherical shells of radii R, 2R, 3R, are given charges 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 **[JEE -2009]**

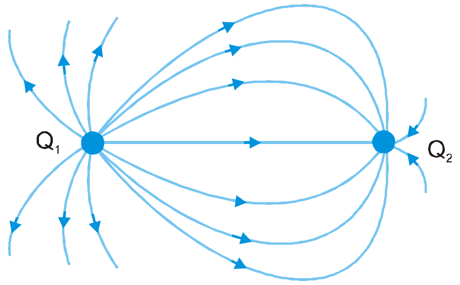
(A) 1 : 2 : 3 **(B)** 1 : 3 : 5 **(C)** 1 : 4 : 9 **(D)** 1 : 8 : 18

22. Under the influence of the Coulomb field of charge +Q, a charge –q is moving around it in an elliptical orbit. Find out the correct statement(s). **[JEE -2009]**

(A) The angular momentum of the charge –q is constant.
(B) The linear momentum of the charge –q is constant.
(C) The angular velocity of the charge – q is constant.
(D) The linear speed of the charge –q is constant.

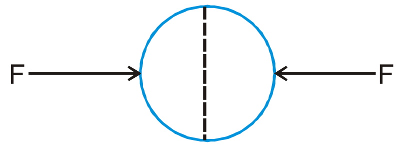
23. A solid sphere of radius R has a charge Q distributed in its volume with a charge density $\rho = kr^a$, where k and a are constants and r is the distance from its centre. If the electric field at $r = \frac{R}{2}$ is $\frac{1}{8}$ times that at r = R, find the value of a. **[JEE -2009]**

24. A few electric field lines for a system of two charges Q_1 and Q_2 fixed at two different points on the x-axis are shown in the figure. These lines suggest that : **[JEE-2010]**



(A) $|Q_1| > |Q_2|$
(B) $|Q_1| < |Q_2|$
(C) at a finite distance to the left of Q_1 the electric field is zero
(D) at a finite distance to the right of Q_2 the electric field is zero

25. 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 **[JEE-2010]**

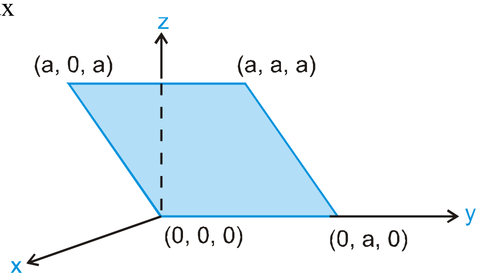


(A) $\frac{1}{\varepsilon_0}\sigma^2 R^2$ **(B)** $\frac{1}{\varepsilon_0}\sigma^2 R$ **(C)** $\frac{1}{\varepsilon_0}\frac{\sigma^2}{R}$ **(D)** $\frac{1}{\varepsilon_0}\frac{\sigma^2}{R^2}$

26. A tiny spherical oil drop carrying a net charge q is balanced in still air with a vertical uniform electric field of strength $\frac{81\pi}{7}\times 10^5\ \text{Vm}^{-1}$. When the field is switched off, the drop is observed to fall with terminal velocity 2×10^{-3} m s^{-1}. Given g = 9.8 m s^{-2}, viscosity of the air = 1.8×10^{-5} Ns m^{-2} and the density of oil = 900 kg m^{-3}, the magnitude of q is : **[JEE-2010]**

(A) 1.6×10^{-19} C **(B)** 3.2×10^{-19} C **(C)** 4.8×10^{-19} C **(D)** 8.0×10^{-19} C

27. 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]**



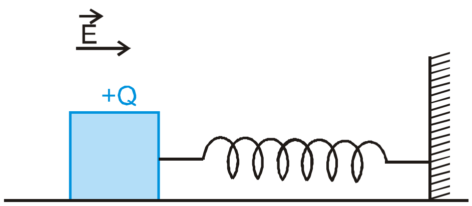
(A) $2E_0a^2$ **(B)** $\sqrt{2}\,E_0a^2$

(C) E_0a^2 **(D)** $\frac{E_0a^2}{\sqrt{2}}$

28. 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) $E_A^{\text{inside}} = 0$ **(B)** $Q_A > Q_B$ **(C)** $\frac{\sigma_A}{\sigma_B} = \frac{R_B}{R_A}$ **(D)** $E_A^{\text{on surface}} < E_B^{\text{on surface}}$

29. A wooden block performs SHM on a frictionless surface with frequency, ν_0. The block carries a charge +Q on its surface. If now a uniform electric field E is switched-on as shown, then the SHM of the block will be **[JEE-2011]**



(A) of the same frequency and with shifted mean position.
(B) of the same frequency and with the same mean position.
(C) of changed frequency and with shifted mean position.
(D) of changed frequency and with the same mean position.

30. Which of the following statement(s) is/are correct? **[JEE-2011]**

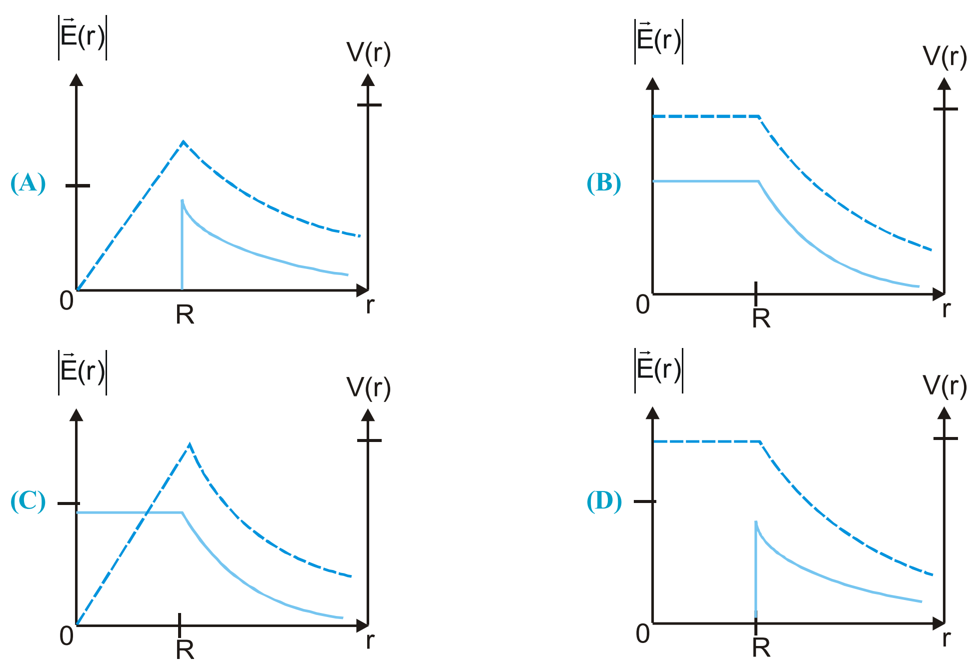
(A) If the electric field due to a point charge varies as $r^{-2.5}$ instead of r^{-2}, then the Gauss law will still be valid.

(B) The Gauss law can be used to calculate the field distribution around an electric dipole.

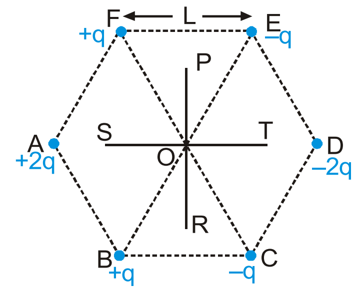
(C) If the electric field between two point charges is zero somewhere, then the sign of the two charges is the same.

(D) The work done by the external force in moving a unit positive charge from point A at potential V_A to point B at potential V_B is $(V_B — V_A)$.

