Chapter 15

Electric Charges and Fields

TYPE A : MULTIPLE CHOICE QUESTIONS

1. A body can be negatively charged by : ***[1998]***
(a) removing some neutrons from it
(b) giving excess electrons to it
(c) removing some protons from it
(d) removing some electrons from it

2. The number of electrons for one coulomb of charge are: ***[1999]***
(a) 6.25×10^{23} (b) 6.25×10^{21}
(c) 6.25×10^{18} (d) 6.25×10^{19}

3. Let E_a be the electric field due to a dipole in its axial plane distant ℓ and E_q be the field in the equatorial plane distant ℓ', then the relation between E_a and E_q will be : ***[2000]***
(a) $E_a = 4E_q$ (b) $E_q = 2E_a$
(c) $E_a = 2E_q$ (d) $E_q = 3E_a$

4. A particle of mass 2g and charge $1\mu C$ is held at a distance of 1m from a fixed charge 1mC. If the particle is released it will be repelled. The speed of particle when it is at a distance of 10 metre from the fixed charge is ***[2000]***
(a) 90 m/s (b) 100 m/s
(c) 45 m/s (d) 55 m/s

5. What is the electric flux associated with one of faces of a cube, when a charge (q) is enclosed in the cube ? ***[2001]***
(a) $\frac{6q}{\varepsilon_0}$ (b) $\frac{q}{6\varepsilon_0}$
(c) $\frac{q}{3\varepsilon_0}$ (d) $\frac{3q}{\varepsilon_0}$

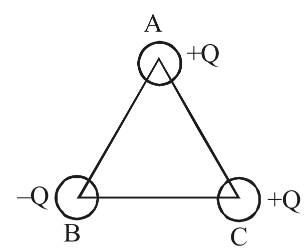
6. The point charges Q and –2Q are placed at some distance apart. If the electric field at the location of Q is E. The electric field at the location of Q is E. The electric field at the location of –2Q will be
(a) $-\frac{3E}{2}$ (b) $-E$ ***[2001]***
(c) $-\frac{E}{2}$ (d) $-2E$

7. How many electrons make up a charge of 20 μC. ***[2002]***
(a) 1.25×10^{14} (b) 2.23×10^{14}
(c) 3.25×10^{14} (d) 5.25×10^{14}

8. A conducting sphere of radius 10 cm is charged with 10 μC. Another uncharged sphere of radius 20 cm is allowed to touch it for some time. After that if the spheres are separated, then surface density of charges on the spheres will be in the ratio of ***[2002]***
(a) 1 : 1 (b) 2 : 1
(c) 1 : 3 (d) 4 : 1

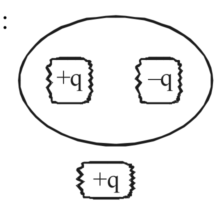
9. An electric dipole placed in a non-uniform electric field experiences : ***[2003]***
(a) both, a torque and a net force
(b) only a force but no torque
(c) only a torque but no net force
(d) no torque and no net force

10. Three charges are placed at the vertices of an equilateral triangle of side 'a' as shown in the following figure. The force experienced by the charge placed at the vertex A in a direction normal to BC is : ***[2003]***



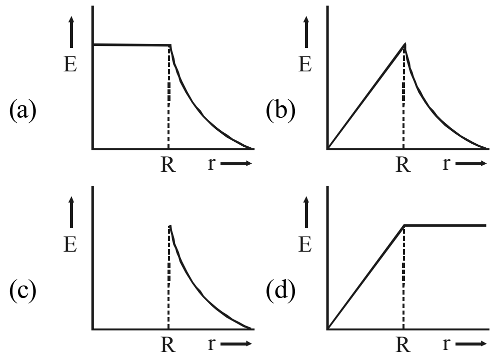
(a) $Q^2/(4\pi\varepsilon_0 a^2)$ (b) $-Q^2/(4\pi\varepsilon_0 a^2)$
(c) zero (d) $Q^2/(2\pi\varepsilon_0 a^2)$

11. Shown below is a distribution of charges. The flux of electric field due to these charges through the surfaces S is : ***[2003]***

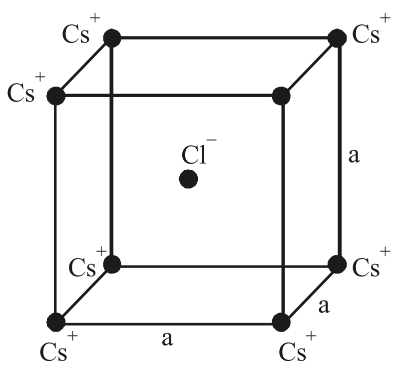


(a) $3q/\varepsilon_0$
(b) $2q/\varepsilon_0$
(c) q/ε_0
(d) zero

12. The electric field due to a uniformly charged non-conducting sphere of radius R as a function of the distance from its centre is represented graphically by ***[2004]***



