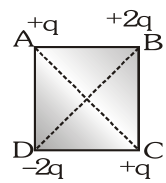
EXERCISE–01 CHECK YOUR GRASP

SELECT THE CORRECT ALTERNATIVE (ONLY ONE CORRECT ANSWER)

1. Using mass (M), length (L), time (T) and current (A) as fundamental quantities, the dimension of permittivity is :
(A) $ML^{-2}T^2A$ (B) $M^{-1} L^{-3} T^4 A^2$ (C) $MLT^{-2}A$ (D) $ML^2T^{-1}A^2$

2. 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

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 :

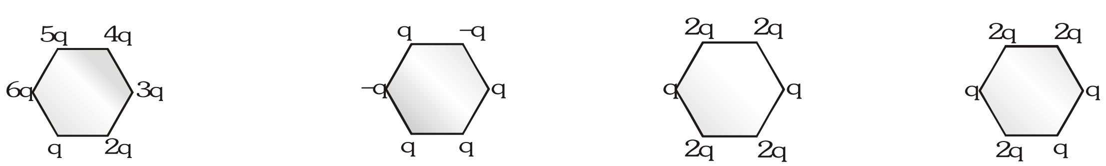


(A) perpendicular to side AB (B) along the diagonal BD
(C) along the diagonal AC (D) zero

4. 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

5. 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

6. 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.



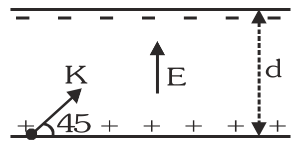
I II III IV

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

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. 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

9. An electron is projected as in figure with kinetic energy K, at an angle θ = 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:

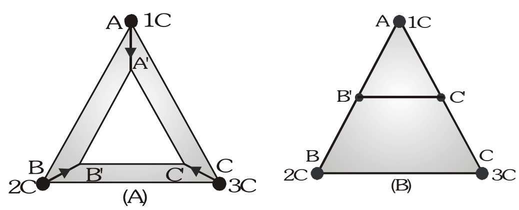


(A) $\frac{K}{qd}$ (B) $\frac{2K}{qd}$ (C) $\frac{K}{2qd}$ (D) Infinite

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

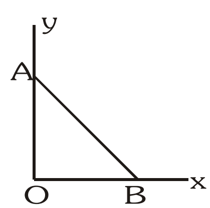
(A) 1200 V/m (B) 0.04 V/m (C) 900 V/m (D) 4500 V/m

11. 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 $W_b = 0$

12. 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) $\left(\frac{qQ}{4\pi \epsilon_0}\frac{1}{a^2}\right)\sqrt{2}\, a$

13. 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) $\frac{q\left(Q_1 - Q_2\right)\left(\sqrt{2}-1\right)}{\left(4\sqrt{2}\pi \epsilon_0 R\right)}$ (C) $\frac{q\sqrt{2}\left(Q_1 + Q_2\right)}{4\pi \epsilon_0 R}$ (D) $\frac{q\left(Q_1 - Q_2\right)\left(\sqrt{2}+1\right)}{\left(4\sqrt{2}\pi \epsilon_0 R\right)}$

14. 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) $\frac{1}{4\pi\varepsilon_0}\frac{3Q^2}{mv^2}$

15. 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

16. 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

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. 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

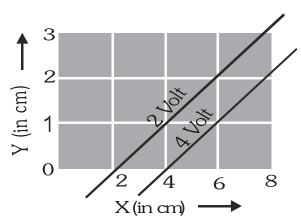
19. The equation of an equipotential line in an electric field is y=2x, then the electric field strength vector at (1, 2) may be :

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

20. 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) $4k\sqrt{3}$

21. 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

22. 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 $\int_{\ell=\infty}^{\ell=0} -\vec{E}\cdot d\vec{\ell}$ (ℓ= 0 being centre of the ring) in volt is :

(A) +2 (B) –1 (C) –2 (D) zero

23. 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

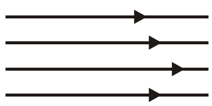
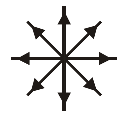
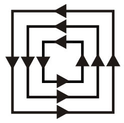
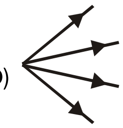
(C) Electric field at all point on y–axis is parallel to x–axis

(D) The dipole moment is 2 qd along the –ve x–axis

24. 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

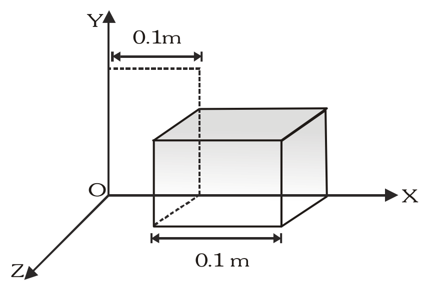
25. Which one of the following pattern of electric line of force can't possible :

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

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. 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) :

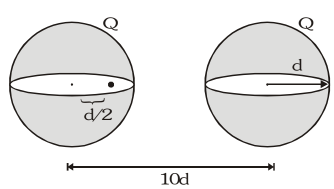


(A) 600 μC (B) 60 μC (C) 7 μμC (D) 6 μμC

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

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

29. 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

30. 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 ?

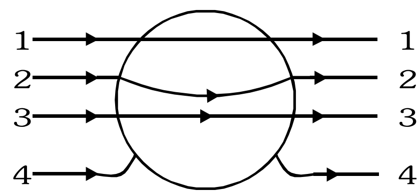
(A) $\frac{4Q}{2\pi\varepsilon_0 R^2}$ (B) $\frac{3Q}{4\pi\varepsilon_0 R^2}$ (C) $\frac{3Q}{2\pi\varepsilon_0 R^2}$ (D) $\frac{Q}{2\pi\varepsilon_0 R}$

31. 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

32. 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

33. 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

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

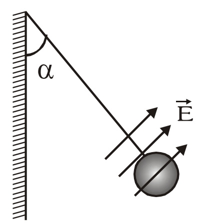
CHECK YOUR GRASP							ANSWER KEY											EXERCISE -1
Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Ans.	B	B	B	A	D	B	C	B	C	D	C	B	B	B	B	C	A	D	D
Que.	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34				
Ans.	B	C	A	A	A	C	A	C	C	A	B	B	A	C	D				

EXERCISE–02

BRAIN TEASURES

Select the correct alternatives (one or more than one correct answers)

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

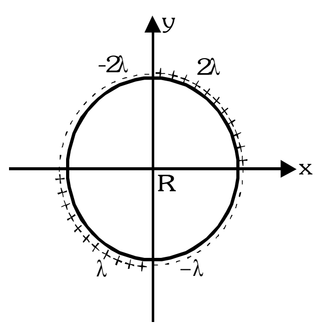


(A) 60^0 (B) 30^0 (C) 45^0 (D) 18^0

2. 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 :

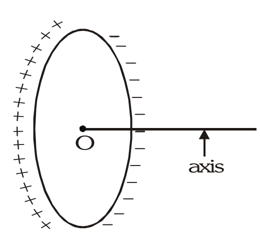
(A) for all values of H (B) only if H > $\frac{R}{\sqrt{2}}$ (C) only if H < $\frac{R}{\sqrt{2}}$ (D) only if H = $\frac{R}{\sqrt{2}}$

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 :



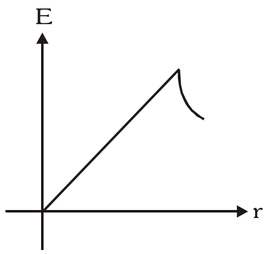
(A) $\frac{-\lambda}{2\pi\varepsilon_0 R}\tilde{i}$ (B) $\frac{\lambda}{2\pi\varepsilon_0 R}\tilde{j}$ (C) $\frac{\sqrt{2}\lambda}{4\pi\varepsilon_0 R}\tilde{i}$ (D) None

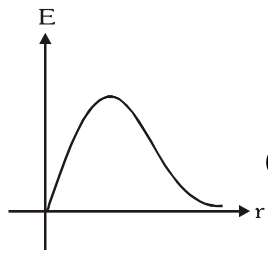
4. The figure shows a nonconducting ring which has positive and negative charge non uniformly distributed on it such that the total charge is zero. Which of the following statements is true?

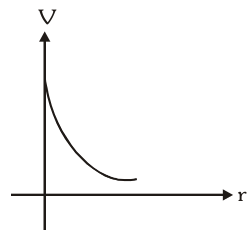


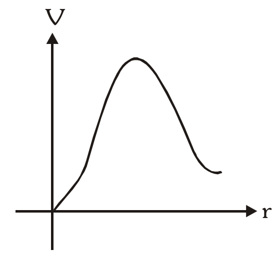
(A) The potential at all the points on the axis will be zero.
(B) The electric field at all the points on the axis will be zero.
(C) The direction of electric field at all points on the axis will be along the axis.
(D) If the ring is placed inside a uniform external electric field then net torque and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

5. 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 :

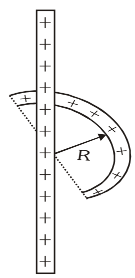
(A)


(B)


(C)


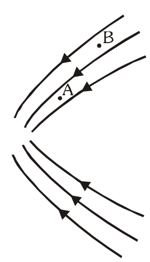
(D)


6. 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) $\frac{\lambda q}{4\pi\varepsilon_0 R}$

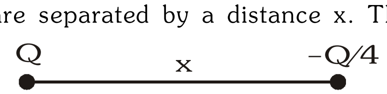
7. Which of the following is true for the figure showing electric lines of force ? (E is electrical field, V is potential)



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

8. 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

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. 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

11. 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

12. 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

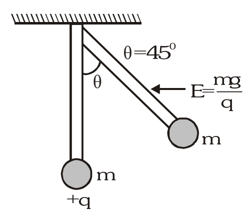
13. Four charges of $1\mu C$, $2\mu C$, $3\mu C$, and $-6\mu C$ are placed one at each corner of the square of side 1m. The square lies in the x–y plane with its centre at the origin.
(A) The electric potential is zero at the origin.
(B) The electric potential is zero everywhere along the x–axis only 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.

