EXERCISES

Question 1.1:

What is the force between two small charged spheres having charges of 2×10^{-7} C and 3×10^{-7} C placed 30 cm apart in air?

Answer 1.1:

Repulsive force of magnitude 6×10^{-3} N

Charge on the first sphere, $q_1 = 2 \times 10^{-7}$ C

Charge on the second sphere, $q_2 = 3 \times 10^{-7}$ C

Distance between the spheres, r = 30 cm = 0.3 m

Electrostatic force between the spheres is given by the relation

$$F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r^2}$$

Where, ε_0 = Permittivity of free space and $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \text{ Nm}^2\text{C}^{-2}$

Therefore, force

$$\text{F} = \frac{9 \times 10^9 \times 2 \times 10^{-7}}{(0.3)^2} = 6 \times 10^{-3}\text{N}$$

Hence, force between the two small charged spheres is 6×10^{-3} N. The charges are of same nature. Hence, force between them will be repulsive.

Question 1.2:

The electrostatic force on a small sphere of charge 0.4 μC due to another small sphere of charge − 0.8 μC in air is 0.2 N.

(a) What is the distance between the two spheres?

(b) What is the force on the second sphere due to the first?

Answer 1.2:

(a) Electrostatic force on the first sphere, F = 0.2 N

Charge on this sphere, $q_1 = 0.4\ \mu C = 0.4 \times 10^{-6}$ C

Charge on the second sphere, $q_2 = -0.8\ \mu C = -0.8 \times 10^{-6}$ C

Electrostatic force between the spheres is given by the relation

$$F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r^2}$$

Where, ε_0 = Permittivity of free space and $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9\ \text{Nm}^2\text{C}^{-2}$

Therefore,

$$r^2 = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{F}$$

$$= \frac{0.4 \times 10^{-6} \times 8 \times 10^{-6} \times 9 \times 10^9}{0.2} = 144 \times 10^{-4}$$

$$\Rightarrow r = \sqrt{144 \times 10^{-4}} = 12 \times 10^{-2} = 0.12\ \text{m}$$

The distance between the two spheres is 0.12 m.

(b) Both the spheres attract each other with the same force. Therefore, the force on the second sphere due to the first is 0.2 N.

Question 1.3:

Check that the ratio $ke^2/G\,m_e m_p$ is dimensionless. Look up a Table of Physical Constants and determine the value of this ratio. What does the ratio signify?

Answer 1.3:

The given ratio is $\frac{ke^2}{Gm_e m_p}$. Where,

G = Gravitational constant. Its unit is N m^2 kg^{-2}

m_e and m_p = Masses of electron and proton and their unit is kg.

e = Electric charge. Its unit is C.

$k = \frac{1}{4\pi\varepsilon_0}$ and its unit is N m^2 C^{-2}.

Therefore, unit of the given ratio

$$\frac{ke^2}{Gm_em_p} = \frac{[Nm^2C^{-2}][C^{-2}]}{[Nm^2kg^{-2}][kg][kg]} = M^0L^0T^0$$

Hence, the given ratio is dimensionless.

$e = 1.6 \times 10^{-19}$ C
$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}
$m_e = 9.1 \times 10^{-31}$ kg
$m_p = 1.66 \times 10^{-27}$ kg
Hence, the numerical value of the given ratio is

$$\frac{ke^2}{Gm_em_p} = \frac{9 \times 10^9 \times (1.6 \times 10^{-19})^2}{6.67 \times 10^{-11} \times 9.1 \times 10^{-31} \times 1.67 \times 10^{-27}} \approx 2.3 \times 10^{39}$$

This is the ratio of electric force to the gravitational force between a proton and an electron, keeping distance between them constant.

Question 1.4:

(a) Explain the meaning of the statement 'electric charge of a body is quantised'.
(b) Why can one ignore quantisation of electric charge when dealing with macroscopic i.e., large scale charges?

Answer 1.4:

(a) Electric charge of a body is quantized. This means that only integral (1, 2… n) number of electrons can be transferred from one body to the other.

Charges are not transferred in fraction. Hence, a body possesses total charge only in integral multiples of electric charge.

(b) In macroscopic or large scale charges, the charges used are huge as compared to the magnitude of electric charge. Hence, quantization of electric charge is of no use on macroscopic scale. Therefore, it is ignored and it is considered that electric charge is continuous.

Question 1.5:

When a glass rod is rubbed with a silk cloth, charges appear on both. A similar phenomenon is observed with many other pairs of bodies. Explain how this observation is consistent with the law of conservation of charge.