13. In the basic CsCl crystal structure, Cs^+ and Cl^- ions are arranged in a bcc configuration as shown in the figure. The net electrostatic force exerted by the eight Cs^+ ions on the Cl^- ion is : ***[2004]***



(a) $\frac{1}{4\pi\varepsilon_0}\frac{4e^2}{3a^2}$ (b) $\frac{1}{4\pi\varepsilon_0}\frac{16e^2}{3a^2}$

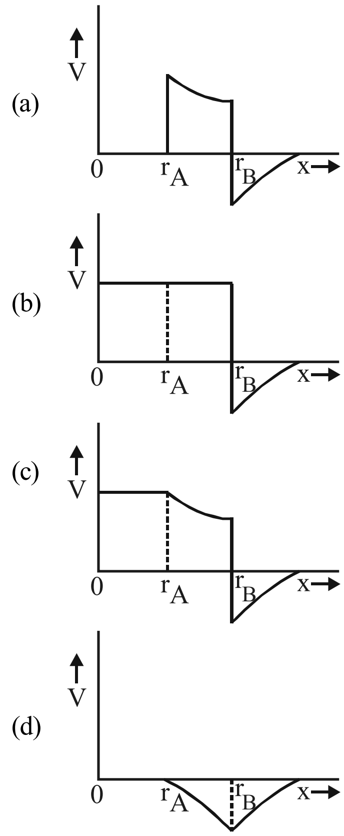
(c) $\frac{1}{4\pi\varepsilon_0}\frac{32e^2}{3a^2}$ (d) zero

14. Two infinitely long parallel conducting plates having surface charge densities $+\sigma$ and $-\sigma$ respectively, are separated by a small distance. The medium between the plates is vacuum. If ε_0 is the dielectric permittivity of vacuum then the electric field in the region between the plates is : ***[2005]***

(a) 0 volt/m (b) $\sigma/2\varepsilon_0$ volt/m

(c) σ/ε_0 volt/m (d) $2\sigma/\varepsilon_0$ volt/m

15. Two concentric conducting thin spherical shells A and B having radii r_A and r_B $(r_B > r_A)$ are charged to Q_A and $-Q_B$ $(|Q_B| > |Q_A|)$. The electrical field along a line, (passing through the centre) is: ***[2005]***



16. A particle having charge q and mass m is projected with velocity $\vec{v} = 2\hat{i} - 3\hat{j}$ in a uniform electric field $\vec{E} = E_0.\hat{j}$. Change in momentum $|\Delta\vec{p}|$ during any time interval t is given by : ***[2005]***

(a) $\sqrt{qE_0t}$ (b) qE_0t

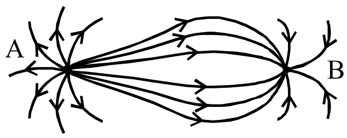
(c) $\frac{qE_0t}{m}$ (d) zero

17. Two parallel large thin metal sheets have equal surface charge densities $(\sigma = 26.4 \times 10^{-12}\ c/m^2)$ of opposite signs. The electric field between these sheets is : ***[2006]***

(a) 1.5 N/C (b) 1.5×10^{-10} N/C

(c) 3 N/C (d) 3×10^{-10} N/C

18. The spatial distribution of the electric field due to two charges (A, B) is shown in figure. Which one of the following statements is correct ? ***[2006]***

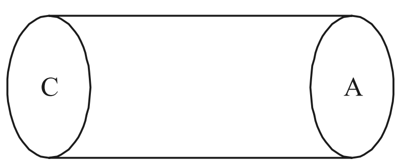


(a) A is +ve and B –ve; |A| > |B|
(b) A is –ve and B +ve; |A| = |B| :
(c) Both are +ve but A > B
(d) Both are –ve but A > B

19. Three point charges +q, –2q and +q are placed at point (x = 0, y = a, z = 0), (x = 0, y = 0, z = 0) and (x = a, y = 0, z = 0) respectively. The magnitude and direction of the electric dipole moment vector of this charge assembly are ***[2008]***

(a) $\sqrt{2qa}$ along + y direction
(b) $\sqrt{2}qa$ along the line joining points (x = 0, y = 0, z = 0) and (x = a, y = a, z = 0)
(c) qa along the line joining points (x = 0, y = 0, z = 0) and (x = a, y = a, z = 0)
(d) $\sqrt{2}$qa along + x direction