31. Consider a thin spherical shell of radius R with its centre at the origin, carrying uniform positive surface charge density. The variation of the magnitude of the electric field $|\vec{E}(r)|$ and the electric potential V(R) with the distance r from the centre, is best represented by which graph ? **[JEE-2012]**



32. Six point charges are kept at the vertices of a regular hexagon of side L and centre O, as shown in the figure. Given that $K = \frac{1}{4\pi\varepsilon_0}\frac{q}{L^2}$, which of the following statement(s) is (are) correct ? **[JEE-2012]**

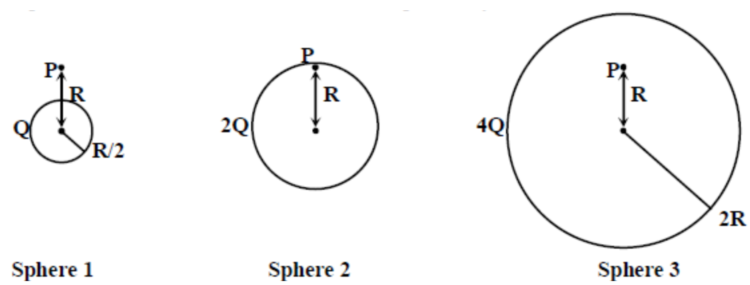


(A) the elecric field at O is 6K along OD
(B) The potential at O is zero
(C) The potential at all points on the line PR is same
(D) The potential at all points on the line ST is same.

33. Let $E_1(R)$, $E_2(R)$ and $E_3(R)$ be the respective electric fields at a distance r from a point charge Q, an infinitely long wire with constant linear charge density λ, and an infinite plane with uniform surface charge density σ. If $E_1(r_0) = E_2(r_0) = E_3(r_0)$ at a given distance r_0, then **[JEE ADVANCED-2014]**

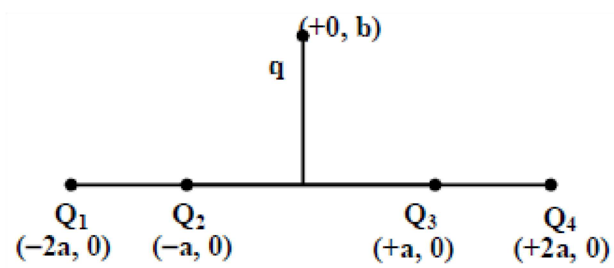
(A) $Q = 4\sigma\pi r_0^2$ **(B)** $r_0 = \frac{\lambda}{2\pi\sigma}$ **(C)** $E_1 = (r_0/2) = 2E_2(r_0/2)$ **(D)** $E_2 = (r_0/2) = 4E_3(r_0/2)$

34. Charges Q, 2Q and 4Q are uniformly distributed in three dielectric solid spheres 1, 2 and 3 of radii R/2, R and 2R respectively, as shown in figure. If magnitudes of the electric fields at point P at a distance R from the centre of spheres 1, 2 and 3 are E_1, E_2 and E_3 respectively, then **[JEE ADVANCED-2014]**



(A) $E_1 > E_2 > E_3$ **(B)** $E_3 > E_1 > E_2$ **(C)** $E_2 > E_1 > E_3$ **(D)** $E_3 > E_2 > E_1$

35. Four charges Q_1, Q_2, Q_3 and Q_4 of same magnitude are fixed along the x axis at x = -2a, –a, +a and +2a, respectively. A positive charge q is placed on the positive y axis at a distance b > 0. Four options of the signs of these charges are given in List I. The direction of the forces on the charge q is given in List II. Match List I with List II and select the correct answer using the code given below the lists. **[JEE ADVANCED-2014]**

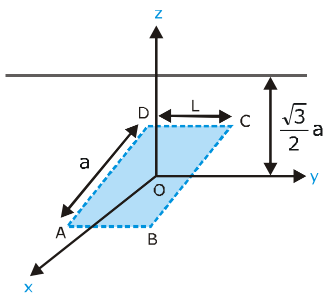


List I	List II
P. Q_1, Q_2, Q_3, Q_4 all positive	**1.** +x
Q. Q_1, Q_2 positive; Q_3, Q_4 negative	**2.** –x
R. Q_1, Q_4 positive ; Q_2, Q_3 negative	**3.** +y
S. Q_1, Q_3 positive; Q_2, Q_4 negative	**4.** –y

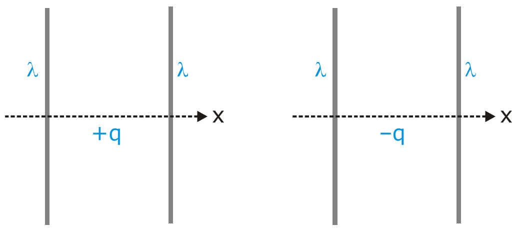
Code:
(A) P-3, Q-1, R-4, S-2 **(B)** P-4, Q-2, R-3, S-1
(C) P-3, Q-1, R-2, S-4 **(D)** P-4, Q-2, R-1, S-3

36. An infinitely long uniform line charge distribution of charge per unit length λ lies parallel to the y-axis in the y-z plane at $z = \frac{\sqrt{3}}{2}a$ (see figure). If the magnitude of the flux of the electric field through the rectangular surface ABCD lying in the x-y plane with its centre at the origin is $\frac{\lambda L}{n\varepsilon_0}$ (ε_0 permittivity of free space), then the value of n is

[JEE ADVANCED-2015]

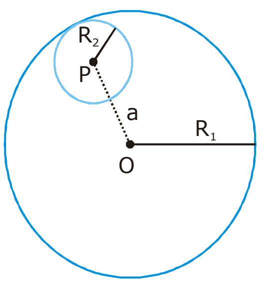


37. The figures below depict two situtions in which two infinitely long static line charges of constant positive line charge density λ are kept parallel to each other. In their resulting electric field, point charges q and –q are kept in equilibrium between them. The point charges are confined to move in the x direction only. If they are given a small displacement about their equilibrium positions, then the correct statement(s) is (are) **[JEE ADVANCED-2015]**



(A) Both charges execute simple harmonic motion.
(B) Both charges will continue moving in the direction of their displacement.
(C) Charge +q executes simple harmonic motion while charge –q continues moving in the direction of its displacement.
(D) Charges –q executes simple harmonic motion while charge +q continues moving in the direction of its displacement.

38. Consider a uniform spherical charge distribution of radius R_1 centred at the origin O. In this distribution, a spherical cavity of radius R_2, centred at P with distance OP = a = $R_1 - R_2$ (see figure) is made. If the electric field inside the cavity at position $\vec{r}$ is $\vec{E}(\vec{r})$, then the correct statement(s) is (are) **[JEE ADVANCED-2015]**



(A) $\vec{E}$ is uniform, its magnitude is independent of R_2 but its direction depends on $\vec{r}$
(B) $\vec{E}$ is uniform, its magnitude depends on R_2 and its direction depends on $\vec{r}$
(C) $\vec{E}$ is uniform, its magnitude is independent of a but its direction depends on $\vec{a}$
(D) $\vec{E}$ is uniform and both its magnitude and direction depends on $\vec{a}$

MOCK TEST

SECTION - I : STRAIGHT OBJECTIVE TYPE

1. A point charge + Q is placed at the centroid of an equilateral triangle. When a second charge + Q is placed at a vertex of the triangle, the magnitude of the electrostatic force on the central charge is 8 N. The magnitude of the net force on the central charge when a third charge + Q is placed at another vertex of the triangle is:

(A) zero **(B)** 4 N **(C)** $4\sqrt{2}$ N **(D)** 8 N

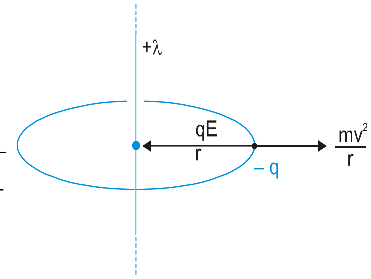
2. The electric field inside a sphere which carries a volume charge density proportional to the distance from the origin $\rho = \alpha r$ (α is a constant) is :