14. 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

15. 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

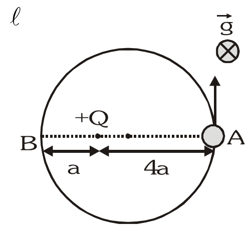
16. A particle of mass m and charge q is thrown in a region where uniform gravitational field and electric field are present. The path of particle :
(A) may be a straight line
(B) may be a circle
(C) may be a parabola
(D) may be a hyperbola

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 :



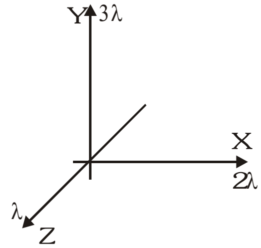
(A) $\sqrt{\frac{g}{\ell}}$
(B) $\sqrt{\frac{2g}{\ell}}$
(C) $\sqrt{\frac{3g}{\ell}}$
(D) $\sqrt{\frac{5g}{\ell}}$

18. 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

19. 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

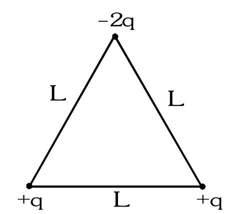
20. The electric potential decreases uniformly from V to –V along X–axis in a coordinate system as we moves from a point $(-x_0, 0)$ to $(x_0, 0)$, then the electric field at the origin :

(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 $\frac{V}{x_0}$

21. 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

22. 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



23. 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) $\frac{2qR}{\pi}$

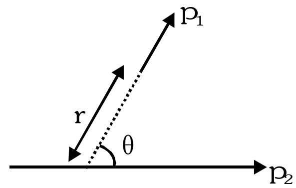
24. An electric dipole is kept on the axis of a uniformly charged ring at distance $R/\sqrt{2}$ from the centre of the ring. The direction of the dipole moment is along the axis. The dipole moment is P, charge of the ring is Q and radius of the ring is R. The force on the dipole is nearly :

(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

25. 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

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



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

27. 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 ϕ=0 (D) If $Q_1\neq$ 0 and Q_2=0 then E=0 but $\phi\neq0$

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

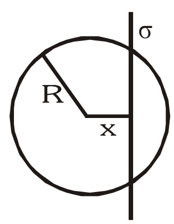
(A) The flux of the electric field passing through the sphere is zero

(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

29. 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) $\dfrac{\pi R^2\sigma}{\varepsilon_0}$ (B) $\dfrac{2\pi\left(R^2-x^2\right)\sigma}{\varepsilon_0}$ (C) $\dfrac{\pi\left(R-x\right)^2\sigma}{\varepsilon_0}$ (D) $\dfrac{\pi\left(R^2-x^2\right)\sigma}{\varepsilon_0}$

30. 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

31. 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.

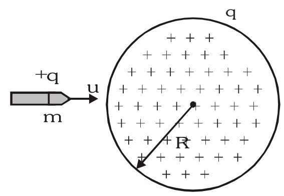
(A) Total charge contained in any spherical volume with its centre at origin is negative.

(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.

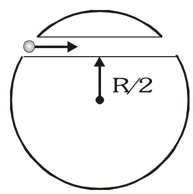
(D) Total charge contained in a spherical volume of radius 3 cm with its centre at origin has magnitude 3 10^{-9} C.

32. 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) $\frac{\sqrt{3}q}{\sqrt{4\pi\varepsilon_0 mR}}$

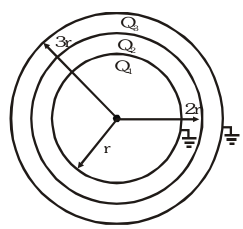
33. A unit positive point charge of mass m is projected with a velocity v inside the tunnel as shown. The tunnel has been made inside a uniformly charged non conducting sphere. The minimum velocity with which the point charge should be projected such that it can it reach the opposite end of the tunnel, 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) $\left[\frac{\rho R^2}{6m\varepsilon_0}\right]^{1/2}$

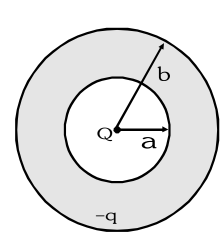
(D) zero because the initial and the final points are at same potential

34. 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) $\frac{Q_3}{Q_2} = \frac{-1}{3}$

35. 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

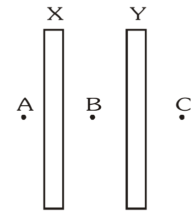
36. In the previous question assume that the electrostatic potential is zero at an infinite distance from the spherical shell. The electrostatic potential at a distance R (a < R < b) from the centre of the shell is where $\left(K = \frac{1}{4\pi\varepsilon_0}\right)$

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

37. 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) $\frac{Kq}{6a}$

38. 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 :



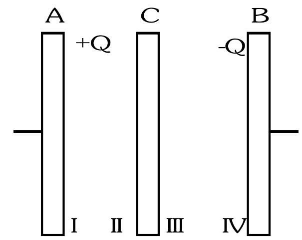
(A) The field at B is $\frac{Q}{2\varepsilon_0 A}$

(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

39. 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?



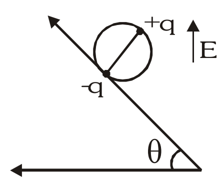
(A) The surface I and II will have equal and opposite charges

(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

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

BRAIN TEASERS — **ANSWER KEY** — EXERCISE -2

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

EXERCISE–03 MISCELLANEOUS TYPE QUESTIONS

TRUE / FALSE

1. The work done in carrying a point charge from one point to another in an electrostatic field depends on the path along which the point charge is carried.

2. An electric line of forces in the x–y plane is given by the equation $x^2 + y^2 = 1$. A particle with unit positive charge, initially at rest at the point x = 1, y = 0 in the x–y plane, will move along the circular line of force.

3. A small metal ball is suspended in a uniform electric field with the help of an insulated thread. If high energy X–ray beam falls on the ball, the ball will be deflected in the direction of the field.

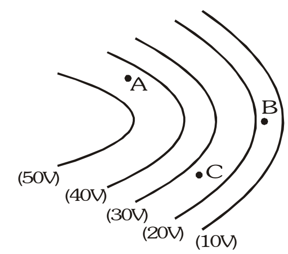
4. A ring of radius R carries a uniformly distributed charge +Q. A point charge –q is placed in the axis of the ring at a distance 2R from the centre of the ring released from rest. The particle executes a simple harmonic motion along the axis of the ring.

5. Two identical metallic spheres of exactly equal masses are taken. One is given a positive charge Q coulomb and the other an equal negative charge. Their masses after charging are different.

FILL IN THE BLANKS

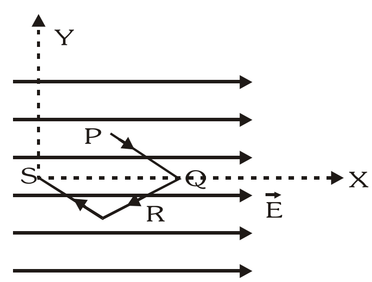
1. Electric lines .... (can/can not) have sudden breaks.

2. Figure shows line of constant potential in a region in which an electric field is present. The values of the potential are written in brackets. Of the point A, B and C, the magnitude of the electric field is greatest at the point. ....



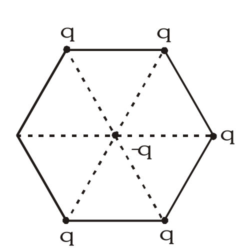
3. Two small balls having equal positive charge Q (coulamb) on each are suspended by two insulating strings of equal length L (metre) from a hook fixed to a stand. The whole set–up is taken in a satellite into space where there is no gravity (state of weightlessness). The angle between the string is .... and the tension in each string is .... newtons.

4. A point charge q moves from point P to point S along the path PQRS (fig.) in a uniform electric field E pointing parallel to the positive direction of the X–axis. The coordiantes of points P, Q, R and S (a, b, 0), (2a, 0, 0) (a, –b, 0) (0, 0, 0) respectively. The work done by electric field is ....



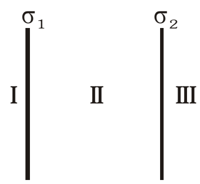
5. The electric potential V at any point x, y, z (all in meters) in space is given by $V = 4x^2$ volt. The electric field at the point (1m, 0.2 m) is .... V/m.

6. Five point charges, each of value +q coulomb, are placed on five vertices of a regular hexagon of side L metre. The magnitude of the force on the point charge of value –q coulomb placed at the centre of the hexagon is .... newton.