20. A hollow cylinder has charge q C within it. If ϕ is the electric flux in unit of voltmeter associated with the curved surface B, the flux linked with the plane surface A in unit of voltmeter will be ***[2008]***



(a) $\frac{1}{2}\left(\frac{q}{\varepsilon_0}-\phi\right)$ (b) $\frac{q}{2\varepsilon_0}$
(c) $\frac{q}{\varepsilon_0}$ (d) $\frac{q}{\varepsilon_0}-\phi$

21. Charge q is uniformly distributed over a thin half ring of radius R. The electric field at the centre of the ring is ***[2008]***

(a) $\frac{q}{2\pi^2\varepsilon_0 R^2}$ (b) $\frac{q}{4\pi^2\varepsilon_0 R^2}$
(c) $\frac{q}{4\pi\varepsilon_0 R^2}$ (d) $\frac{q}{2\pi\varepsilon_0 R^2}$

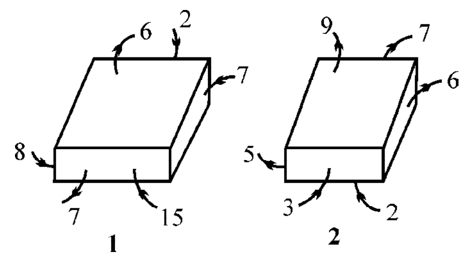
22. The electric field at a distance r from the centre in the space between two concentric metallic spherical shells of radii r_1 and r_2 carrying charge Q_1 and Q_2 is $(r_1 < r < r_2)$ ***[2009]***

(a) $\frac{Q_1+Q_2}{4\pi\in_0 (r_1+r_2)^2}$ (b) $\frac{Q_1+Q_2}{4\pi\in_0 r^2}$
(c) $\frac{Q_1}{4\pi\in_0 r^2}$ (d) $\frac{Q_2}{4\pi\in_0 r^2}$

23. The potential at a point *P* due to an electric dipole is 1.8×10^5V. If *P* is at a distance of 50 cm apart from the centre *O* of the dipole and if *CP* makes an angle 60° with the positive side of the axial line of the dipole, what is the moment of the dipole? ***[2010]***

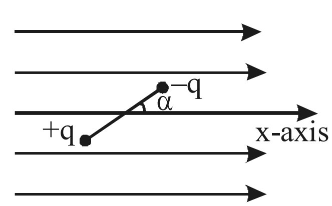
(a) 10 C–m (b) 10^{-3} C–m
(c) 10^{-4} C–m (d) 10^{-5} C–m

24. The figure shows two situations in which a Gaussian cube sits in an electric field. The arrows and values indicate the directions and magnitudes (in N–m^2/C) of the electric fields. What is the net charge (in the two situations) inside the cube? ***[2011]***



(a) (1) negative (2) positive
(b) (1) negative (2) zero
(c) (1) positive (2) positive
(d) (1) positive (2) zero

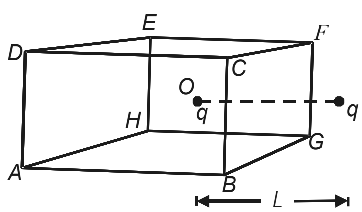
25. There exists a non-uniform electric field along x-axis as shown in the figure below. The field increases at a uniform rate along +ve x-axis. A dipole is placed inside the field as shown. Which one of the following is correct for the dipole? ***[2012]***



(a) Dipole moves along positive x-axis and undergoes a clockwise rotation
(b) Dipole moves along negative x-axis and undergoes a clockwise rotation
(c) Dipole moves along positive x-axis and undergoes a anticlockwise rotation
(d) Dipole moves along negative x-axis and undergoes a anticlockwise rotation

26. Two point charges +q and –q are held fixed at (–d, 0) and (d, 0) respectively of a x – y coordinate system. Then ***[2013]***
(a) the electric field E at all points on the axis has the same direction
(b) work has to be done in bringing a test charge from ∞ to the orgin
(c) electric field at all points on y-axis is along x-axis
(d) the dipole moment is 2qd along the x-axis

27. A charged particle q is placed at the centre O of cube of length L ($A\ B\ C\ D\ E\ F\ G\ H$). Another same charge q is placed at a distance L from O. Then the electric flux through $ABCD$ is ***[2013]***



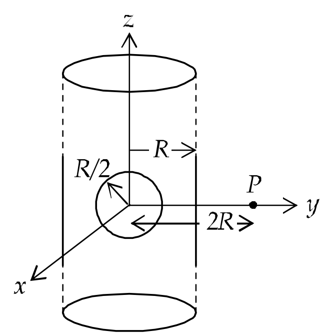
(a) $q/4\pi\epsilon_0 L$ (b) zero
(c) $q/2\pi\epsilon_0 L$ (d) $q/3\pi\epsilon_0 L$