(A) $\dfrac{\alpha r^3}{4 \epsilon_0}$ **(B)** $\dfrac{\alpha r^2}{4 \epsilon_0}$ **(C)** $\dfrac{\alpha r^2}{3 \epsilon_0}$ **(D)** none of these

3. A particle of charge - q & mass *m* moves in a circle of radius *r* around an infinitely long line charge of linear charge density + λ. Then time period of revolution of charge will be :

(A) $T = 2\pi r\sqrt{\dfrac{m}{2k\lambda q}}$ **(B)** $T^2 = \dfrac{4\pi^2 m}{2k\lambda q} r^3$

(C) $T = \dfrac{1}{2\pi r}\sqrt{\dfrac{2k\lambda q}{m}}$ **(D)** $T = \dfrac{1}{2\pi r}\sqrt{\dfrac{m}{2k\lambda q}}$

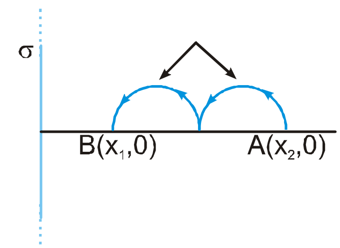


where $k = \dfrac{1}{4\pi \epsilon_0}$

4. An infinitely long plate has surface charge density σ. As shown in the fig, a point charge q is moved from A to B. Net work done by electric field is:

(A) $\dfrac{\sigma q}{2 \epsilon_0}(x_1 - x_2)$ **(B)** $\dfrac{\sigma q}{2 \epsilon_0}(x_2 - x_1)$

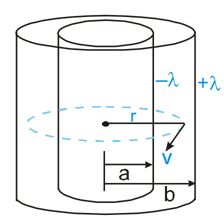
(C) $\dfrac{\sigma q}{\epsilon_0}(x_2 - x_1)$ **(D)** $\dfrac{\sigma q}{\epsilon_0}(2\pi r + r)$



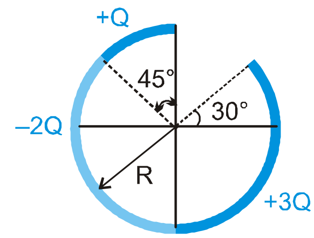
5. Figure shows two large cylindrical shells having uniform linear charge densities + λ and – λ. Radius of inner cylinder is 'a' and that of outer cylinder is 'b'. A charged particle of mass m, charge q revolves in a circle of radius r (where a < r < b). Then it's speed 'v' is : (Neglect gravity and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

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

(C) $\sqrt{\dfrac{\lambda q}{\pi \epsilon_0 m}}$ **(D)** $\sqrt{\dfrac{\lambda q}{4\pi\varepsilon_0 m}}$



6. Figure shows three circular arcs, each of radius R and total charge as indicated. The net elecric potential at the centre of curvature is :



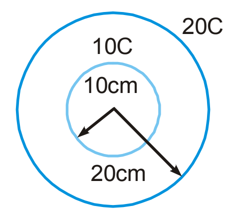
(A) $\frac{Q}{2\pi\varepsilon_0 R}$ **(B)** $\frac{Q}{4\pi\varepsilon_0 R}$

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

7. An electric field is given by $E_x = -2x^3$ kN/C. The potential of the point (1, –2), if potential of the point (2, 4) is taken as zero, is

(A) -7.5×10^3 V **(B)** 7.5×10^3 V **(C)** -15×10^3 V **(D)** 15×10^3 V

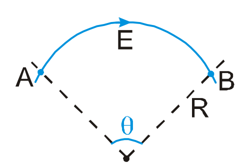
8. Two concentric uniformly charged spheres of radius 10 cm & 20 cm are arranged as shown in the figure. Potential difference between the spheres is:



(A) 4.5×10^{11} V **(B)** 2.7×10^{11} V

(C) 0 **(D)** none of these

9. Figure shows an electric line of force which curves along a circular arc. The magnitude of electric field intensity is same at all points on this curve and is equal to E. If the potential at A is V, then the potential at B is :



(A) $V - ER\theta$ **(B)** $V - 2ER\sin\frac{\theta}{2}$

(C) $V + ER\theta$ **(D)** $V + 2ER\sin\frac{\theta}{2}$

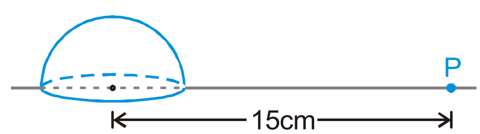
10. Figure shows a solid hemisphere with a charge of 5 nC distributed uniformly throughout its volume. The hemisphere lies on a plane and point P is located on the plane, along a radial line from the centre of curvature at distance 15 cm. The electric potential at point P due to the hemisphere, is :

(A) 150 V

(B) 300 V

(C) 450 V

(D) 600 V



11. A point charge Q is placed at a distance d from the centre of an uncharged conducting sphere of radius R. The potential of the sphere is (d > R) :

(A) $\frac{1}{4\pi\epsilon_0}.\frac{Q}{(d-R)}$ **(B)** $\frac{1}{4\pi\epsilon_0}.\frac{Q}{d}$ **(C)** $\frac{1}{4\pi\epsilon_0}.\frac{Q}{R}$ **(D)** zero

12. Two point dipoles of dipole moments $p\hat{k}$ & $\frac{p}{2}\hat{k}$ are located at (0, 0, 0) & (1 m, 0, 2 m) respectively. The resultant electric field due to the two dipoles at the point (1 m, 0, 0) is :

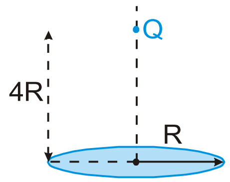
(A) $\frac{9p}{32\pi\epsilon_0}\hat{k}$ **(B)** $\frac{-7p}{32\pi\epsilon_0}\hat{k}$ **(C)** $\frac{7p}{32\pi\epsilon_0}\hat{k}$ **(D)** none of these

13. A dipole of dipole moment p is kept at the centre of a ring of radius R and charge Q. The dipole moment has direction along the axis of the ring. The resultant force on the ring due to the dipole is:

(A) zero **(B)** $\frac{kPQ}{R^3}$ **(C)** $\frac{2kPQ}{R^3}$

(D) $\frac{kPQ}{R^3}$ only if the charge is uniformly distributed on the ring.

14. A charge Q is placed at a distance of 4R above the centre of a disc of radius R. The magnitude of flux through the disc is ϕ. Now a hemispherical shell of radius R is placed over the disc such that it forms a closed surface. The flux through the curved surface taking direction of area vector along outward normal as positive, is

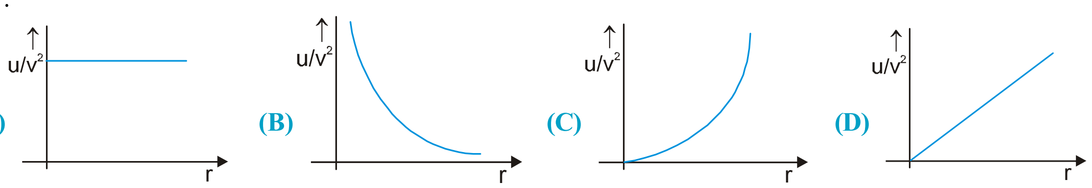


(A) zero **(B)** ϕ **(C)** $-\phi$ **(D)** 2ϕ

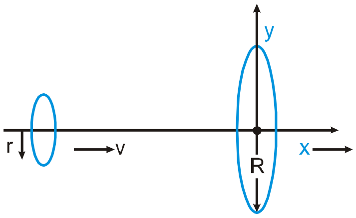
15. A conducting disc of radius R rotates about its axis with an angular velocity ω. Then the potential difference between the centre of the disc and its edge is (no magnetic field is present) :