MATCH THE COLUMN

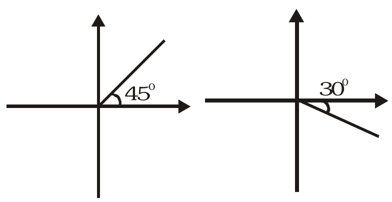
1. Two parallel metallic plates have surface charge densities σ_1 and σ_2 as shown in figure.



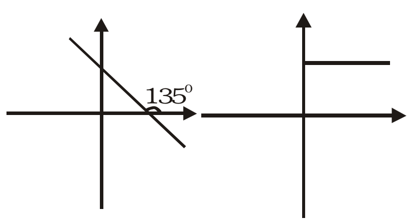
	Column–I		Column–II
(A)	If $\sigma_1 + \sigma_2 = 0$	(p)	Electric field in region III is towards right
(B)	If $\sigma_1 + \sigma_2 > 0$	(q)	Electric field in region I is zero
(C)	If $\sigma_1 + \sigma_2 < 0$	(r)	Electric field in region I is towards right
		(s)	Nothing can be said

2. 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

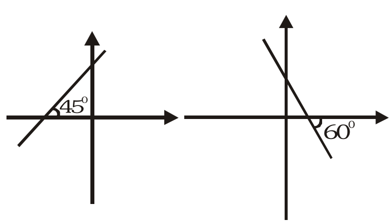
Column–I : V versus x, V versus y **Column–II : Range of angle**

(A) 

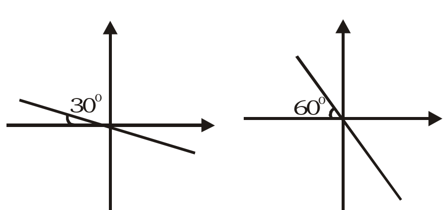
(p) $0^0 \leq \theta < 45^0$

(B) 

(q) $45^0 \leq \theta < 90^0$

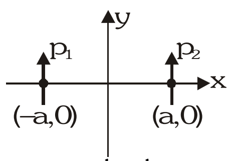
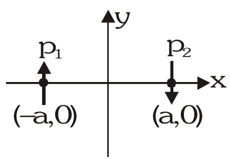
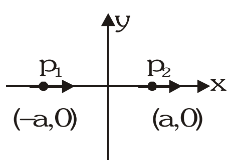
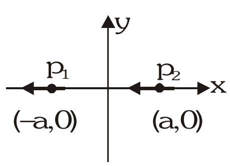
(C) 

(r) $90^0 \leq \theta < 135^0$

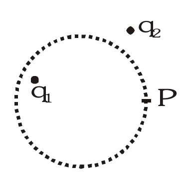
(D) 

(s) $135^0 \leq \theta < 180^0$

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.

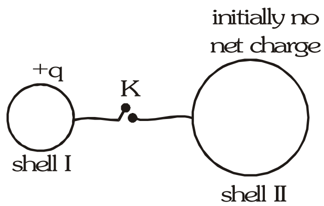
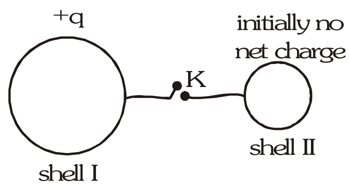
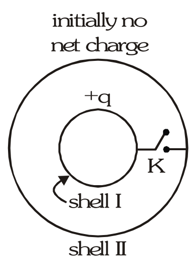
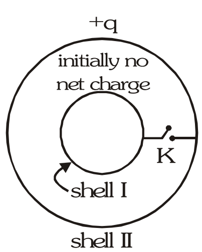
Column I	Column II
(A)  ($\vec{p}_1$ and $\vec{p}_2$ are perpendicular to x–axis as shown)	(p) The torque on one dipole due to other is zero
(B)  ($\vec{p}_1$ and $\vec{p}_2$ are perpendicular to x–axis as shown)	(q) The potential energy of one dipole in electric field of other dipole is negative
(C)  ($\vec{p}_1$ 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. 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

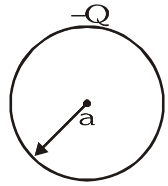
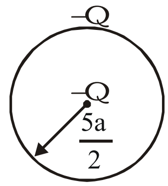
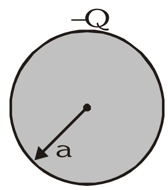
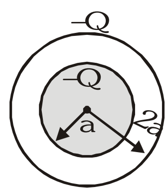
5. Column–I gives certain situations involving two thin conducting shells connected by a conducting wire via a key K. In all situations one sphere has net charge +q and other sphere has no net charge. After the key K is pressed, column–II gives some resulting effect.

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

6. 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

7. 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)	$\frac{1}{8\pi \in_0}\frac{Q^2}{a}$ in magnitude
(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		(q)	$\frac{3}{20\pi \in_0}\frac{Q^2}{a}$ 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

ASSERTION & REASON

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

1. **Statement–1** : Charge is invariant.
and
Statement–2 : Charge does not depends on speed or frame of reference.
(A) Statement–1 is True, Statement–2 is True ; Statement–2 is not a correct explanation for Statement–1
(B) Statement–1 is True, Statement–2 is False.
(C) Statement–1 is False, Statement–2 is True.
(D) Statement–1 is True, Statement–2 is True ; Statement–2 is a correct explanation for Statement–1

2. **Statement–1** : Mass of ion is slightly differed from its element.
and
Statement–2 : Ion is formed, when some electrons are removed or added so the mass changes
(A) Statement–1 is True, Statement–2 is True ; Statement–2 is not a correct explanation for Statement–1
(B) Statement–1 is True, Statement–2 is False.
(C) Statement–1 is True, Statement–2 is True ; Statement–2 is a correct explanation for Statement–1
(D) Statement–1 is False, Statement–2 is True.

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

4. **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.
and
Statement–2 : The number of electric lines of force originating or terminating on a charge is proportional to the magnitude of charge.
(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.

5. **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.
and
Statement–2 : This force is due to the induced charge on the conducting surface which is at zero potential
(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.

6. **Statement–1** : When two charged spheres are touched, then total charge is always devides equally.
and
Statement–2 : Flow of charge take place untill potential equals.
(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 False, Statement–2 is True.
(D) Statement–1 is True, Statement–2 is False.

7. **Statement–1** : The particles such as photon or neutrino which have no (rest) mass can never have a charge.
and
Statement–2 : Charge can not exist without mass.
(A) Statement–1 is True, Statement–2 is True ; Statement–2 is not a correct explanation for Statement–1
(B) Statement–1 is True, Statement–2 is True ; Statement–2 is a correct explanation for Statement–1
(C) Statement–1 is True, Statement–2 is False.
(D) Statement–1 is False, Statement–2 is True.

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

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

10. **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.

and

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

(A) Statement–1 is True, Statement–2 is False.
(B) Statement–1 is False, Statement–2 is True.
(C) Statement–1 is True, Statement–2 is True ; Statement–2 is a correct explanation for Statement–1
(D) Statement–1 is True, Statement–2 is True ; Statement–2 is not a correct explanation for Statement–1

11. **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.

and

Statement–2 : Conducting surface is equipotential surface.

(A) Statement–1 is True, Statement–2 is True ; Statement–2 is not a correct explanation for Statement–1
(B) Statement–1 is True, Statement–2 is True ; Statement–2 is a correct explanation for Statement–1
(C) Statement–1 is True, Statement–2 is False.
(D) Statement–1 is False, Statement–2 is True.

12. **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.

and

Statement–2 : Electric field intensity due to spherical charge distribution can be found out by using Gauss law.

(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.

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

and

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

(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 False.
(C) Statement–1 is False, Statement–2 is True.
(D) Statement–1 is True, Statement–2 is True ; Statement–2 is not a correct explanation for Statement–1

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

and

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

(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.

15. **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.

and

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

(A) Statement–1 is True, Statement–2 is True ; Statement–2 is not a correct explanation for Statement–1
(B) Statement–1 is True, Statement–2 is False.
(C) Statement–1 is False, Statement–2 is True.
(D) Statement–1 is True, Statement–2 is True ; Statement–2 is a correct explanation for Statement–1

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

and

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

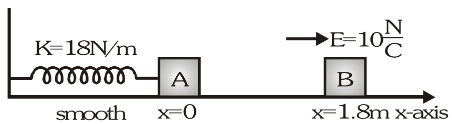
(C) Statement–1 is True, Statement–2 is False.

(D) Statement–1 is False, Statement–2 is True.

COMPREHENSION BASED QUESTIONS

Comprehension #1

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.

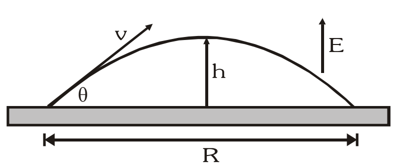
(A) $-\frac{2}{9}$ (B) $-\frac{1}{3}$ (C) $-\frac{5}{9}$ (D) $-\frac{7}{9}$

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 # 2

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 # 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) $\frac{1}{3} \ \ 10^{-30}$ m/s (B) $\frac{1}{3} \ \ 10^{3}$ m/s (C) $\frac{2}{3} \ \ 10^{3}$ 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

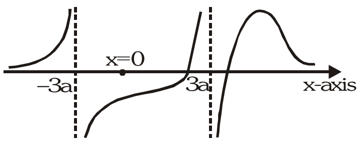
Electric potential is a scalar quantity. Due to a point charge q at distance r, the potential is given by $V = \frac{q}{4\pi \epsilon_0 r}$.