28. In a medium of dielectric constant K, the electric field is $\vec{E}$. If ϵ_0 is permittivity of the free space, the electric displacement vector is ***[2014]***
(a) $\dfrac{K\vec{E}}{\epsilon_0}$ (b) $\dfrac{\vec{E}}{K\epsilon_0}$
(c) $\dfrac{\epsilon_0\vec{E}}{K}$ (d) $K\epsilon_0\vec{E}$

29. Three charge q, Q and 4q are placed in a straight line of length l at points distant 0, $\frac{1}{2}$ and l respectively from one end. In order to make the net froce on q zero, the charge Q must be equal to ***[2015]***
(a) –q (b) – 2q
(c) $\dfrac{-q}{2}$ (d) q

30. The electrostatic potential inside a charged spherical ball is given by $\phi = ar^2 + b$ where r is the distance from the centre a, b are constants. Then the charge density inside the ball is ***[2015]***
(a) $-6a\varepsilon_0 r$ (b) $-24\pi a\varepsilon_0$
(c) $-6a\varepsilon_0$ (d) $-24\pi a\varepsilon_0 r$

31. An infinitely long solid cylinder of radius R has a uniform volume charge density ρ. It has a spherical cavity of radius $R/2$ with its centre on the axis of the cylinder, as shown in the figure. The magnitude of the electric field at the point P, which is at a distance $2R$ from the axis of the cylinder, is given by the expression $\dfrac{23\rho R}{16K\varepsilon_0}$. The value of k is ***[2016]***



(a) 6 (b) 5
(c) 7 (d) 4

32. An electric dipole of moment $\vec{P}$ is placed in a uniform electric field $\vec{E}$ such that $\vec{P}$ points along $\vec{E}$. If the dipole is slightly rotated about an axis perpendicular to the plane containing $\vec{E}$ and $\vec{P}$ and passing through the centre of the dipole, the dipole executes simple harmonic motion. Consider I to be the moment of inertia of the dipole about the axis of rotation. What is the time period of such oscillation? ***[2016]***
(a) $\sqrt{(pE/I)}$ (b) $2\pi\sqrt{(I/pE)}$
(c) $2\pi\sqrt{(I/2pE)}$ (d) None of these

33. A hollow insulated conduction sphere is given a positive charge of 10 μC. What will be the electric field at the centre of the sphere if its radius is 2 m? ***[2017]***
(a) Zero (b) 5 μCm^{-2}
(c) 20 μCm^{-2} (d) 8 μCm^{-2}

TYPE B : ASSERTION REASON QUESTIONS

Directions for (Qs. 34-38) : These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following five responses.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) If the Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.
(e) If the Assertion is incorrect but the Reason is correct.

34. **Assertion:** Electron move away from a region of higher potential to a region of lower potential.
Reason: An electron has a negative charge. *[1999]*

35. **Assertion :** A metallic shield in form of a hollow shell may be built to block an electric field.
Reason : In a hollow spherical shield, the electric field inside it is zero at every point. *[2001]*

36. **Assertion :** Electric lines of force never cross each other.
Reason : Electric field at a point superimpose to give one resultant electric field. *[2002]*

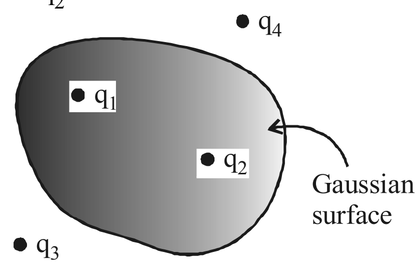
37. **Assertion :** The Coulomb force is the dominating force in the universe.
Reason : The Coulomb force is weaker than the gravitational force. *[2003]*

38. **Assertion :** In a cavity within a conductor, the electric field is zero.
Reason : Charges in a conductor reside only at its surface. *[2007]*

Directions for (Qs. 39-43) : Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.

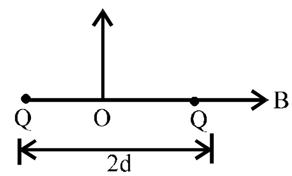
(a) If both Assertion and Reason are correct and Reason is the correct explanation of Assertion.
(b) If both Assertion and Reason are correct, but Reason is not the correct explanation of Assertion.
(c) If Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.

39. **Assertion :** Four point charges q_1, q_2, q_3 and q_4 are as shown in figure. The flux over the shown Gaussian surface depends only on charges q_1 and q_2.