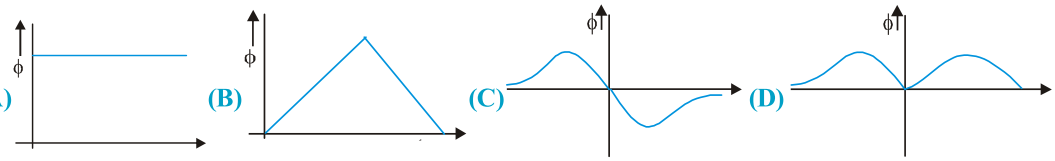
(A) zero **(B)** $\frac{m_e\omega^2 R^2}{2e}$ **(C)** $\frac{m_e\omega R^3}{3e}$ **(D)** $\frac{e m_e\omega R^2}{2}$

16. At distance 'r' from a point charge, the ratio $\frac{u}{v^2}$ (where 'u' is energy density and 'v' is potential) is best represented by :

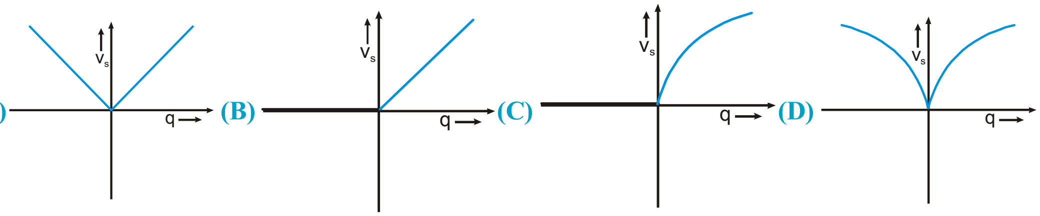


17. A ring of radius R is placed in the plane with its centre at origin and its axis along the x-axis and having uniformly distributed positive charge. A ring of radius r (<< R) and coaxial with the larger ring is moving along the axis with constant velocity then the variation of electrical flux (ϕ) passing through the smaller ring with Position will be best represented by:





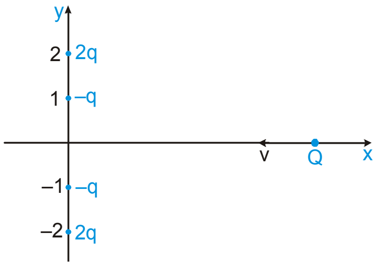
18. A negative charge Q is distributed uniformly in volume of a sphere of radius R and a point charge particle of charge q (may be negative or positive) is present on the surface of this sphere then the variation of escape velocity (v_s) of charge 'q' as a function of 'q' will be [neglect gravitational interaction]



19. Electrical potential 'v' in space as a function of co-ordinates is given by, $v = \frac{1}{x} + \frac{1}{y} + \frac{1}{z}$. Then the electric field intensity at (1, 1, 1) is given by:

(A) $-(\hat{i} + \hat{j} + \hat{k})$ **(B)** $\hat{i} + \hat{j} + \hat{k}$ **(C)** zero **(D)** $\frac{1}{\sqrt{3}}(\hat{i} + \hat{j} + \hat{k})$

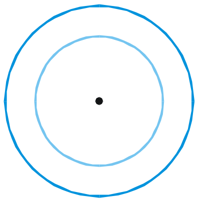
20. Four charges are rigidly fixed along the Y axis as shown. A positive charge approaches the system along the X axis with initial speed just enough to cross the origin. Then its total energy at the origin is



(A) zero **(B)** positive

(C) negative **(D)** data insufficient

21. In the figure two conducting concentric spherical shells are shown. If the electric potential at the centre is 20 V & the electric potential of the outer shell is 5 V, then the potential of the inner shell is:

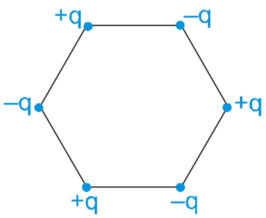


(A) 5 V **(B)** 15 V **(C)** 20 V **(D)** 25 V

22. A dipole of dipole moment $\vec{P} = 2\hat{i} - 3\hat{j} + 4\hat{k}$ is placed at point A (2, –3, 1). The electric potential due to this dipole at the point B (4, – 1, 0) is equal to (All the parameters specified here are in S.I. units.)

(A) 2×10^9 volts **(B)** -2×10^9 volts **(C)** 3×10^9 volts **(D)** -3×10^9 volts

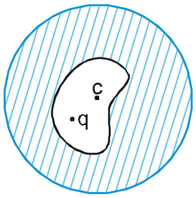
23. Six charges of magnitude + q and –q are fixed at the corners of a regular hexagon of edge length a as shown in the figure. The electrostatic interaction energy of the charged particles is :



(A) $\frac{q^2}{\pi \in_0 a}\left[\frac{\sqrt{3}}{8} - \frac{15}{4}\right]$ **(B)** $\frac{q^2}{\pi \in_0 a}\left[\frac{\sqrt{3}}{2} - \frac{9}{4}\right]$

(C) $\frac{q^2}{\pi \in_0 a}\left[\frac{\sqrt{3}}{4} - \frac{15}{2}\right]$ **(D)** $\frac{q^2}{\pi \in_0 a}\left[\frac{\sqrt{3}}{2} - \frac{15}{8}\right]$

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



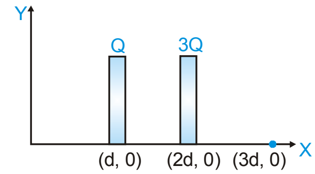
(A) only induced charge on outer surface will redistribute.

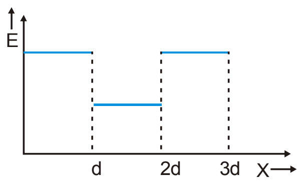
(B) only induced charge on inner surface will redistribute.

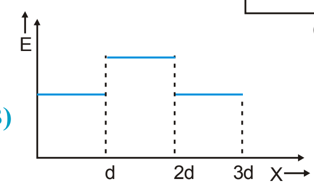
(C) both induced charge on outer and inner surface will redistribute.

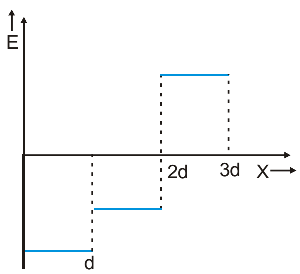
(D) force on charge q placed inside the cavity will change.

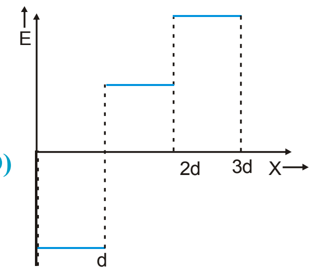
25. Two very large thin conducting plates having same cross-sectional area are placed as shown in figure. They are carrying charges 'Q' and '3Q' respectively. The variation of electric field as a function at x (for x = 0 to x = 3d) will be best represented by.