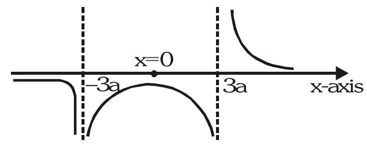
A point charge q is placed at (3a, 0) and another charge –2q is placed at (–3a 0).

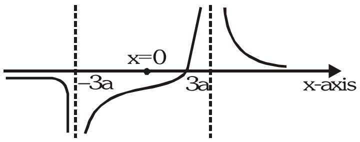
1. At how many points on the x–axis, (at finite distance) electric potential will be zero ?

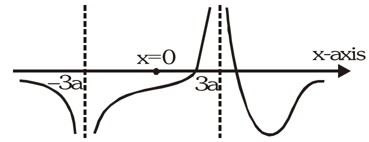
(A) 1 (B) 2 (C) 3 (D) 4

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

(A)


(B)


(C)


(D)


Comprehension #5

- 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 :–

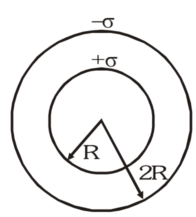
(A) 4.4 m/s (B) 3.1 m/s (C) 5.2 m/s (D) 6.1 m/s

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 # 6

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 # 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

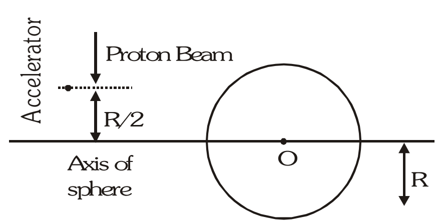
(B) Once the potential of the dome reaches the dielectric strength of the air, the air heats the metal of the dome, and it is no longer a good conductor

(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

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.

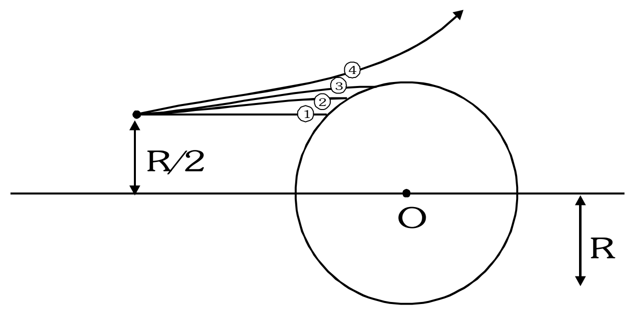


The protons in the beam that collide with the sphere will cause it to become charged. The subsequent potential field at the accelerator due to the sphere can be neglected. The angular momentum of a particle is defined in a similar way to the moment of a force. It is defined as the moment of its linear 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

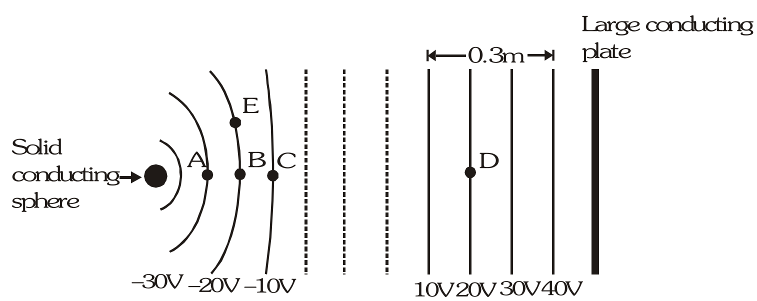
(A) $\frac{3m_P v_0^2}{8e}$ (B) $\frac{3m_P v_0^2}{4e}$ (C) $\frac{3m_P v_0^2}{2e}$ (D) None of these

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 # 9

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 $\in_0 = 8.85 \quad 10^{-12}\ C^2/N\ m^2$]



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

(A) $8.85 \quad 10^{-10}\ C/m^2$ (B) $-8.85 \quad 10^{-10}\ C/m^2$

(C) $17.7 \quad 10^{-10}\ C/m^2$ (D) $-17.7 \quad 10^{-10}\ C/m^2$

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

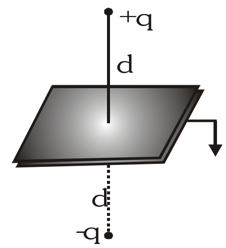
(C) it will move towards C (D) it will move towards E

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

(A) $2 \quad 10^{-5}$ J (B) $-2 \quad 10^{-5}$ J (C) $4 \quad 10^{-5}$ J (D) $-4 \quad 10^{-5}$ J

Comprehension # 10 (Method of electrical images)

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) $\frac{1}{4\pi\epsilon_0}q^2\left[\frac{1}{y}-\frac{1}{d}\right]$

MISCELLANEOUS TYPE QUESTION **ANSWER KEY** EXERCISE -3

- ***True / False*** 1. F 2. F 3. T 4. F 5. T
- ***Fill in the Blanks*** 1. cannot 2. B 3. 180^0, $\frac{Q^2}{16\pi\epsilon_0 L^2}$ 4. –qEa 5. $-8\tilde{i}$ 6. $9\times10^9\frac{q^2}{L^2}$
- ***Match the Column***
  1. (A) r, (B) r, (C) p
  2. (A) s, (B) p, (C) r (D) q
  3. (A) p,r (B) p,q,s (C) p,q (D) p,q
  4. (A) r (B) r (C) p
  5. (A) p,q (B) p,q (C) p,q,s (D) r,s
  6. (A) q, (B) p,s (C) p,q,r (D) q,r
  7. (A) p,s (B) q,s (C) q,s (D) s
- ***Assertion - Reason*** 1. D 2. C 3. C 4. B 5. A 6. C 7. B 8. C 9.D 10. B 11. A 12. B 13. D 14. A 15. D 16. D
- ***Comprehension Based***

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

EXERCISE–04 [A] CONCEPTUAL SUBJECTIVE EXERCISE

1. 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).

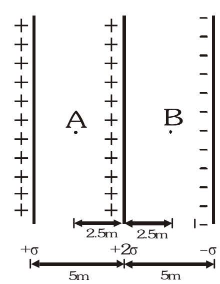
2. Two equal point charges $Q = +\sqrt{2}\ \mu C$ are placed at each of the two opposite corners of a square and equal point charges q at each of the other two corners. What must be the value of q so that the resultant force on Q is zero ?

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.

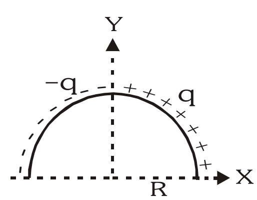
4. A thin circular wire of radius r has a charge Q. If a point charge q is placed at the centre of the ring, then find the increase in tension in the wire.

5. An infinite number of charges, each equal to Q=10 μC 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.

6. 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.

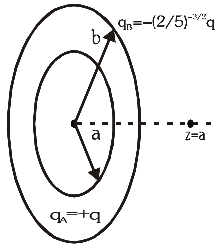


7. Find the electric field at centre of semicircular ring shown in figure.

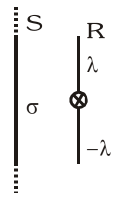


8. A clock face has negative charges –q, –2q, –3q, ..., –12q fixed at the position of the corresponding numerals on the dial. The clock hands do not disturb the net field due to point charges. At what time does the hour hand, point in the same direction of electric field at the centre of the dial.

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.

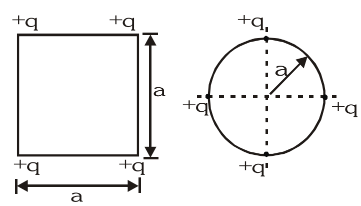


10. In the figure shown S is a large nonconducting sheet of uniform charge density σ. A rod R of length ℓ and mass 'm' is parallel to the sheet and hinged at its mid point. The linear charge densities on the upper and lower half of the rod are shown in the figure. Find the angular acceleration of the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



11. 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.

12. 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).



(i) (ii)

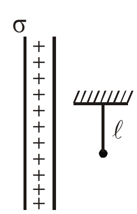
13. Two identical particles of mass m carry charge Q each. Initially one is at rest on a smooth horizontal plane and the other is projected along the plane directly towards the first from a large distance with an initial speed v. Find the closest distance of approach.

14. 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?

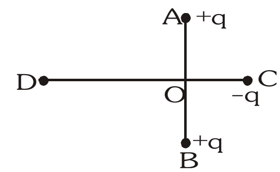
15. Three point charges q, 2q and 8q are to be placed on a 9cm long straight line. Find the positions where the charges should be placed such that the potential energy of this system is minimum. In this situation, what is the electric field at the position of the charge q due to the other two charges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

16. 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.

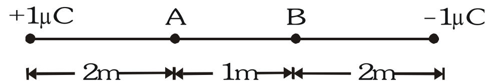
17. A simple pendulum of length ℓ and bob mass m is hanging in front of a large nonconducting sheet having surface charge density σ. If suddenly a charge +q is given to the bob & it is released from the position shown in figure. Find the maximum angle through which the string is deflected from vertical.



