Electric Charges and Fields

CHAPTER 1

NCERT FOCUS

ANSWERS

Topic 1

1. (a) The net charge possessed by a body is an integral multiple of charge of an electron *i.e.*, $q = \pm ne$, where $n = 0, 1, 2, 3,$ ... is the number of electrons lost or gained by the body and $e = 1.6 \times 10^{-19}$ C is charge of an electron. This is called law of quantization of charge.

(b) At macroscopic level, charges are enormously large as compared to the charge of an electron, $e = 1.6 \times 10^{-19}$ C. Even a charge of 1 nC contains nearly 10^{13} electronic charges. So, at this large scale, charge can have a continuous value rather than discrete integral multiple of e, and hence, the quantization of electric charge can be ignored.

2. When a glass rod is rubbed with a silk cloth, electrons from the glass rod are transferred to the piece of silk cloth. Due to this, the glass rod acquires positive (+) charge whereas the silk cloth acquires negative (–) charge. Before rubbing, both the glass rod and silk cloth are neutral and after rubbing the net charge on both of them is also equal to zero. Such similar phenomenon is observed with many other pairs of bodies. Thus, in an isolated system of bodies, charge is neither created nor destroyed, it is simply transferred from one body to the other. So, it is consistent with the law of conservation of charge.

3. (a) $q = ne$ or $n = \dfrac{q}{e} = \dfrac{3\times10^{-7}}{1.6\times10^{-19}}$

$= 1.875 \times 10^{12}$

so, 1.875×10^{12} electrons have transferred from wool to polythene, as polythene acquires negative charge.

(b) Yes, mass of 1.875×10^{12} electrons

i.e., $m = nm_e = 1.875 \times 10^{12} \times 9.1 \times 10^{-31}$ kg

$= 1.71 \times 10^{-18}$ kg has transferred from wool to polythene.

Topic 2

1. $F = \dfrac{1}{4\pi\varepsilon_0}\dfrac{q_1q_2}{r^2} = 9 \times 10^9 \times \dfrac{2\times10^{-7}\times3\times10^{-7}}{(30\times10^{-2})^2}$

or $F = 6 \times 10^{-3}$ N (repulsive in nature, as the two charges are like charges.)

2. (a) Given, $F_{12} = 0.2$ N, $q_1 = 0.4 \times 10^{-6}$ C,

$q_2 = -0.8 \times 10^{-6}$ C

As, $F_{12} = \dfrac{1}{4\pi\varepsilon_0}\dfrac{q_1q_2}{r^2}$

or $r^2 = \dfrac{1}{4\pi\varepsilon_0}\dfrac{q_1q_2}{F_{12}}$

$= 9 \times 10^9 \times \dfrac{0.4\times10^{-6}\times0.8\times10^{-6}}{0.2}$

or $r^2 = 14.4 \times 10^{-3} = 1.44 \times 10^{-2}$

or $r = 1.2 \times 10^{-1}$ m = 12 cm

(b) By Newton's third law, $F_{21} = F_{12} = 0.2$ N attractive

3. The ratio of electrostatic force to the gravitational force between an electron and a proton separated by a distance r from each other is

$$\frac{F_{\text{electrostatic}}}{F_{\text{gravitational}}} = \frac{Ke\cdot e/r^2}{Gm_em_p/r^2} = \frac{Ke^2}{Gm_em_p}$$

So, $\left[\dfrac{Ke^2}{Gm_em_p}\right] = \left[\dfrac{F_{\text{electrostatic}}}{F_{\text{gravitational}}}\right] = \dfrac{\text{MLT}^{-2}}{\text{MLT}^{-2}} = 1$

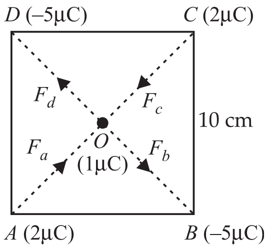
Thus, the ratio $\dfrac{Ke^2}{Gm_em_p}$ is dimensionless.

$$\frac{Ke^2}{Gm_em_p} = \frac{9\times10^9\times(1.6\times10^{-19})^2}{6.67\times10^{-11}\times9.1\times10^{-31}\text{kg}\times1.67\times10^{-27}\text{ kg}}$$

$= 0.23 \times 10^{40} = 2.3 \times 10^{39}$

This ratio signifies that electrostatic forces are 10^{39} times stronger than gravitational forces.

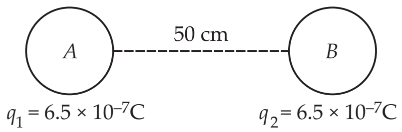
4. (a)



Forces of repulsion on 1 μC charge at O due to 2 μC charge, at A and C are equal and opposite. Therefore, they cancel. Similarly, forces of attraction on 1 μC charge at O, due to –5 μC charges at B and at D are also equal and opposite. Therefore, these also cancel.