Answer 1.5:

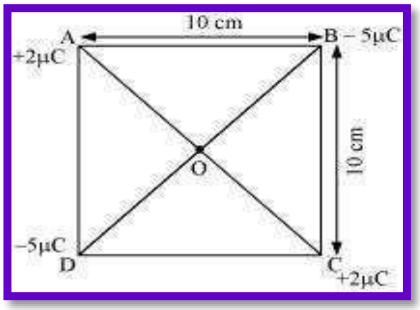
Rubbing produces charges of equal magnitude but of opposite nature on the two bodies because charges are created in pairs. This phenomenon of charging is called charging by friction. The net charge on the system of two rubbed bodies is zero. This is because equal amount of opposite charges annihilate each other. When a glass rod is rubbed with a silk cloth, opposite natured charges appear on both the bodies. This phenomenon is in consistence with the law of conservation of energy. A similar phenomenon is observed with many other pairs of bodies.

Question 1.6:

Four point charges $q_A = 2\ \mu C$, $q_B = -5\ \mu C$, $q_C = 2\ \mu C$, and $q_D = -5\ \mu C$ are located at the corners of a square ABCD of side 10 cm. What is the force on a charge of 1 μC placed at the centre of the square?

Answer 1.6:

The given figure shows a square of side 10 cm with four charges placed at its corners. O is the centre of the square.



Where,

(Sides) AB = BC = CD = AD = 10 cm

(Diagonals) AC = BD = $10\sqrt{2}$ cm

AO = OC = DO = OB = $5\sqrt{2}$ cm

A charge of amount 1μC is placed at point O.

Force of repulsion between charges placed at corner A and centre O is equal in magnitude but opposite in direction relative to the force of repulsion between the charges placed at corner C and centre O. Hence, they will cancel each other. Similarly, force of attraction between charges placed at corner B and centre O is equal in magnitude but opposite in direction relative to the force of attraction between the charges placed at corner D and centre O. Hence, they will also cancel each other. Therefore, net force caused by the four charges placed at the corner of the square on 1 μC charge at centre O is zero.

Question 1.7:

(a) An electrostatic field line is a continuous curve. That is, a field line cannot have sudden breaks. Why not?

(b) Explain why two field lines never cross each other at any point?

Answer 1.7:

(a) An electrostatic field line is a continuous curve because a charge experiences a continuous force when traced in an electrostatic field. The field line cannot have sudden breaks because the charge moves continuously and does not jump from one point to the other.

(b) If two field lines cross each other at a point, then electric field intensity will show two directions at that point. This is not possible. Hence, two field lines never cross each other.

Question 1.8:

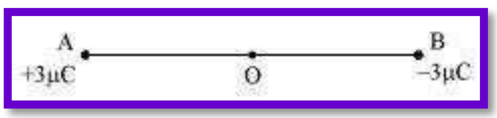
Two point charges $q_A = 3\ \mu C$ and $q_B = -3\ \mu C$ are located 20 cm apart in vacuum.

(a) What is the electric field at the midpoint O of the line AB joining the two charges?

(b) If a negative test charge of magnitude 1.5×10^{-9} C is placed at this point, what is the force experienced by the test charge?

Answer 1.8:

(a) The situation is represented in the given figure. O is the mid-point of line AB.



Distance between the two charges, AB = 20 cm

∴ AO = OB = 10 cm

Net electric field at point O = E

Electric field at point O caused by +3μC charge,

$$E_1 = \frac{1}{4\pi\varepsilon_0} \cdot \frac{3 \times 10^{-6}}{(OA)^2} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{3 \times 10^{-6}}{(10 \times 10^{-2})^2}\ NC^{-1} \quad along\ OB$$

Where, ε_0 = Permittivity of free space and $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ Nm^2C^{-2}

Therefore,

Magnitude of electric field at point O caused by −3μC charge,

$$E_2 = \left|\frac{1}{4\pi\varepsilon_0}.\frac{-3 \times 10^{-6}}{(OB)^2}\right| = \frac{1}{4\pi\varepsilon_0}.\frac{3 \times 10^{-6}}{(10 \times 10^{-2})^2}\ NC^{-1} \quad along\ OB$$

$$\therefore E = E_1 + E_2 = 2 \times \frac{1}{4\pi\varepsilon_0}.\frac{3 \times 10^{-6}}{(10 \times 10^{-2})^2}\ NC^{-1} \quad along\ OB$$

[*Since the magnitudes of E_1 and E_2 are equal and in the same direction*]

$$\therefore E = 2 \times 9 \times 10^9 \times \frac{3 \times 10^{-6}}{(10 \times 10^{-2})^2}\ NC^{-1}$$

= 5.4×10^6 NC^{-1} along OB

Therefore, the electric field at mid-point O is 5.4×10^6 N C^{-1} along OB.