18. Two fixed, equal, positive charges, each of magnitude $q = 5 \quad 10^{-5}$ 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.



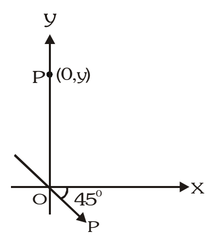
19. Positive and negative charges of $1\mu C$ each are placed at two points as shown in the figure. Find the potential difference between A and B-



20. 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.

21. 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.

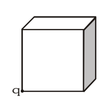
22. A dipole is placed at origin of coordinate system as shown in figure,find the electric field at point P (0, y).



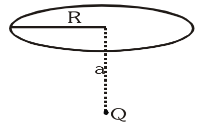
23. Two point dipoles $p\tilde{k}$ and $\frac{P}{2}\tilde{k}$ are located at (0, 0, 0) and (1m, 0, 2m) respectively. Find the resultant electric field due to the two dipoles at the point (1m, 0, 0).

24. 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.

25. 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.



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 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.

28. 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.

29. 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.

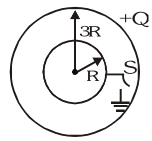
30. Three concentric spherical metallic shells, A, B and C of radii a, b and c (a < b < c) have surface charge densities σ, $-\sigma$ and σ respectively.

(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.

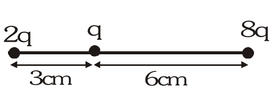
31. There are 27 drops of a conducting fluid. Each has a radius r and they are charged to a potential V_0. They are then combined to form a bigger drop. Find its potential.

32. 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.



33. 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.

CONCEPTUAL SUBJECTIVE EXERCISE — **ANSWER KEY** — EXERCISE-4(A)

1. $3.17 \quad 10^{-9}$ C
2. $\frac{-1}{2}\mu C$
3. $\frac{1}{4\pi\epsilon_0}\frac{qQ}{d(d+L)}$
4. $\frac{qQ}{8\pi^2\epsilon_0 r^2}$
5. $\left(\frac{8.1}{8}\right)\times 10^4 N/C$
6. zero
7. $\frac{-4kq}{\pi R^2}\hat{i}$
8. 9.30
9. 2
10. $\frac{3\sigma\lambda}{2m\epsilon_0}$
11. 2.25 q
12. $\frac{-Kq^2}{a}\left(3-\sqrt{2}\right)$
13. $\frac{Q^2}{m\pi\epsilon_0 V^2}$
14. 1.8 10^5 sec
15. 

, E=0
16. $\sqrt{\frac{2KQ^2}{mR}}$
17. $2\tan^{-1}\left(\frac{\sigma q_0}{2\epsilon_0 mg}\right)$
18. 8.48 m from O
19. 3000 volt
20. (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) $\sqrt{\frac{Qq}{8\pi\epsilon_0 ma}}$
21. $20\sqrt{\ell n2}$
22. $\frac{KP}{\sqrt{2}y^3}\left(-\hat{i}-2\hat{j}\right)$
23. $\frac{-7}{8}kp\hat{k}$
24. 45^0, 135^0, 225^0, 315^0
25. $\frac{q}{24\epsilon_0}$
26. a= $\frac{R}{\sqrt{3}}$
27. $\frac{Q}{2\epsilon_0}$
28. $\frac{1}{2\pi}\sqrt{\frac{qQ}{4\pi\epsilon_0 mR^3}}$
29. $\frac{Q(R+r)}{4\pi\epsilon_0\left(r^2+R^2\right)}$
30. (i) $V_A = \frac{\sigma}{\epsilon_0}$ (a–b+c),

$V_B = \frac{\sigma}{\epsilon_0}\left(\frac{a^2}{b}-b+c\right)$,

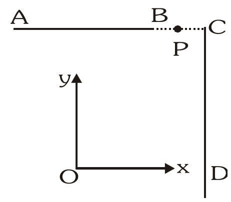
$V_C = \frac{\sigma}{\epsilon_0}\left(\frac{a^2}{c}-\frac{b^2}{c}+c\right)$

(ii) a+b=c
31. $9V_0$
32. $\frac{-Q}{3}$
33. $\frac{-\pi\sigma^2 R^3}{\epsilon_0}$

EXERCISE–04 [B] BRAIN STORMING SUBJECTIVE EXERCISE

1. 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 1^{st} ball touches the ground at a distance ℓ from the initial vertical. At what height will the 2^{nd} ball be at this instant? The air drag & the charges induced should be neglected.

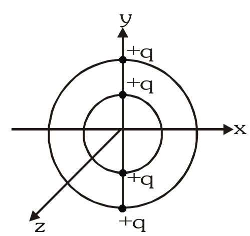
2. Two wires AB & CD, each 1m length, carry a total charge of 0.2 microcoulomb each and are placed as shown in figure. The ends B & C are separated 1m distance. Determine the value of electric intensity at the point P in the vector form. Note that P is the mid point of BC.



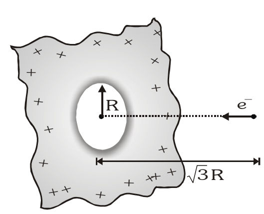
3. Two identical balls of charges q_1 & q_2 initially have equal velocity of the same magnitude and direction. After a uniform electric field is applied for some time, the direction of the velocity of the first ball changes by 60^0 and the magnitude is reduced by half. The direction of the velocity of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

4. 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.

5. 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.

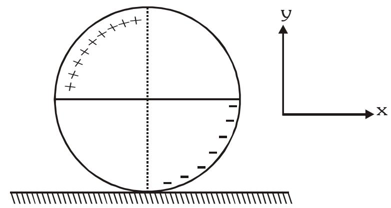


6. An infinite dielectric sheet having charge density σ has a hole of radius R in it. An electron is released on the axis of the hole at a distance $\sqrt{3}$ R from the centre. What will be the velocity which it crosses the plane of sheet. (e = charge on electron and m= mass of electron).



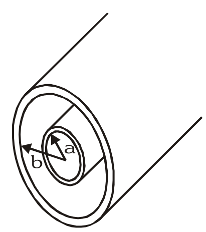
7. Small identical balls with equal charges are fixed at vertices of regular 2009 –gon with side a. At a certain instant, one of the balls is released & a sufficiently long time interval later, the ball adjacent to the first released ball is freed. The kinetic energies of the released balls are found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

8. 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 $\vec{E} = E_0\tilde{i}$ 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.



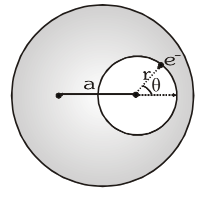
9. The electric field in a region is given by $\vec{E} = \frac{E_0 x}{\ell}\vec{i}$. Find the charge contained inside a cubical volume bounded by the surfaces x = 0, x =a, y=0, y=a, z=0 and z=a. [Take E_0 = 5 10^3 N/C, ℓ = 2cm and a = 1cm]

10. 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



11. 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 = $\frac{KQr^2}{R^4}$.

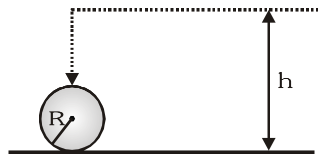
12. A cavity of radius r is present inside a solid dielectric sphere of radius R, having a volume charge density of ρ. The distance between the centres of the sphere and the cavity is a. An electron e is kept inside the cavity at angle θ =45^0 as shown. How long will it take to touch the sphere again?



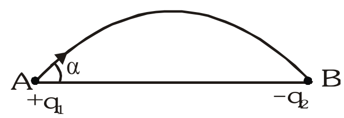
13. Two small metallic balls of radii R_1 & R_2 are kept in vacuum at a large distance compared to the radii. Find the ratio between the charges on the two balls at which electrostatic energy of the system is minimum. What is the potential difference between the two balls? Total charge of balls is constant.

14. 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.

15. 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.



17. 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 $-q_2$?