Hence, the net force on the charge of 1 μC at O is zero.

5. (a) $F = \dfrac{1}{4\pi\varepsilon_0}\dfrac{q_1q_2}{r^2}$



or $F = 9\times10^9 \dfrac{(6.5\times10^{-7})^2}{(0.5)^2}$

or $F = 1.520 \times 10^{-5}$ N

(b) $q_1' = 2q_1,\ q_2' = 2q_2$ and $r' = \dfrac{r}{2}$

So, $F' = \dfrac{1}{4\pi\varepsilon_0}\dfrac{q_1'\times q_2'}{(r')^2} = \dfrac{1}{4\pi\varepsilon_0}\dfrac{2q_1\times 2q_2}{\left(\dfrac{r}{2}\right)^2}$

or $F' = 16 \times 1.520 \times 10^{-5} = 24.32 \times 10^{-5}$ N

or $F' = 2.432 \times 10^{-3}$ N.

Topic 3

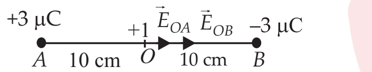
1. A field line cannot have sudden breaks because the moving test charge never jumps from one position to the other.

(b) Two field lines never cross each other at any point, because if they do so, we will obtain two tangents pointing in two different directions of electric field at a point, which is not possible.

2. (a) Electric fields at O due to the charges at A and B are

$$E_{OA} = E_{OB} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2} = 9\times10^9 \times \frac{3\times10^{-6}\text{ C}}{(20/2\times10^{-2}\text{ m})^2}$$

or $E_{OA} = E_{OB} = 27 \times 10^5$ N C^{-1}



As, they are directed in same direction, so net electric field at midpoint O is

$E = E_{OA} + E_{OB} = 2E_{OB} = 2 \times 27 \times 10^5$

or $E = 5.4 \times 10^6$ N C^{-1} directed along OB.

(b) When test charge $q_0 = -1.5 \times 10^{-9}$ C is placed at point O, it experiences a force

$F = q_0 E = 1.5 \times 10^{-9} \times 5.4 \times 10^6$

or $F = 8.1 \times 10^{-3}$N

In direction opposite to that of E *i.e.*, along OA.

3. (a) Area of square, $A = a^2 = 10^2 = 100$ cm^2

$= 100 \times 10^{-4}$ m$^2 = 10^{-2}$ m^2

As the plane is along yz plane, so area vector $\vec{A}$ is directed along x-axis

i.e., $\vec{A} = (10^{-2}\,\hat{i})$ m^2

∴ Electric Flux through the square is

$\phi = \vec{E}\cdot\vec{A} = (3 \times 10^3\,\hat{i}).(10^{-2}\,\hat{i})$

or $\phi = 30$ V-m

(b) When normal to plane *i.e.*, $\vec{A}$ makes an angle of 60° with $\vec{E}$, then

$\phi = EA\cos 60° = 3 \times 10^3 \times 10^{-2} \times 1/2 = 1.5 \times 10$

or $\phi' = 15$ V-m.

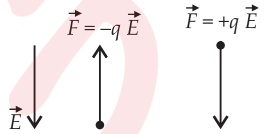
4. $\phi_{net} = 0$, As the net electric flux with closed surface like cube in uniform electric field is equal to zero, because the number of lines entering the cube is the same as the number of lines leaving the cube.

5. Torque on dipole is, $\tau = pE\sin 30°$

or $\tau = 4 \times 10^{-9} \times 5 \times 10^4 \times \dfrac{1}{2}$ or $\tau = 10 \times 10^{-5}$

or $\tau = 1 \times 10^{-4}$ N m.

6. Particles 1 and 2 are negatively charged as they experience forces in direction opposite to that of electric field $\vec{E}$, whereas particle 3 is positively charged as it experience force in the direction of electric field $\vec{E}$.



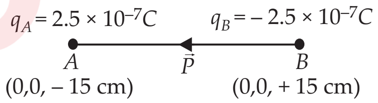
Particle-3 has the highest charge to mass ratio, as it shows maximum deflection in the electric field.