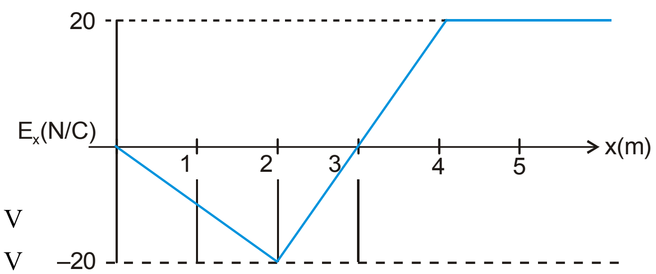
(A)


(B)


(C)


(D)


26. A graph of the x component of the electric field as a function of x in a region of space is shown. The Y and Z components of the electric field are zero in this region. If the electric potential is 10 V at the origin, then potential at x = 2.0 m is :

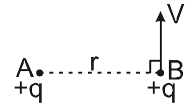


(A) 10 V　　**(B)** 40 V

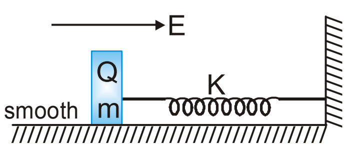
(C) – 10 V　　**(D)** 30 V

27. In the figure shown, A is a fixed charge. B (of mass m) is given a velocity V perpendicular to line AB. At this moment the radius of curvature of the resultant path of B is

(A) 0　　**(B)** ∞ (infinity)　　**(C)** $\frac{4\pi \in_0 r^2 mv^2}{q^2}$　　**(D)** r



28. In the figure shown, initially the spring of negligible mass is in undeformed state and the block has zero velocity E is a uniform electric field, then : (K = spring constant)



(i) The maximum speed of the block will be $\frac{QE}{\sqrt{mK}}$

(ii) The maximum speed of the block will be $\frac{2QE}{\sqrt{mK}}$

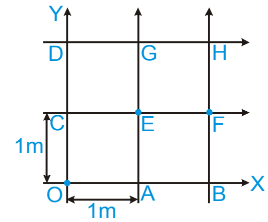
(iii) The maximum compression of the spring will be $\frac{QE}{K}$

(iv) The maximum compression of the spring will be $\frac{2QE}{K}$

(A) only (i) and (iii) are correct　　**(B)** only (i) and (iv) are correct

(C) only (ii) and (iii) are correct　　**(D)** only (ii) and (iv) are correct

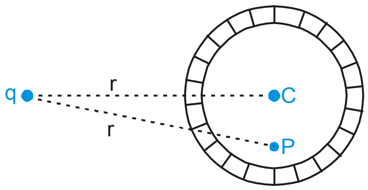
29. The grid (each square of 1m × 1m), represents a region in space containing a uniform electric field. If potentials at points O, A, B, C, D, E, F, G & H are respectively 0, – 1, – 2, 1, 2, 0, – 1, 1, and 0 volts, then find the electric field intensity.



(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

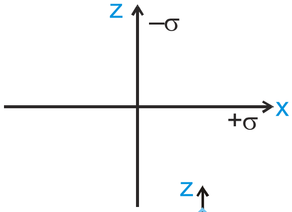
30. A neutral conducting spherical shell is kept near a charge q as shown. The potential at point P due to the induced charges is :

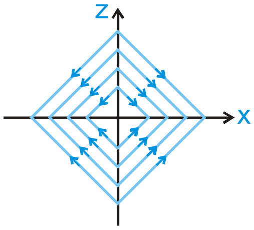


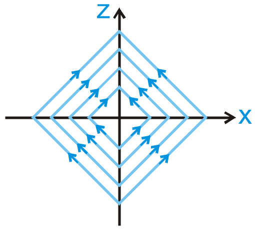
(A) $\frac{kq}{r}$ **(B)** $\frac{kq}{r'}$

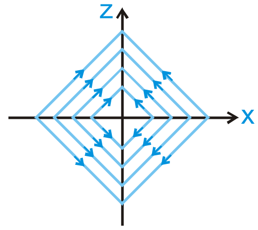
(C) $\frac{kq}{r}-\frac{kq}{r'}$ **(D)** $\frac{kq}{CP}$

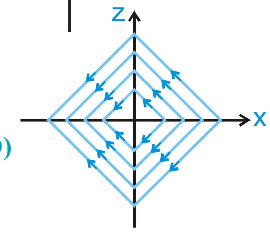
31. Two infinitely large charged planes having uniform surface charge density +σ and –σ are placed along x-y plane and yz plane respectively as shown in the figure. Then the nature of electric lines of forces in x-z plane is given by :



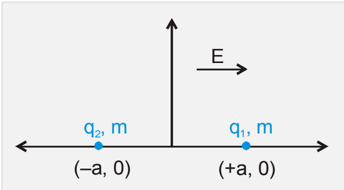
(A) 

(B) 

(C) 

(D) 

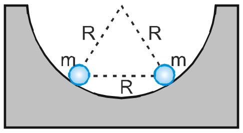
32. Two positively charged particles of charges q_1 and q_2 have mass m each. A uniform electric field having magnitude E exists in positive x direction as shown in the figure. The given two charged particles are released from rest at t = 0 as shown in the figure. If position of q_1 at t = 2 sec is given by coordinate (+2a, 0) then the x-coordinate of q_2 at t = 2 sec is (neglect gravitational interaction between the particles) -



(A) $\frac{q_1+q_2}{m}E-2a$ **(B)** $\frac{q_1+q_2}{m}E-a$

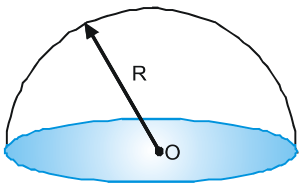
(C) $2\left(\frac{q_1+q_2}{m}\right)E-2a$ **(D)** $2\left(\frac{q_1+q_2}{m}\right)E-a$

33. Two identical small balls each have a mass m and charge q. When placed in a hemispherical bowl of radius R with frictionless, non-conducting walls, the beads move and at equilibrium, the line joining the balls is horizontal and the distance between them is R (figure). Neglect any induced charge on the hemispherical bowl . Then the charge on each bead is: (here, $K=\frac{1}{4\pi\epsilon_0}$)



(A) $q=R\left(\frac{mg}{K\sqrt{3}}\right)^{1/2}$ **(B)** $q=\left(R\frac{mg}{K\sqrt{3}}\right)^{1/2}$ **(C)** $q=R\left(\frac{\sqrt{3}\,mg}{K}\right)^{1/2}$ **(D)** $q=\left(R\frac{\sqrt{3}\,mg}{K}\right)^{1/2}$

34. Charge Q coulombs is uniformly distributed throughout the volume of a solid hemisphere of radius R metres. Then the potential at centre O of the hemisphere in volts is :

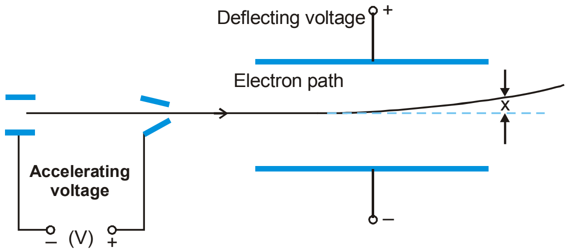


(A) $\frac{1}{4\pi\varepsilon_o}\frac{3Q}{2R}$ **(B)** $\frac{1}{4\pi\varepsilon_o}\frac{3Q}{4R}$

(C) $\frac{1}{4\pi\varepsilon_o}\frac{Q}{4R}$ **(D)** $\frac{1}{4\pi\varepsilon_o}\frac{Q}{8R}$

SECTION - II : MULTIPLE CORRECT ANSWER TYPE

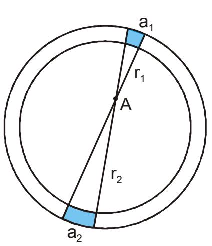
35. The diagram shows part of an evacuated tube in which a stream of electrons from an electron gun passes between a pair of parallel large deflecting plates. The vertical displacement of the electron beam as it leaves the parallel plates is x. (Do not consider gravity and the electron enters the deflecting region parallel to the plates)



Which one of A to D below will change the displacement x of the beam as it leaves the parallel plates
(A) increasing the accelerating voltage
(B) increasing the deflecting voltage
(C) increasing the distance between the electron gun and the deflecting plates
(D) increasing the distance between the two deflecting plates

36. A particle of mass 2Kg and charge1mC is projected vertically with a velocity $10ms^{-1}$. There is a uniform horizontal electric field of 10^4N/C.
(A) the horizontal range of the particle is 10m **(B)** the time of flight of the particle is 2s
(C) the maximum height reached is 5m **(D)** the horizontal range of the particle is 0.

37. A wire having a uniform linear charge density λ, is bent in the form of a ring of radius R. Point A as shown in the figure, is in the plane of the ring but not at the centre. Two elements of the ring of lengths a_1 and a_2 subtend very small same angle at the point A. They are at distances r_1 and r_2 from the point A respectively.