BRAIN STORMING SUBJECTIVE EXERCISE **ANSWER KEY** EXERCISE-4(B)

1.	$H_2 = h_1 + h_2 - g\left(\frac{\ell}{v}\right)^2$	2.	$\left(-820\tilde{i}+1990\tilde{j}\right)\frac{V}{m}$
3.	$\frac{v}{\sqrt{3}}$	4.	$\sqrt{\frac{\lambda q}{2 \in_0 m}}$
5.	$W_{\text{first step}} = \left(\frac{8}{3}-\frac{4}{\sqrt{5}}\right)\frac{Kq^2}{r}$, $W_{\text{second step}} = 0$, $W_{\text{total}} = 0$	6.	$v=\sqrt{\frac{\sigma eR}{m \in_0}}$
7.	$\sqrt{4\pi \in_0 Ka}$	8.	$2\lambda RE_0\tilde{i}$
9.	2.2 10^{-12}C	10.	$0,\frac{2K\lambda}{r},0$
12.	$\sqrt{\frac{6\sqrt{2}mr \in_0}{e\rho a}}$	13.	$\frac{Q_1}{Q_2} = \frac{R_1}{R_2}$
14.	$\sqrt{\frac{2KQq}{mR}\left(\frac{r-R}{r}+\frac{3}{8}\right)}$	15.	$n = \frac{4\pi \in_0 mg(h-R)R}{Q^2}$
16.	$2\sin^{-1}\left[\sin\frac{\alpha}{2}\sqrt{\frac{q_1}{q_2}}\right]$		

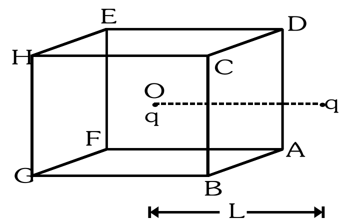
EXERCISE–05(A)

PREVIOUS YEAR QUESTIONS

1. On moving a charge of 20 C by 2 cm, 2 J of work is done, then the potential difference between the points is- [AIEEE - 2002]

(1) 0.1 V (2) 8 V (3) 2 V (4) 0.5 V

2. A charged particle q is placed at the centre O of cube of length L (ABCDEFGH). Another same charge q is placed at a distance L from O. Then the electric flux through ABCD is- [AIEEE-2002]



(1) $q/4\pi\in_0 L$ (2) zero (3) $q/2\pi\in_0 L$ (4) $q/3\pi\in_0 L$

3. 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) $\dfrac{2Q}{4\pi \in_0 R}$ (2) $\dfrac{2Q}{4\pi \in_0 R} - \dfrac{2q}{4\pi \in_0 R}$

(3) $\dfrac{2Q}{4\pi \in_0 R} + \dfrac{q}{4\pi \in_0 R}$ (4) $\dfrac{(q+Q)}{4\pi \in_0} \dfrac{2}{R}$

4. Two spherical conductors B and C having equal radii and carrying equal charges in them, repel each other with a force F when kept apart at some distance. A third spherical conductor having same radius as that of B but uncharged, is brought in contact with B, then brought in contact with C and finally removed away from both. The new force of repulsion between B and C is- [AIEEE-2004]

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

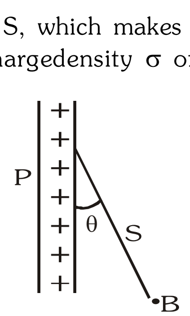
5. A charged particle q is shot towards another charged particle Q which is fixed, with a speed v. It approaches Q upto a closest distance r and then returns. If q was given a speed 2v, the closest distance of approach would be- [AIEEE-2004]

(1) r (2) 2r (3) r/2 (4) r/4

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

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

7. 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 chargedensity σ of the sheet is proportional to- [AIEEE-2005]



(1) cosθ (2) cotθ (3) sinθ (4) tanθ

8. Two point charges + 8q and – 2q are located at x = 0 and x = L respectively. The location of a point on the x-axis at which the net electric field due to these two point charges is zero is- [AIEEE-2005]

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

9. Two thin wire rings each having a radius R are placed at a distance d apart with their axes coinciding. The charges on the two rings are +q and –q. The potential difference between the centres of the two rings is- [AIEEE-2005]

(1) $\frac{qR}{4\pi \in_0 d^2}$ (2) $\frac{q}{2\pi \in_0}\left[\frac{1}{R}-\frac{1}{\sqrt{R^2+d^2}}\right]$ (3) zero (4) $\frac{q}{4\pi \in_0}\left[\frac{1}{R}-\frac{1}{\sqrt{R^2+d^2}}\right]$

10. An electric dipole is placed at an angle of 30 to a non-uniform electric field. The dipole will experience-
(1) a translational force only in the direction of the field [AIEEE-2006]
(2) a translational force only in a direction normal to the direction of the field
(3) a torque as well as a translational force
(4) a torque only

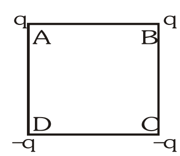
11. Two spherical conductors A and B of radii 1 mm and 2 mm are separated by a distance of 5 cm and are uniformly charged. If the spheres are connected by a conducting wire then in equilibrium condition, the ratio of the magnitude of the electric fields at the surfaces of spheres A and B is- [AIEEE -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

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

12. An electric charge 10^{-3} μC is placed at the origin (0, 0) of X-Y coordinate 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 V (2) zero (3) 2V (4) 4.5 V

13. 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-



(1) $\vec{E}$ remains unchanged, V changes (2) both $\vec{E}$ and V change [AIEEE-2007]

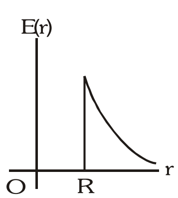
(3) $\vec{E}$ and V remain unchanged (4) $\vec{E}$ changes and V remains unchanged

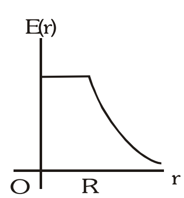
14. The potential at a point x (measured in μm) due to some charges situated on the x-axis is given by : $V(x) = 20/(x^2 - 4)$ volt. The electric field E at x = 4 μm is given by : [AIEEE-2007]

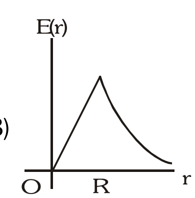
(1) $\frac{5}{3}$ V/μm and in the –ve x direction (2) $\frac{5}{3}$ V/μm and in the +ve x direction

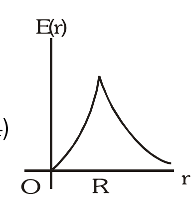
(3) $\frac{10}{9}$ V/μm and in the –ve x direction (4) $\frac{10}{9}$ V/μm and in the +ve x direction

15. A thin spehrical shell of radius R has a 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 $0 \le r < \infty$, where r is the distance from the centre of the shell? [AIEEE - 2008]

(1) 

(2) 

(3) 

(4) 

16. 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 $\frac{Q}{q}$ equals :- [AIEEE - 2009]

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

This question contains Statement–1 and Statement–2. Of the four choices given after the statements, choose the one that best describes the two statements.

17. **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.
Statement–2 : The net work done by a conservative force on an object moving along closed loop is zero. [AIEEE - 2009]
(1) Statement–1 is true, Statement–2 is true; Statement–2 is not the correct explanation of Statement–1
(2) Statement–1 is false, Statement–2 is true
(3) Statement–1 is true, Statement–2 is false
(4)Statement–1 is true, Statement–2 is true; Statement–2 is the correct explanation of Statement–1

18. Two points P and Q are maintained at the potential of 10V and –4V, respectively. The work done in moving 100 electrons from P to Q is :- [AIEEE - 2009]
(1) $-2.24 \quad 10^{-16}$ J (2) $2.24 \quad 10^{-16}$ J (3) $-9.60 \quad 10^{-17}$ J (4) $9.60 \quad 10^{-17}$ J

19. 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 the sphere, the magnitude of electric field is [AIEEE - 2009]

(1) $\frac{Qr_1^2}{4\pi\epsilon_0 R^4}$ (2) $\frac{Qr_1^2}{3\pi\epsilon_0 R^4}$ (3) 0 (4) $\frac{Q}{4\pi\epsilon_0 r_1^2}$

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

21. 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 $\rho(r) = 0$ for r > R, where r is the distance from the origin. The electric field at a distance r (r < R) from the origion is given by : [AIEEE - 2010]

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

22. Two identical charged spheres are suspended by strings of equal lengths. The strings make an angle of 30 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) 1 (2) 4 (3) 3 (4) 2

23. Two identical charged spheres suspended from a common point by two massless string of length ℓ are initially a distance $d(d \ll \ell)$ apart because of their mutual repulsion. The charge begins to leak from both the spheres at a constant rate. As a result the charges approach each other with a velocity v. Then as a function of distance x between them :- [AIEEE - 2011]
(1) $v \propto x^{1/2}$ (2) $v \propto x$ (3) $v \propto x^{-1/2}$ (4) $v \propto x^{-1}$

24. 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 constant. Then the charge density inside the ball is :- [AIEEE - 2011]
(1) $-24\pi a\epsilon_0$ (2) $-6 a\epsilon_0$ (3) $-24\pi a\epsilon_0 r$ (4) $-6 a\epsilon_0 r$

25. 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]

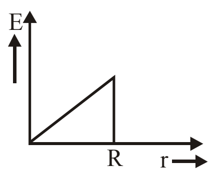
(1) $\frac{1}{4\pi\epsilon_0}\frac{2qQ}{a}\left(1-\frac{1}{\sqrt{5}}\right)$ (2) zero (3) $\frac{1}{4\pi\epsilon_0}\frac{2qQ}{a}\left(1+\frac{1}{\sqrt{5}}\right)$ (4) $\frac{1}{4\pi\epsilon_0}\frac{2qQ}{a}\left(1-\frac{2}{\sqrt{5}}\right)$

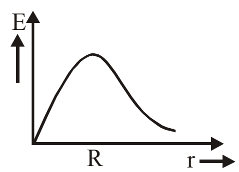
26. **This question has Statement-1 and Statement-2. Of the four choices given after the statements, choose the one that best describes the two statements.**
An insulating solid sphere of radius R has a uniformaly positive charge density ρ. As a result of this uniform charge distribution there is a finite value of electric potential at the centre of the sphere, at the surface of the sphre and also at a point out side the sphere. The electric potential at infinity is zero. [AIEEE - 2012]
Statement-1: When a charge 'q' is taken from the centre to the surface of the sphere, its potential energy changes by $\frac{q\rho}{3\epsilon_0}$

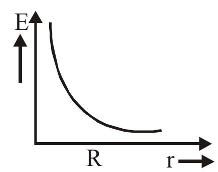
Statement-2: The electric field at a distance r (r < R) from the centre of the sphere is $\frac{\rho r}{3\epsilon_0}$.