Reason : Electric field at all points on Gaussian surface depends only on charges q_1 and q_2. *[2012]*

40. **Assertion :** Consider two identical charges placed distance 2d apart, along x-axis.



The equilibrium of a positive test charge placed at the point O midway between them is stable for displacements along the x-axis.
Reason: Force on test charge is zero. *[2013]*

41. **Assertion :** A deuteron and an α-particle are placed in an electric field. If F_1 and F_2 be the forces acting on them and a_1 and a_2 be their accelerations respectively then, $a_1 = a_2$.
Reason : Forces will be same in electric field. *[2015]*

42. **Assertion :** In the absence of an external electric field, the dipole moment per unit volume of a polar dielectric is zero.
Reason : The dipoles of a polar dielectric are randomly oriented. *[2016]*

43. **Assertion :** The positive charge particle is placed in front of a spherical uncharged conductor. The number of lines of forces terminating on the sphere will be more than those emerging from it.
Reason : The surface charge density at a point on the sphere nearest to the point charge will be negative and maximum in magnitude compared to other points on the sphere. *[2017]*

HINTS & SOLUTIONS

Type A : Multiple Choice Questions

1. (b) A body can be negatively charged by adding some excess electron to it.

2. (c) 1 electron carries a charge of 1.6×10^{-19} coulomb.
No. of electron in one coulomb

$$= \frac{1}{1.6 \times 10^{-19}}$$

$$= \frac{10^{19}}{1.6} = \frac{10}{1.6} \times 10^{18} = 6.25 \times 10^{18}.$$

3. (c) We know that for short dipole,

field at axial point, $E_a = \frac{2p}{d^3}$

and field at equatorial point, $E_q = \frac{p}{d^3}$

So, $E_a = 2E_q$

4. (a) Potential at 1 m from the charge

$$V_A = \frac{K.10^{-6}}{1} = K \times 10^{-6}$$

Potential at 10 m from the charge

$$V_B = \frac{K.10^{-6}}{10} = K \times 10^{-7}$$

Potential diff.= $V_A - V_B = K(10^{-6} - 10^{-7})$

Its velocity at 10 m is V, then

$$\frac{1}{2} \times mv^2 = (V_A - V_B) \times q$$

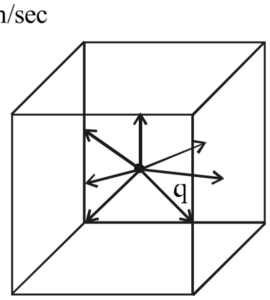
$$\frac{1}{2} \times 2 \times 10^{-3} \times v^2 = K \times 10^{-6}\left(1 - \frac{1}{10}\right) \times 10^{-3}$$

$$v^2 = \frac{K \times 10^{-9} \times 9}{10^{-3} \times 10} = K \times \frac{9}{10} \times 10^{-6}$$

$$= 9 \times 10^9 \times \frac{9}{10} \times 10^{-6} = 81 \times 100$$

v = 90 m/sec

5. (b)



Charge q is lying inside the cube. Flux coming out of it $= \frac{q}{\epsilon_0}$. It is now distributed evenly over six faces. So, flux passing through one face

$$= \frac{q}{\epsilon_0} \times \frac{1}{6} = \frac{q}{6\epsilon_0}$$

6. (c) Field at Q is E. So, force on Q = QE
This force will be applied on –2Q. Also according to Coulomb's law. So, field at –2Q is $\frac{QE}{-2Q} = \frac{E}{2}$.

7. (a) Charge on an electron
$= 1.6 \times 10^{-19}$ coulomb

No. of electrons required $= \frac{20 \times 10^{-6}}{1.6 \times 10^{-19}}$

$$= \frac{20}{1.6} \times 10^{13} = 1.25 \times 10^{14}$$

8. (b) Let the common potential after the touch is V. So, applying conservation of charge
$10 \times 10^{-6} = V \times C_1 + V \times C_2$

$$V = \frac{10 \times 10^{-6}}{(C_1 + C_2)}$$

Charge on first sphere

$$= C_1 V = \frac{10 \times 10^{-6}}{(C_1 + C_2)} \times C_1$$

Charge on second sphere

$$= C_2 V = \frac{10 \times 10^{-6}}{(C_1 + C_2)} \times C_2$$

Charge densities are,

$$= \frac{10 \times 10^{-6} \times C_1}{(C_1 + C_2)4\pi r_1^2} \ \& \ \frac{10 \times 10^{-6} \times C_2}{(C_1 + C_2)4\pi r_2^2}$$