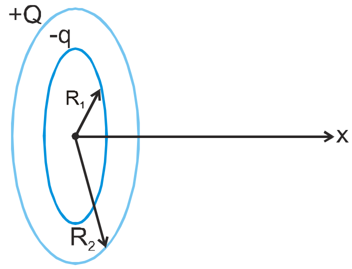
(A) The ratio of charge of elements a_1 and a_2 is r_1/r_2.
(B) The element a_1 produced greater magnitude of electric field at A than element a_2.
(C) The elements a_1 and a_2 produce same potential at A.
(D) The direction of net electric field at A is towards element a_2.

38. Two infinite, parallel, non–conducting sheets carry equal positive charge density σ. One is placed in the yz plane at x = 0 and the other at x = a. Take potential V = 0 at x = 0.

(A) For $0 \le x \le a$, potential $V_x = 0$. **(B)** For $x \ge a$, potential $V_x = -\frac{\sigma}{\epsilon_0}(x-a)$

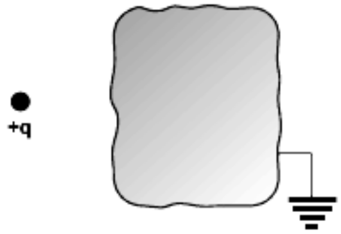
(C) For $x \ge a$, potential $V_x = \frac{\sigma}{\epsilon_0}(x-a)$ **(D)** For $x \le 0$ potential $V_x = \frac{\sigma}{\epsilon_0}x$

39. Two concentric rings of radii $R_1 = \sqrt{6}$ m and $R_2 = 4$m are placed in y-z plane with their centres at origin. They have uniform charge – q and $+Q = 2\sqrt{2}\,q$ on the inner and outer rings respectively. Consider the electrostatic potential to be zero at infinity. Then



(A) The electric potential is zero at origin.
(B) The electric field intensity is zero at r = 2 m.
(C) A positive charged particle disturbed from origin along the x-axis will restore back to origin.
(D) Where potential is maximum on the x-axis, field intensity is zero.

40. In front of an earthed conductor a point charge + q is placed as shown in figure :

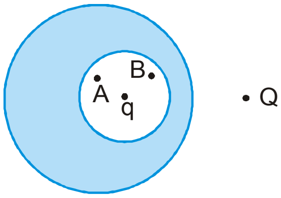


(A) On the surface of conductor the net charge is negative.
(B) On the surface of conductor at some points charges are negative and at some points charges may be positive distributed non uniformly
(C) Inside the conductor electric field due to point charge is non zero
(D) None of these

SECTION - III : ASSERTION AND REASON TYPE

41. **Statement 1 :** Electric field E at a point P is zero if potential at that point is zero.
Statement 2 : Potential difference between two points in space is zero if electric field at all points in space is zero.
(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.

42. **Statement-1 :** A point charge q is placed at centre of spherical cavity inside a spherical conductor as shown. Another point charge Q is placed outside the conductor as shown. Now as the point charge Q is pushed away from conductor, the potential difference $(V_A - V_B)$ between two points 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; 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

43. **Statement-1 :** For a non-uniformly charged thin circular ring with net charge zero, the electric field at any point on axis of the ring is zero.

Statement-2 : For a non-uniformly charged thin circular ring with net charge zero, the electric potential at each point on axis of the ring is zero.

(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.

44. **Statement-1 :** A uniformly charged disc has a pin hole at its centre. The electric field at the centre of the disc is zero.

Statement-2 : Disc can be supposed to be made up of many rings. Also electric field at the centre of uniformly charged ring is zero..

(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.

45. **Statement-1 :** Total work done by non uniform electric field on a charged particle starting from rest till any time is non negative. (assume no other forces act on the charged particle)

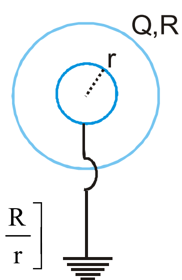
Statement-2 : The angle between electrostatic force and velocity of the charged particle released from rest in non uniform electric field is always acute. (assume no other forces act on the charged particle)

(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.

SECTION - IV : COMPREHENSION TYPE

Comprehension # 1

A metal ball (Neutral) with radius r is concentric with hollow metal sphere of radius 'R', having charge 'Q' as shown in figure, Now ball is connected with a very long wire to earth. Then :



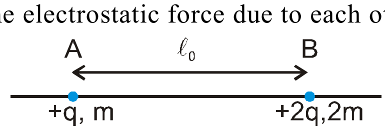
46. Potential difference between sphere and metal ball, after grounding is :

(A) $\frac{kQ}{R}$ **(B)** $-\frac{kQr}{R^2}$ **(C)** $\frac{kQ}{R}\left[1-\frac{r}{R}\right]$ **(D)** $\frac{kQ}{r}\left[1-\frac{R}{r}\right]$

47. After grounding :
(A) net electric field between sphere and ball is zero.
(B) electric field between ball and sphere is zero due to ball only.
(C) electric field between sphere and ball due to ball is non–zero.
(D) electric field between sphere and ball is non-zero, due to sphere

Comprehension # 2

Two positive point charges A and B have charge +q and +2q; mass m and 2m respectively as shown. Both the charges are released from rest when they are at a distance ℓ_0 apart. Neglect gravity and also assume the only force acting on either charge is the electrostatic force due to each other.



48. The speed of charge A at the instant separation between both charges is $2\ell_0$ is :

(A) $\sqrt{\dfrac{q^2}{12\pi\epsilon_0 m\ell}}$ (B) $\sqrt{\dfrac{q^2}{6\pi\epsilon_0 m\ell}}$ (C) $\sqrt{\dfrac{q^2}{4\pi\epsilon_0 m\ell}}$ (D) $\sqrt{\dfrac{q^2}{3\pi\epsilon_0 m\ell}}$

49. The work done by electrostatic force on charge A while the separation between both charges changes from ℓ_0 to $2\ell_0$ is.

(A) $\dfrac{q^2}{12\pi\epsilon_0 \ell}$ (B) $\dfrac{q^2}{6\pi\epsilon_0 \ell}$ (C) $\dfrac{q^2}{4\pi\epsilon_0 \ell}$ (D) $\dfrac{q^2}{24\pi\epsilon_0 \ell}$

50. Total work done by electrostatic force on charge A + charge B while the separation between both charges changes from ℓ_0 to $2\ell_0$ is.

(A) $\dfrac{q^2}{12\pi\epsilon_0 \ell}$ (B) $\dfrac{q^2}{6\pi\epsilon_0 \ell}$ (C) $\dfrac{q^2}{4\pi\epsilon_0 \ell}$ (D) $\dfrac{q^2}{24\pi\epsilon_0 \ell}$

Comprehension # 3

A charge q is divided into three equal parts and placed symmetrically on a circle of radius r. The same charge is divided into four equal parts and placed symmetrically on the same circle. The electric field intensities at the centre of the circle in two situations are zero.

51. The ratio of electric potentials at the centre in the two situations is

(A) $\dfrac{2}{\sqrt{3}}$ (B) $\dfrac{1}{1}$ (C) $\dfrac{4}{3}$ (D) $\dfrac{16}{9}$

52. The potential energy of the system in first situation where the charge is divided into three equal parts is

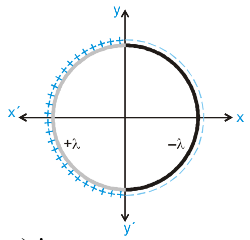
(A) $\dfrac{1}{4\pi\varepsilon_o}\dfrac{q^2}{r}$ (B) $\dfrac{1}{36\pi\varepsilon_o}\dfrac{q^2}{r}$ (C) $\dfrac{1}{12\sqrt{3}\pi\varepsilon_o}\dfrac{q^2}{r}$ (D) $\dfrac{1}{12\pi\varepsilon_o}\dfrac{q^2}{r}$

53. If a charge (part charge) is removed from one location in both the situations, the ratio of magnitudes of the electric field intensities at the centre is

(A) $\dfrac{1}{2}$ (B) $\dfrac{1}{1}$ (C) $\dfrac{2}{3}$ (D) $\dfrac{4}{3}$

Comprehension # 4

A thin ring of radius R metres is placed in x-y plane such that its centre lies on origin. The half ring in region x< 0 carries uniform linear charge density +λ C/m and the remaining half ring in region x> 0 carries uniform linear charge density –λ C/m.