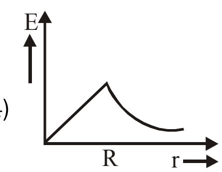
(1) Statement-1 is true, Statement-2 is true and Statement-2 is the correct explanation of Statement-1.
(2) Statement-1 is true, Statement-2 is true and Statement-2 is not the correct explanation of statement-1.
(3) Statement-1 is true, Statement-2 is false
(4) Statement-1 is false, Statement-2 is true.

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

(1) 

(2) 

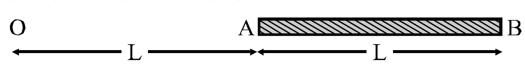
(3) 

(4) 

28. 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 porportional to [AIEEE - 2013]

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

29. 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 a distance L from the end A is :- [AIEEE - 2013]



(1) $\frac{Q}{8\pi\epsilon_0 L}$ (2) $\frac{3Q}{4\pi\epsilon_0 L}$ (3) $\frac{Q}{4\pi\epsilon_0 L\ln 2}$ (4) $\frac{Q\ln 2}{4\pi\epsilon_0 L}$

ANSWER-KEY

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Ans.	1	2	3	4	4	2	4	1	2	3	3	2	4	4	1	3	4	2	1	4
Que.	21	22	23	24	25	26	27	28	29											
Ans.	3	4	3	2	1	4	4	1	4											

EXERCISE–05(B)

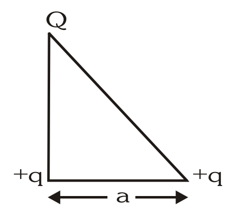
PREVIOUS YEAR QUESTIONS

MCQ'S WITH ONE CORRECT ANSWERS

1. A charge +q is fixed at each of the points $x = x_0$, $x = 3x_0$, $x = 5x_0$.......∞ on the x–axis and a charge –q is fixed at each of the points $x = 2x_0$, $x = 4x_0$, $x = 6x_0$.....∞. Here x_0 is a positive constant. Take the electric potential at a point due to a charge Q at a distance r from it to be $Q/4\pi\varepsilon_0 r$. Then the potential at the origin to the above system of charges is :– [IIT-JEE 1998]

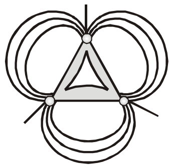
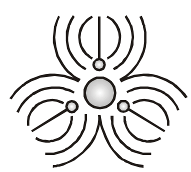
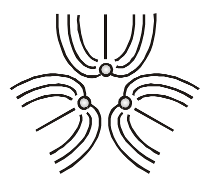
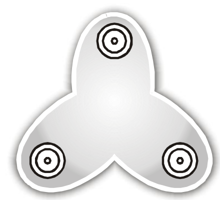
(A) zero (B) $\frac{q}{8\pi\varepsilon_0 x_0 \ell n 2}$ (C) infinite (D) $\frac{q\ell n(2)}{4\pi\varepsilon_0 x_0}$

2. Three charges Q, +q and +q are placed at the vertices of a right angle triangle (isoscles triangle) as shown. The net electrostatic energy of the configuration is zero, if Q is equal to : [IIT-JEE 2000]



(A) $\frac{-q}{1+\sqrt{2}}$ (B) $\frac{-2q}{2+\sqrt{2}}$ (C) –2q (D) +q

3. Three positive charges of equal value q are placed at the vertices of an equilateral triangle. The resulting line of force should be sketched as in :– [IIT-JEE 2001]

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

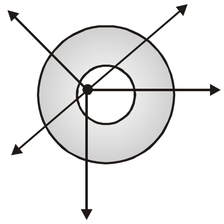
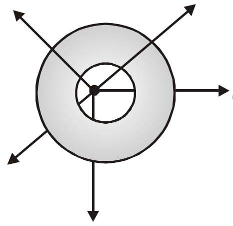
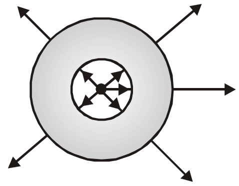
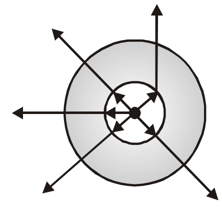
4. A uniform electric field pointing in positive x–direction exists in a region. Let A be the origin, B be the point on the x–axis at x = +1 cm and C be on the point on the y–axis at y = +1cm. Then the potentials at the A, B and C satisfy : [IIT-JEE 2001]

(A) $V_A < V_B$ (B) $V_A > V_B$ (C) $V_A < V_C$ (D) $V_A > V_C$

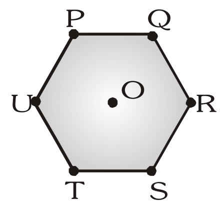
5. Two equal point charges are fixed at x = –a and x = +a on the x–axis. Another point charge Q is placed at the origin. The change in the electrical potential energy of Q, when it is displaced by a small distance x along the x–axis, is approximately proportional to : [IIT-JEE 2002]

(A) x (B) x^2 (C) x^3 (D) 1/x

6. A metallic shell has a point charge q kept inside its cavity. Which one of the following diagrams correctly represents the electric lines of forces ? [IIT-JEE 2003]

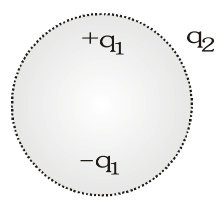
(A)  (B)  (C)  (D) 

7. Six charges, three positive and three negative of equal magnitude are to be placed starts from P in clockwise order at the vertices of a regular hexagon such that the electric field at O is double the electric field when only one positive charge of same magnitude is placed at R. Which of the following arrangements of charge is possible for, P, Q, R, S, T and U respectively ? **[IIT-JEE 2004]**



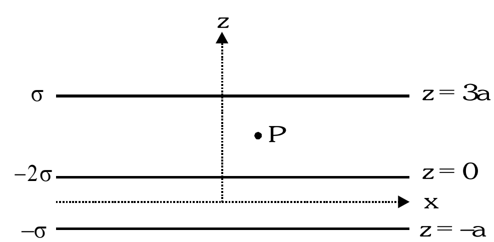
(A) +, –, +, –, –, +
(B) +, –, +, –, +, –
(C) +, +, –, +, –, –
(D) –, +, +, –, +, –

8. Consider the charge configuration and a spherical Gaussian surface as shown in the figure. When calculating the flux of the electric field over the spherical surface, the electric field will be due to : **[IIT-JEE 2004]**



(A) q_2
(B) only the positive charges
(C) all the charges
(D) $+q_1$ and $-q_1$

9. Three infinitely long charge sheets are placed which charge density as shown in figure. The electric field at point P is :– **[IIT-JEE 2005]**

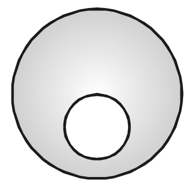


(A) $\frac{2\sigma}{\varepsilon_0}\tilde{k}$
(B) $-\frac{2\sigma}{\varepsilon_0}\tilde{k}$
(C) $\frac{4\sigma}{\varepsilon_0}\tilde{k}$
(D) $-\frac{4\sigma}{\varepsilon_0}\tilde{k}$

10. A long, hollow conducting cylinder is kept coaxialy inside another long, hollow conducting cylinder of larger radius. Both the cylinders are initially electrically neutral :– **[IIT-JEE 2007]**
(A) A potential difference appears between the two cylinders when a charge density is given to the inner cylinder
(B) A potential difference appears between the two cylinders when a charge density is given to the outer cylinder
(C) No potential difference appears between the two cylinders when a uniform line charge is kept along the axis of the cylinder
(D) No potential difference appears between the two cylinders when same charge density is given to both the cylinder

11. Consider a neutral conduting sphere. A positive point charge is placed outside the sphere. The net charge on the sphere is then **[IIT-JEE 2007]**
(A) negative and distrubuted 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.