7. The total charge of the system is,

$q_{net} = q_A + q_B$

or $q_{net} = 2.5 \times 10^{-7} - 2.5 \times 10^{-7}$ or $q_{net} = 0$

and the total electric dipole moment of the system is



$p = q.2a = 2.5 \times 10^{-7}$C $\times 2 \times 15 \times 10^{-2}$ m

or $p = 75 \times 10^{-9}$ C m

or $p = 7.5 \times 10^{-8}$ C m directed along BA

Topic 4

1. (a) $\phi = 8 \times 10^3$ N m^2 C^{-1}

or $\dfrac{q}{\varepsilon_0} = 8 \times 10^3$ N m^2 C^{-1}

or $q = 8 \times 10^3\,\varepsilon_0 = 8 \times 10^3 \times 8.85 \times 10^{-12}$

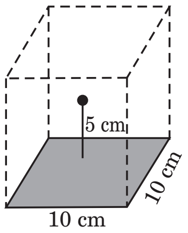
or $q = 7.08 \times 10^{-8}$ C

(b) As $\phi = 0$

or $\dfrac{q_{net}}{\varepsilon_0} = 0$ or $q_{net} = 0$

So, the net charge enclosed by that closed surface is zero, although it may have some charges inside it.

2. Let us assume that the given square be one face of the cube of edge 10 cm.



As charge of +10 μC is at a distance of 5 cm above the centre of a square, so it is enclosed by the cube. Hence by Gauss's theorem, electric flux linked with the cube is

$$\phi = \frac{q}{\varepsilon_0} = \frac{10\times10^{-6}}{8.85\times10^{-12}} = 1.13 \times 10^6 \text{ N m}^2\text{ C}^{-1}$$

So, the magnitude of the electric flux through the square is

$$\phi_{sq} = \frac{\phi}{6} = \frac{1.13}{6} \times 10^6 \text{ or } \phi_{sq} = 1.9 \times 10^5 \text{ N m}^2\text{ C}^{-1}$$

3. $\phi = \frac{q}{\varepsilon_0} = \frac{2\times10^{-6}}{8.85\times10^{-12}} = 0.23 \times 10^6$

or $\phi = 2.3 \times 10^5$ N m^2 C^{-1}.

4. (a) On increasing the radius of the Gaussian surface, charge enclosed by it remains the same and hence the electric flux linked with Gaussian surface also remains the same.

(b) $\phi = \frac{q}{\varepsilon_0}$ or $q = \phi\,\varepsilon_0$

or $q = -1 \times 10^3 \times 8.85 \times 10^{-12}$

or $q = -8.85 \times 10^{-9}$ C = –8.85 nC.

5. $R = \frac{2.4 \text{ m}}{2} = 1.2$ m,

$\sigma = 80.0\ \mu\text{ C m}^{-2} = 80 \times 10^{-6}\text{ C m}^{-2}$

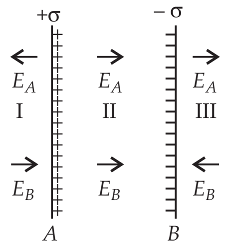
(a) As $\sigma = \frac{q}{4\pi R^2}$

So, $q = 4\pi R^2 \times \sigma = 4 \times 3.14 \times (1.2^2) \times 80 \times 10^{-6}$

or $q = 1.45 \times 10^{-3}$ C

(b) $\phi = \frac{q}{\varepsilon_0} = \frac{1.45\times10^{-3}}{8.85\times10^{-12}} = 1.64 \times 10^8$ N m^2 C^{-1}

6. As both the plates have same surface charge density σ, so



$$E_A = E_B = \frac{\sigma}{2\varepsilon_0}$$

(a) In region-I,

$$E_I = E_B - E_A = \frac{\sigma}{2\varepsilon_0} - \frac{\sigma}{2\varepsilon_0} \text{ or } E_I = 0$$

(b) In region-III, $E_{III} = E_A - E_B = \frac{\sigma}{2\varepsilon_0} - \frac{\sigma}{2\varepsilon_0}$ or $E_{III} = 0$

(c) In region-I $E_{III} = E_A + E_B = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0} = \frac{\sigma}{\varepsilon_0}$

or $E_{II} = \frac{17.0\times10^{-22}}{8.85\times10^{-12}} = 1.92 \times 10^{-10}$ N C–1.

7. $r = 20$ cm = 0.20 m, $E = 1.5 \times 103$ N C^{-1},

$R = 10$ cm = 0.1 m

$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$ or $1.5 \times 10^3 = 9 \times 10^9 \times \frac{q}{(0.20)^2}$

or $q = \frac{1.5\times10^3\times0.04}{9\times10^9} = 6.67 \times 10^{-9}$

Since electric field points radially inwards, so charge is negative *i.e.*

$q = -6.67$ *n*C.

8. $E = 9 \times 104$ N C^{-1}, $r = 2$ cm = 2 × 10–2 m

As $E = \frac{\lambda}{2\pi\varepsilon_0 r}$

So, $\lambda = 2\pi\varepsilon_0 r\cdot E = \frac{1}{2\times9\times10^9} \times 9 \times 10^4 \times 2 \times 10^{-2}$

or $\lambda = 1 \times 10^{-7}$ C m^{-1} = 0.1 μ C m^{-1}.