and their ratio $= \frac{C_1}{C_2} \times \frac{r_2^2}{r_1^2}$

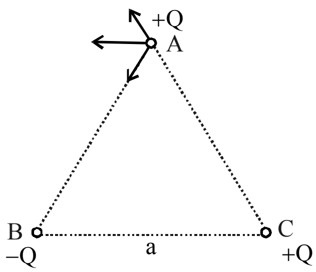
$$= \frac{4\pi\epsilon_0 r_1}{4\pi\epsilon_0 r_2} \times \frac{r_2^2}{r_1^2}$$

$$= \frac{r_2}{r_1} = \frac{20}{10} = 2:1$$

[Capacity of spherical capacitor $= 4\pi\epsilon_0 R$]

9. **(a)** An electric dipole placed in a non-uniform electric field experiences a torque and a net force. In a uniform field it experiences only torque.

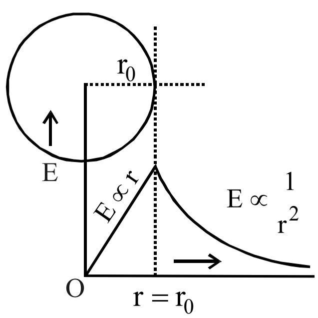
10. **(c)**



From the figure it is clear that force on Q due to charges on B and C will be as shown in the figure. Their resultant will be parallel to BC. So, their component perpendicular to BC will be zero.

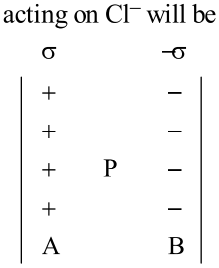
11. **(d)** Net charge inside the surface is zero. So, flux through the surface is zero.

12. **(b)** Inside a uniformly charged non-conducting sphere, charge is uniformly distributed. So, field is there. In such cases electric field is directly proportional to the distance from the centre. Outside the sphere, field is inversely proportional to (distance)^2. So, graph is as follows



13. **(d)** All Cs ions are symmetrically distributed around Cl^- so, resultant of all the forces acting on Cl^- will be zero.

14. **(c)**



Field at P due to plate, $A = \frac{\sigma}{2\varepsilon_0}$

Field at P due to plate, $B = \frac{\sigma}{2\varepsilon_0}$

Both are acting in the same direction so,

$$\text{Total field} = \frac{2\sigma}{2\varepsilon_0} = \frac{\sigma}{\varepsilon_0}$$

15. **(c)** Electric field inside sphere A is zero. Potential inside is uniform. If we move out of the sphere starting from centre, we find potential dropping to –ve value at the surface of B. After that it becomes zero at infinity as we take potential at infinity to be zero.

16. **(b)** Impulse = mv – mu = Change in momentum

$= \text{force} \times \text{time } qE_0 \times t = qE_0t$

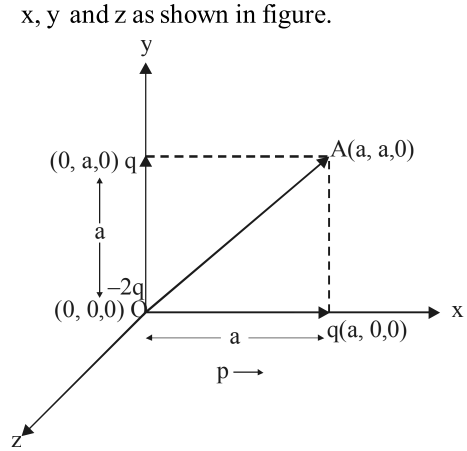
= Change in momentum

17. **(c)** Field between two parallel sheet

$$= \frac{\sigma}{\epsilon_0} = \frac{26.4 \times 10^{-12}}{8.85 \times 10^{-12}} = 3\ N/C$$

18. **(a)** A is positive as electric lines are coming out of it. B is negative as electric lines are entering into it.

19. **(b)** The given charge assembly can be represented using the three co-ordinate axes x, y and z as shown in figure.



The charge –2q is placed at the origin O. One +q charge is place at (a, 0, 0) and the other +q charge is placed at (0, a, 0). Thus the system has two dipoles along x-axis and y-axis respectively.

As the electric dipole moment is directed from the negative to the positive charge hence the resultant dipole moment will be along $\overrightarrow{OA}$ where co-ordinates of point A are (a, a, 0). The magnitude of each dipolemoment,

$p = qa$

So, the magnitude of resultant dipole moment is

$$P_R = \sqrt{p^2 + p^2} = \sqrt{(qa)^2 + (qa)^2}$$

$$= \sqrt{2}\, qa$$

20. (a) Let electric flux linked with surfaces A, B, and C are ϕ_A, ϕ_B and ϕ_C respectively.