12. 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 **[IIT-JEE 2007]**

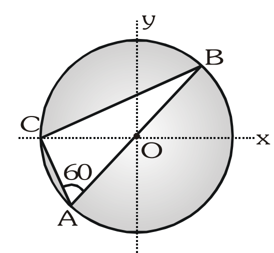


(A) zero everywhere (B) non–zero and uniform
(C) non–uniform (D) zero only at its center

13. 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

(A) positive (B) negative **[IIT-JEE 2007]**
(C) zero (D) depends on the path connecting the initial and final positions

14. 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 = 60 . **[IIT-JEE 2008]**



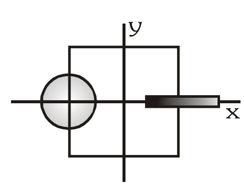
(A) The electric field at point O is $\frac{q}{8\pi \in_0 R^2}$ directed along the negative x–axis

(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 $\frac{q}{12\pi\varepsilon_0 R}$

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



(A) $\frac{-2C}{\in_0}$ (B) $\frac{2C}{\in_0}$ (C) $\frac{10C}{\in_0}$ (D) $\frac{12C}{\in_0}$

16. 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 charges 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 **[IIT-JEE 2009]**

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

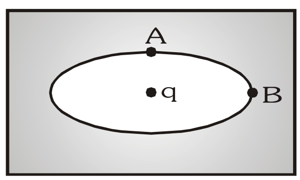
17. Under the influence of the Coulomb field of charge +Q, a charge – q is moving around it in an elliptical orbit. Find out the correct statement(s) :- [IIT-JEE 2009]
(A) The angular momentum of the charge –q is constant
(B) The linear momentum of the charge –q is constant
(C) The angular velocity of the charge – q is constant
(D) The linear speed of the charg – q is constant

MCQ'S WITH ONE OR MORE THAN ONE CORRECT ANSWERS

1. A positively charged thin metal ring of radius R is fixed in the x–y plane with its centre at the origin O. A negativity charged particle P is released from rest at the point $(0, 0, z_0)$ where $z_0 > 0$. Then the motion of P is :–
(A) pariodic for all values of z_0 satisfying $0 < z_0 < \infty$ [IIT-JEE 1998]
(B) simple harmonic for all values of z_0 satisfying $0 < z_0 \le R$
(C) approximately simple harmonic provided $z_0 << R$
(D) such that P crosses O and continues to move along the negative z–axis towards $z = -\infty$

2. A non–conducting solid sphere of radius R is uniformly charged. The magnitude of the electric field due to the sphere at a distance r from its centre : [IIT-JEE 1998]
(A) increases as r increases for r < R
(B) decreases as r increases for $0 < r < \infty$
(C) decreases as r increases for $R < r < \infty$
(D) is discontinuous at r = R

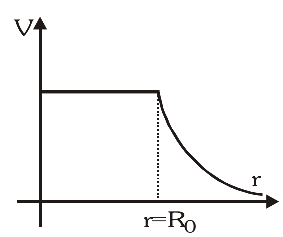
3. An elliptical cavity is carved within a perfect conductor. A positive charge q is placed at the centre of the cavity. The points A and B are on the cavity surface as shown in the figure. Then : [IIT-JEE 1999]



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

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

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

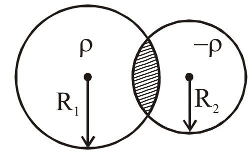


Then which option(s) are correct :
(A) Total charge within $2R_0$ is q
(B) Total electrostatic energy for $r \le R_0$ is zero
(C) At $r = R_0$ electric field is discontinuous
(D) There will be no charge anywhere except at $r = R_0$

5. Two non-conducting solid spheres of radii R and 2R, having uniform volume charge densities ρ_1 and ρ_2 respectively, touch each other. The net electric field at a distance 2R from the centre of the smaller sphere, along the line joining the centres of the spheres, is zero. The ratio $\dfrac{\rho_1}{\rho_2}$ can be [IIT-JEE 2013]

(A) –4 (B) $-\dfrac{32}{25}$ (C) $\dfrac{32}{25}$ (D) 4

6. Two non-conducting spheres of radii R_1 and R_2 and carrying uniform volume charge densities $+\rho$ and $-\rho$, respectively, are placed such that they partially overlap, as shown in the figure. At all points in the overlapping region :- **[IIT-JEE 2013]**



(A) the electrostatic field is zero

(B) the electrostatic potential is constant

(C) the electrostatic field is constant in magnitude

(D) the electrostatic field has same direction

REASONING TYPE

1. **Statement–1** : For practical purposes, the earth is used as a reference at zero potential in electrical circuits.

and

Statement–2 : The electrical potential of a sphere of radius R with charge Q uniformly distributed on the surface is given by $\dfrac{Q}{4\pi\varepsilon_0 R}$. **[IIT-JEE 2008]**

(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

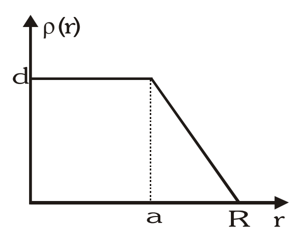
(C) Statement–1 is True, Statement–2 is False

(D) Statement–1 is False, Statement–2 is True

LINKED COMPREHENSION TYPE **[IIT-JEE 2008]**

Paragraph for Question 1 to 3

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.



1. 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

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

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

3. The electric field within the nucleus is generally observed to be linearly dependent on r. This implies :–

(A) a = 0 (B) $a = \dfrac{R}{2}$ (C) a = R (D) $a = \dfrac{2R}{3}$

SUBJECTIVE QUESTIONS

1. A conducting sphere S_1 of radius r is attached to an insulating handle. Another conducting sphere S_2 of radius R is mounted on an insulating stand. S_2 is initially uncharged.

S_1 is given a charge Q brought into contact with S_2 and removed. S_1 is recharged such that the charge on it is again Q and it is again brought into contact with S_2 and removed. This procedure is repeated n times.

(i) Find the electrostatic energy of S_2 after n such contacts with S_1. **[IIT-JEE 1998]**

(ii) What is the limiting value of this energy as $n \to \infty$?

2. A non–conducting disc of radius a and uniform positive surface charge density σ is placed on the ground with its axis vertical. A particle of mass m and positive charge q is dropped, along the axis of the disc from a height H with zero initial velocity. The particle has $\dfrac{q}{m} = \dfrac{4 \epsilon_0 g}{\sigma}$. **[IIT-JEE 1999]**

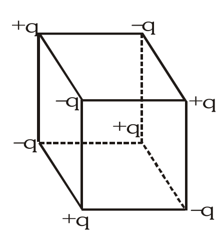
(i) Find the value of H if the particle just reaches the disc.

(ii) Sketch the potential energy of the particle as a function of its height and find its equilibrium position.

3. Four point charges +8μC, –1 μC, –1 μC and + 8μC are fixed at the points $-\sqrt{27/2}$ m, $-\sqrt{3/2}$ m, $+\sqrt{3/2}$ m and $+\sqrt{27/2}$ m respectively on the y–axis. A particle of mass 6 10^{-4} kg and charge +0.1 μC moves along the x–direction. Its speed at x = +∞ is v_0. Find the least value of v_0 for which the particle will cross the origin. Find also the kinetic energy of the particle at the origin. Assume that space is gravity free ($1/4\pi\epsilon_0$ = 9 10^9 Nm^2/C^2). **[IIT-JEE 2000]**

4. A small ball of mass 2 10^{-3} kg having a charge of 1μC is suspended by a string of length 0.8 m. Another identical ball having the same charge is kept at the point of suspension. Determine the minimum horizontal velocity which should be imparted to the lower ball, so that it can make complete revolution. **[IIT-JEE 2001]**

5. Eight point charges are placed at the corners of a cube of edge a as shown in figure. Find the work done in disassembling this system of charges. **[IIT-JEE 2003]**



6. A positve point charge q is fixed at origin. A dipole with a dipole moment $\vec{p}$ is placed along the x–axis far away from the origin with $\vec{p}$ pointing along positive x–axis Find : (i) The kinetic energy of the dipole when it reaches a distance d from the origin, and (ii) The force experienced by the charge q at this moment. **[IIT-JEE 2003]**

7. There are two large parallel metallic plates S_1 and S_2 carrying surface charge densities σ_1 and σ_2 respectively ($\sigma_1 > \sigma_2$) placed at a distance d apart in vacuum. Find the work done by the electric field in moving a point charge q at distance a(a < d) from S_1 towards S_2 along a line making an angle $\pi/4$ with the normal to the plates. **[IIT-JEE 2004]**

8. A conducting bubble of radius a, thickness t(t << a) has potential V. Now the bubble collapses into a droplet. Find the potential of the droplet. **[IIT-JEE 2005]**

9. A solid sphere of radius R has a charge Q distrubuted 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. **[IIT-JEE 2009]**

PREVIOUS YEARS QUESTIONS **ANSWER KEY** EXERCISE -5

- <u>MCQ's</u> 1. D 2. B 3. C 4. B 5. B 6. C 7. D 8. C 9. B
  10. A 11. D 12. B 13. C 14. C 15. A 16. B 17. A
- <u>MCQ's</u> 1. A,C 2. A,C 3. C 4. A,B,C,D 5. B,D 6. C,D
- <u>*Assertion - Reason Questions*</u> 1. A
- <u>*Comprehension based question*</u> 1. A 2. B 3. C
- <u>*Subjective Questions*</u>

1. (i) $U_n = \dfrac{q_n^2}{8\pi \in_0 R}$ (ii) $U_\infty = \dfrac{Q^2R}{8\pi \in_0 r^2}$ Here $q_n = \dfrac{QR}{r}\left[1-\left(\dfrac{R}{R+r}\right)^n\right]$

2. (i) $H = \dfrac{4}{3}a$ (ii) $H = \dfrac{a}{\sqrt{3}}$

3. $(v_0)_{min}$ = 3 m/s, K = 3 10^{-4} J

4. 5.86 m/s

5. W = 5.824 $\left[\dfrac{q}{4\pi \in_0 a}\right]$

6. (i) KE = $\dfrac{qP}{4\pi \in_0 d^2}$ (ii) $\vec{F} = \dfrac{pq}{2\pi \in_0 d^3}\tilde{i}$

7. $W = \dfrac{(\sigma_1 - \sigma_2)qa}{\sqrt{2} \in_0}$

8. $V' = V\left(\dfrac{q}{3t}\right)^{1/3}$

9. 2