54. Then the electric potential (in volts) at point P whose coordinates are (0m, $+\dfrac{R}{2}$m) is

(A) $\dfrac{1}{4\pi\varepsilon_o}\dfrac{\lambda}{2}$ (B) 0 (C) $\dfrac{1}{4\pi\varepsilon_o}\dfrac{\lambda}{4}$ (D) cannot be determined

55. The direction of electric field at point P whose coordinates are $(0m, +\frac{R}{2}m)$ is

(A) Along positive x-direction
(B) Along negative x-direction
(C) Along negative y-direction
(D) None of these

56. The dipole moment of the ring in C–m is

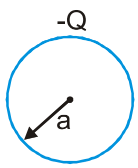
(A) $-(2\pi R^2\lambda)\,\hat{i}$
(B) $(2\pi R^2\lambda)\,\hat{i}$
(C) $-(4R^2\lambda)\,\hat{i}$
(D) $(4R^2\lambda)\,\hat{i}$

SECTION - V : MATRIX - MATCH TYPE

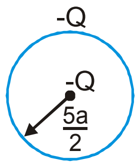
57. In each situation of column-I, some charge distributions are given with all details explained. The electrostatic potential energy and its nature is given in column -II. Then match situation in column-I with the corresponding results in column-II and indicate your answer by darkening appropriate bubbles in the 4 × 4 matrix given in the OMR.

Column-I

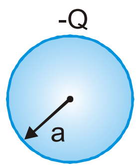
(A) A thin shell of radius a and having a charge – Q uniformly distributed over its surface as shown



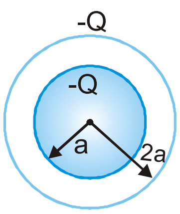
(B) A thin shell of radius $\frac{5a}{2}$ and having a charge – Q uniformly distributed over its surface and a point charge – Q placed at its centre as shown.



(C) A solid sphere of radius a and having a charge – Q uniformly distributed throughout its volume as shown.



(D) A solid sphere of radius a and having a charge – Q uniformly distributed throughout its volume. The solid sphere is surrounded by a concentric thin uniformly charged spherical shell of radius 2a and carrying charge –Q as shown



Column-II

(P) $\frac{1}{8\pi \epsilon_0}\frac{Q^2}{a}$ in magnitude

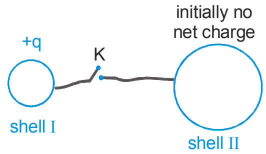
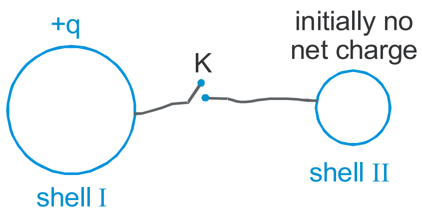
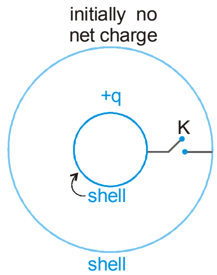
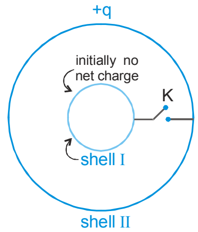
(Q) $\frac{3}{20\pi \epsilon_0}\frac{Q^2}{a}$ in magnitude

(R) $\frac{2}{5\pi \epsilon_0}\frac{Q^2}{a}$ in magnitude

(S) Positive in sign

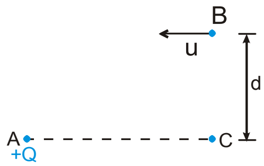
(T) zero

58. Column I gives certain situations involving two thin conducting shells connected by a conducting wire via a key K. In all situations one sphere has net charge +q and other sphere has no net charge. After the key K is pressed, column II gives some resulting effect. Match the figures in Column I with the statements in Column II and indicate your answer by darkening appropriate bubbles in the 4 × 4 matrix given in the ORS.

Column I	Column II
(A) 	(P) charge flows through connecting wire
(B) 	(Q) Potential energy of system of spheres decreases.
(C) 	(R) No heat is produced.
(D) 	(S) The sphere I has no charge after equilibrium is reached.
	(T) charge does not flows through connecting wire

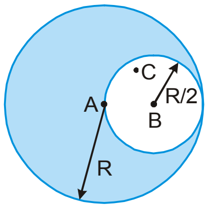
SECTION - VI : INTEGER TYPE

59. A positive charge +Q is fixed at a point A. Another positively charged particle of mass m and charge +q is projected from a point B with velocity u as shown in the figure. The point B is at large distance from A and at distance 'd' from the line AC. The initial velocity is parallel to the line AC. The point C is at very large distance from A. Find the minimum distance (in meter) of +q from +Q during the motion. Take $Qq = 4\pi\epsilon_0 mu^2 d$ and $d = (\sqrt{2}-1)$ meter.



60. Consider a cube of side a = 0.1 m placed such that its six faces are given by equations x = 0, x = +a, y = 0, y = +a, z = 0 and z = +a, placed in electric field given by $\vec{E} = x^2\hat{i} + y\hat{j}$ N/C. Find the electric flux crossing out of the cube in the unit of 10^{-4} N m^2/C.

61. A solid sphere of radius 'R' has a cavity of radius $\frac{R}{2}$. The solid part has a uniform charge density 'ρ' and cavity has no charge. Find the electric potential at point 'A'. $\frac{\rho R}{x\varepsilon_0}$ then x is.



ANSWER KEY

EXERCISE - 1

1. B **2.** B **3.** B **4.** D **5.** A **6.** B **7.** C **8.** B **9.** C **10.** B **11.** D **12.** C **13.** B
14. B **15.** C **16.** B **17.** A **18.** D **19.** D **20.** C **21.** B **22.** A **23.** A **24.** C **25.** A **26.** A
27. C **28.** C **29.** B **30.** A **31.** C **32.** B **33.** A **34.** D

EXERCISE - 2 : PART - I

1. B **2.** A, B **3.** A **4.** B **5.** A **6.** A **7.** A, D **8.** D **9.** A, B, C
10. B **11.** B **12.** A **13.** A,C **14.** A,C **15.** A,C **16.** A **17.** B **18.** B
19. A **20.** B **21.** B **22.** A **23.** A,D **24.** A **25.** D **26.** B **27.** A, D
28. A, B, C **29.** A, C, D **30.** D **31.** A **32.** A, B, C **33.** B **34.** B **35.** C **36.** D
37. D **38.** D **39.** A, C, D **40.** B

PART - II

1. C **2.** D **3.** C **4.** A **5.** B **6.** C **7.** B **8.** C **9.** D **10.** B **11.** B **12.** A **13.** A
14. D **15.** D **16.** D

EXERCISE - 3 : PART - I

1. A $\rightarrow$ S; B $\rightarrow$ P; C $\rightarrow$ R; D $\rightarrow$ Q
2. A $\rightarrow$ R ; B $\rightarrow$ R $\rightarrow$ C $\rightarrow$ P
3. A $\rightarrow$ P,R ; B $\rightarrow$ P,Q,S ; C $\rightarrow$ P,Q ; D $\rightarrow$ P,Q
4. A $\rightarrow$ P,Q ; B $\rightarrow$ P,Q ; C $\rightarrow$ P,Q,S; D $\rightarrow$ R,S
5. A $\rightarrow$ R; B $\rightarrow$ R ; C $\rightarrow$ P
6. A $\rightarrow$ P,S; B $\rightarrow$ Q,S ; C $\rightarrow$ Q,S ; D $\rightarrow$ S
7. A $\rightarrow$ Q ; B $\rightarrow$ P,S ; C $\rightarrow$ P,Q,R ; D $\rightarrow$ Q,R