Thus $\phi_{total} = \phi_A + \phi_B + \phi_C$

$\because \phi_A = \phi_C$

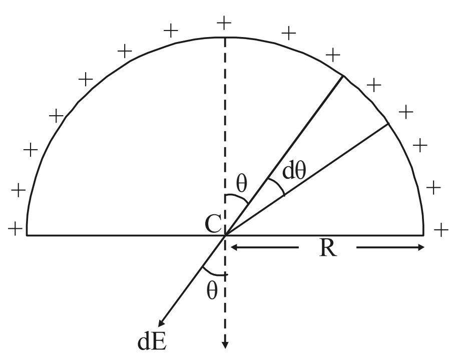
and $\phi_{total} = \dfrac{q}{\epsilon_0}$ (From Gauss's Law)

$\therefore \dfrac{q}{\epsilon_0} = 2\phi_A + \phi_B$ But $\phi_B = \phi$ (given)

Hence, $\dfrac{q}{\epsilon_0} = 2\phi_A + \phi$

or $\dfrac{q}{\epsilon_0} - \phi = 2\phi_A$ or $\phi_A = \dfrac{1}{2}\left(\dfrac{q}{\epsilon_0} - \phi\right)$

21. (a)



From figure, $d\ell = R d\theta$

Charge on $d\ell = \lambda R d\theta$,

where λ = linear charge density.

Electric field at centre due to $d\ell$

$$dE = k.\frac{\lambda R d\theta}{R^2}$$

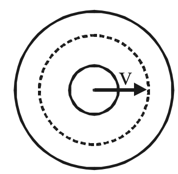
We need to consider only the component $dE \cos\theta$, as the component $dE \sin\theta$ will cancel out.

$\therefore$ Total field at centre $= 2\int_0^{\pi/2} dE \cos\theta$

$$= 2\int_0^{\pi/2} \frac{k\lambda R\cos\theta}{R^2} d\theta = \frac{2k\lambda}{R}\int_0^{\pi/2}\cos\theta d\theta$$

$$= \frac{q}{2\pi^2 \epsilon_0 R^2} \qquad \left(\text{since } \lambda = \frac{q}{\pi R}\right)$$

22. (c) $\int E.dx = \dfrac{Q_1}{\epsilon_0} \Rightarrow E = \dfrac{Q_1}{4\pi r^2 \epsilon_0}$



23. (d) $V = \dfrac{1}{4\pi\varepsilon_0}\dfrac{p\cos\theta}{r^2}$

Here, $V = 1.8 \times 10^5 V$, $\theta = 60°$,

$r = 50 \times 10^{-2} = 0.5$ m

$$\therefore 1.8 \times 10^5 = 9 \times 10^9 \times \frac{p\cos 60°}{(0.5)^2}$$

or $p = \dfrac{1.8 \times 10^5 \times 0.25 \times 2}{9 \times 10^9} = 10^{-5}$C–m

24. (a) The field lines in 1 are :

(6 + 7)out – (2 + 7+ 15 + 8)in = 19 (in)

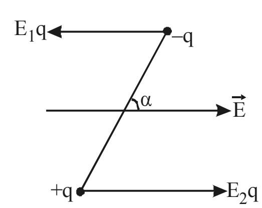
It represents negative charge.

The field lines in 2 are :

(9 + 5 + 6) out – (7+ 3 + 2) in = 8 (out)

It represents positive charge.

25. (d) The dipole is placed in a non-uniform field, therefore a force as well as a couple acts on it. The force on the negative charge is more ($F \propto E$) and is directed along negative x-axis. Thus the dipole moves along negative x-axis and rotates in an anticlockwise direction.



26. (c) If we take a point M on the X-axis as shown in the figure, then the net electric field is in X-direction.

$\therefore$ Option (a) is incorrect.

If we take a point N on Y-axis, we find net electric field along +X direction. The same will be true for any point on Y-axis. (c) is a correct option.

$W_{\infty 0} = q(V_\infty - V_0) = q(0-0) = 0$

$\therefore$ (b) is incorrect. The direction of dipole moment is from –ve to +ve. Therefore (d) is incorrect.

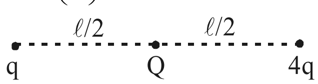
27. (b) The flux for both the charges exactly cancels the effect of each other.

28. (d) Electric displacement vector, $\vec{D} = \varepsilon \vec{E}$

As, $\varepsilon = \varepsilon_0 K \qquad \therefore \vec{D} = \varepsilon_0 K \vec{E}$

29. (a) $(F_{net})_q = 0$

$$\Rightarrow k\frac{Qq}{\left(\frac{\ell}{2}\right)^2} + k\frac{4q^2}{\ell^2} = 0$$



where $k = \dfrac{1}{4\pi\varepsilon_0}$

$\Rightarrow 4Qq + 4q^2 = 0$

$\Rightarrow Q = -q$

30. (c) Electric field, $E = -\dfrac{d\phi}{dt} = -2ar$

By Gauss's theorem $E(4\pi r^2) = \dfrac{q}{\varepsilon_0}$

$\Rightarrow q = -8\pi\varepsilon_0 a r^3$

$$\rho = \frac{dq}{dV} = \frac{dq}{dr} \times \frac{dr}{dV}$$

$$= (-24\pi\varepsilon_0 a r^2)\left(\frac{1}{4\pi r^2}\right) = -6\varepsilon_0 a$$

31. (a) We suppose that the cavity is filled up by a positive as well as negative volume charge of ρ. So the electric field now produced at P is the superposition of two electric fields.

(i) The electric field created due to the infinitely long solid cylinder is

$E_1 = \dfrac{\rho R}{4\varepsilon_0}$ directed towards the $+Y$ direction

(ii) The electric field created due to the spherical negative charge density

$E_2 = \dfrac{\rho R}{96\varepsilon_0}$ directed towards the $-Y$ direction.

$\therefore$ The net electric field is

$$E = E_1 - E_2 = \frac{1}{6}\left[\frac{23\rho R}{16\varepsilon_0}\right]$$

32. (b) The dipole experiences a torque pE sin θ tending to bring itself back in the direction of field.

Therefore, on being released (i.e. rotated) the dipole oscillates about an axis through its centre of mass and perpendicular to the field. If I is the moment of inertia of the dipole about the axis of rotation, then the equation of motion is

$I.d^2\theta/dt^2 = -pE \sin\theta$

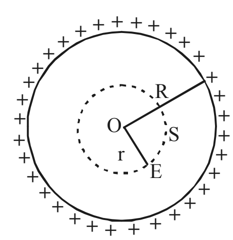
For small amplitude $\sin\theta \approx \theta$

Thus $d^2\theta/dt^2 = -(pE/I).\theta = -\omega^2\theta$

where $\omega = \sqrt{(pE/I)}$.

This is a S.H.M., whose period of oscillation is $T = 2\pi/\omega = 2\pi\sqrt{(I/pE)}$.

33. (a) Charge resides on the outer surface of a conducting hollow sphere of radius R. We consider a spherical surface of radius r < R. By Gauss theorem



$\oint_s \vec{E}.d\vec{s} = \dfrac{1}{\varepsilon_0} \times$ charge enclosed or

$E \times 4\pi r^2 = \dfrac{1}{\varepsilon_0} \times 0 \Rightarrow E = 0$

i.e., electric field inside a hollow sphere is zero.

Type B : Assertion Reason Questions

34. **(e)** Direction of electric field is from region of high potential to low potential & electron or any -ve charged particle will move against the field or lower potential to higher potential.

35. **(a)** A metallic shield may be used to block an electric field because field inside a metallic shield is zero.

36. **(b)** Electric lines of force never cross each other. Electric field at a point add up vectorally to give one resultant electric field. So, they do not have independent existence at the point of superposition so, electric lines of force do not cross each other (crossing of electric lines of force at a point means at a point two fields are having independent existence).

37. **(d)** Gravitational force is the dominating force in the universe so Assertion is incorrect. Gravitational force is weaker than Coulombic force so, Reason is incorrect.

38. **(a)** Net field inside the conductor is zero because by virtue of induced charges, applied and induced electric fields are equal and opposite thus the net charge resides on surface only. If any cavity is there inside the conductor, electric field will be zero in it.

39. **(d)** Electric field at any point depends on presence of all charges.

40. **(b)** If +ve charge is displaced along x-axis, then net force will always act in a direction opposite to that of displacement and the test charge will always come back to its original position.

41. **(c)** $q_d = e,\ m_d = 2m_p = 2m$

$q_\alpha = 2e, m_\alpha = 4m_p = 4m$

$F_1 = F_\alpha = eE, F_2 = F_\alpha = 2eE \neq F_1$

Further, $a_1 = \frac{F_1}{2m} = \frac{eE}{2m}$

and $a_2 = \frac{F_2}{2m} = \frac{2eE}{4m} = \frac{eE}{2m} = a_1$

42. **(a)**

43. **(d)** No. of lines entering the surface = No. of lines leaving the surface.