PART - II

Comp. #1 : 1. B 2. D 3. D 4. D 5. C
Comp. #2 : 1. B 2. C 3. D
Comp. #3 : 1. D 2. A 3. C 4. C 5. A
Comp. #4 : 1. B 2. A
Comp. #5 : 1. B 2. D
Comp. #6 : 1. C 2. D 3. B 4. A 5. B
Comp. #7 : 1. A 2. B 3. C
Comp. #8 : 1. A 2. B 3. A
Comp. #9 : 1. D 2. D 3. C
Comp. #10 : 1. A 2. B 3. D

EXERCISE - 4

1. $\frac{-1}{2}\mu C$

2. 3.17×10^{-9} C

3. $\frac{1}{4\pi \epsilon_0}\frac{qQ}{d(d+L)}$

4. $\left(\frac{8.1}{8}\right)\times 10^4 N/C$

5. $\frac{qQ}{8\pi^2 \epsilon_0 r^2}$

6. 9.30

7. $\frac{-4kq}{\pi R^2}\tilde{i}$

8. zero

9. 2

10. $\frac{-Kq^2}{a}\left(3-\sqrt{2}\right)$

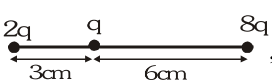
11. $\frac{3\sigma\lambda}{2m \epsilon_0}$

12. 2.25 q

13. 1.8×10^5 sec

14. $\frac{Q^2}{m\pi \epsilon_0 V^2}$

15. $\sqrt{\frac{2KQ^2}{mR}}$

16. 

, E=0

17. $2\tan^{-1}\left(\frac{\sigma q_0}{2 \epsilon_0 mg}\right)$

18. 3000 volt

19. 8.48 m from O

20. $20\sqrt{\ell n2}$

21. **(i)** 4a, (5a, 0) **(ii)** $V=\frac{Q}{4\pi \epsilon_0}\left(\frac{1}{3a-x}-\frac{1}{3a+x}\right)$ for $x \le 3a$ $\frac{Q}{4\pi \epsilon_0}\left(\frac{1}{x-3a}-\frac{q}{3a+x}\right)$ for $x > 3a$

(iii) $\sqrt{\frac{Qq}{8\pi\epsilon_0 ma}}$ **22.** $\frac{-7}{8}kp\tilde{k}$ **23.** $\frac{KP}{\sqrt{2}y^3}\left(-\tilde{i}-2\tilde{j}\right)$ **24.** $\frac{q}{24\epsilon_0}$ **25.** $45^0, 135^0, 225^0, 315^0$

26. $a=\frac{R}{\sqrt{3}}$ **27.** $\frac{1}{2\pi}\sqrt{\frac{qQ}{4\pi\epsilon_0 mR^3}}$ **28.** $\frac{Q}{2\epsilon_0}$

29 (i) $V_A=\frac{\sigma}{\epsilon_0}(a-b+c)$, $V_B=\frac{\sigma}{\epsilon_0}\left(\frac{a^2}{b}-b+c\right)$, $V_C=\frac{\sigma}{\epsilon_0}\left(\frac{a^2}{c}-\frac{b^2}{c}+c\right)$ **(ii)** a+b=c **30.** $\frac{Q(R+r)}{4\pi\epsilon_0\left(r^2+R^2\right)}$

31. $\frac{-\pi\sigma^2R^3}{\epsilon_0}$ **32.** $9V_0$ **33.** $\frac{-Q}{3}$ **34.** $\left(-820\tilde{i}+1990\tilde{j}\right)\frac{V}{m}$ **35.** $H_2=h_1+h_2-g\left(\frac{\ell}{v}\right)^2$

36. $\sqrt{\frac{\lambda q}{2\epsilon_0 m}}$ **37.** $\frac{v}{\sqrt{3}}$ **38.** $v=\sqrt{\frac{\sigma eR}{m\epsilon_0}}$ **39.** $W_{\text{first step}}=\left(\frac{8}{3}-\frac{4}{\sqrt{5}}\right)\frac{Kq^2}{r}$, $W_{\text{second step}}=0$, $W_{\text{total}}=0$

40. $2\lambda RE_0\tilde{i}$ **41.** $\sqrt{4\pi\epsilon_0 Ka}$ **42.** $0,\frac{2K\lambda}{r},0$ **43.** 2.2×10^{-12}C **44.** $\sqrt{\frac{6\sqrt{2}mr\epsilon_0}{e\rho a}}$

46. $\sqrt{\frac{2KQq}{mR}\left(\frac{r-R}{r}+\frac{3}{8}\right)}$ **47.** $\frac{Q_1}{Q_2}=\frac{R_1}{R_2}$ **48.** $2\sin^{-1}\left[\sin\frac{\alpha}{2}\sqrt{\frac{q_1}{q_2}}\right]$ **49.** $n=\frac{4\pi\epsilon_0 mg(h-R)R}{Q^2}$

EXERCISE - 5 : PART -I

1. 3 **2.** 2 **3.** 1 **4.** 4 **5.** 4 **6.** 2 **7.** 1 **8.** 2 **9.** 3
10. 4 **11.** 1 **12.** 3 **13.** 1 **14.** 2 **15.** 4 **16.** 4 **17.** 4 **18.** 3
19. 4 **20.** 1 **21.** 2 **22.** 3 **23.** 2 **24.** 3 **25.** 4 **26.** 4 **27.** 3
28. 3 **29.** 1 **30.** 4 **31.** None **32.** 1 or 2 **33.** 3 **34.** 4

PART - II

1. A **2.** $\frac{4kq^2}{a}\left[3+\frac{1}{\sqrt{3}}-\frac{3}{\sqrt{2}}\right]$ **3.** **(a)** $U=p\frac{kQ}{d^2}$ **(b)** $F=\frac{2kp}{d^3}{}'Q\,(\hat{j})$ **4.** A

5. C **6.** $\frac{(\sigma_1-\sigma_2)Qa}{2\sqrt{2}\varepsilon_0}$ **7.** D **8.** C **9.** $V'=V\left(\frac{a}{3t}\right)^{1/3}$ **10.** A,B,C,D

11. A **12.** D **13.** B **14.** C **15.** C **16.** A **17.** B **18.** C **19.** B
20. A **21.** B **22.** A **23.** 2 **24.** A, D **25.** A **26.** D **27.** C **28.** A,B,C,D
29. A **30.** C **31.** D **32.** A, B, C **33.** C **34.** C **35.** A **36.** 0006 **37.** C
38. D

MOCK TEST

1. D **2.** B **3.** A **4.** A **5.** A **6.** A **7.** B **8.** A **9.** A
10. B **11.** B **12.** B **13.** B **14.** C **15.** B **16.** B **17.** C **18.** C
19. B **20** B **21.** C **22.** B **23.** D **24.** A **25.** C **26.** D **28.** B
29. B **30.** C **31.** C **32.** C **33.** A **34.** A **35.** A,B,C,D **36.** A,B,C **37.** A,B,C,D
38. A,B,D **39.** B,C,D **40.** A, B, C **41.** D **42.** A **43.** D **44.** A **45.** C **46.** C
47. C **48.** D **49.** B **50.** C **51.** B **52.** C **53.** D **54.** B **55.** A
56. C **57.** $A\to P,S$; $B\to Q,S$; $C\to Q,S$; $D\to S$ **58.** $A\to P,Q$; $B\to P,Q$; $C\to P,Q,S$; $D\to R,S,T$
59. 1 **60.** 11 **61.** 6