(b) A test charge of amount 1.5×10^{-9} C is placed at mid – point O.

q = 1.5×10^{-9} C

Force experienced by the test charge = F

∴ F = qE

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

= 8.1×10^{-3} N

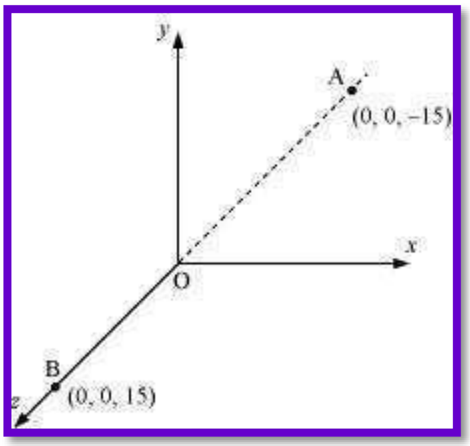
The force is directed along line OA. This is because the negative test charge is repelled by the charge placed at point B but attracted towards point A. Therefore, the force experienced by the test charge is 8.1×10^{-3} N along OA.

Question 1.9:

A system has two charges $q_A = 2.5 \times 10^{-7}$ C and $q_B = -2.5 \times 10^{-7}$ C located at points A: (0, 0, − 15 cm) and B: (0, 0, + 15 cm), respectively. What are the total charge and electric dipole moment of the system?

Answer 1.9:

Both the charges can be located in a coordinate frame of reference as shown in the given figure.



At A, amount of charge, $q_A = 2.5 \times 10^{-7}$C

At B, amount of charge, $q_B = -2.5 \times 10^{-7}$ C

Total charge of the system, $q = q_A + q_B = 2.5 \times 10^{7}$ C $- 2.5 \times 10^{-7}$ C = 0

Distance between two charges at points A and B,

d = 15 + 15 = 30 cm = 0.3 m

Electric dipole moment of the system is given by, p

$= q_A \times d = q_B \times d = 2.5 \times 10^{-7} \times 0.3$

$= 7.5 \times 10^{-8}$ C m along positive z-axis

Therefore, the electric dipole moment of the system is 7.5×10^{-8} C m along positive z−axis.

Question 1.10:

An electric dipole with dipole moment 4×10^{-9} C m is aligned at 30° with the direction of a uniform electric field of magnitude 5×10^{4} N C^{-1}. Calculate the magnitude of the torque acting on the dipole.

Answer 1.10:

Electric dipole moment, $p = 4 \times 10^{-9}$ C m

Angle made by p with a uniform electric field, $\theta = 30°$

Electric field, $E = 5 \times 10^{4}$ N C^{-1}

Torque acting on the dipole is given by the relation, $\tau = pE \sin\theta$

$$= 4 \times 10^{-9} \times 5 \times 10^{4} \times \sin 30 = 20 \times 10^{-5} \times \frac{1}{2} = 10^{-4} \text{ Nm}$$

Therefore, the magnitude of the torque acting on the dipole is 10^{-4} N m.

Question 1.11:

A polythene piece rubbed with wool is found to have a negative charge of 3×10^{-7} C.

(a) Estimate the number of electrons transferred (from which to which?)

(b) Is there a transfer of mass from wool to polythene?

Answer 1.11:

(a) When polythene is rubbed against wool, a number of electrons get transferred from wool to polythene. Hence, wool becomes positively charged and polythene becomes negatively charged.

Amount of charge on the polythene piece, $q = -3 \times 10^{-7}$ C

Amount of charge on an electron, $e = -1.6 \times 10^{-19}$ C Number of electrons transferred from wool to polythene = n

n can be calculated using the relation, q = ne

$$n = \frac{q}{e} = \frac{-3 \times 10^{-7}}{-1.6 \times 10^{-19}} = 1.87 \times 10^{12}$$

Therefore, the number of electrons transferred from wool to polythene is 1.87×10^{12}.

(b) Yes.

There is a transfer of mass taking place. This is because an electron has mass, $m_e = 9.1 \times 10^{-3}$ kg

Total mass transferred to polythene from wool, $m = m_e \times n$

$= 9.1 \times 10^{-31} \times 1.85 \times 10^{12}$

$= 1.706 \times 10^{-18}$ kg

Hence, a negligible amount of mass is transferred from wool to polythene.

Question 1.12:

(a) Two insulated charged copper spheres A and B have their centers separated by a distance of 50 cm. What is the mutual force of electrostatic repulsion if the charge on each is 6.5×10^{-7} C? The radii of A and B are negligible compared to the distance of separation.

(b) What is the force of repulsion if each sphere is charged double the above amount, and the distance between them is halved?

Answer 1.12:

(a) Charge on sphere A, $q_A = 6.5 \times 10^{-7}$ C

Charge on sphere B, $q_B = 6.5 \times 10^{-7}$ C

Distance between the spheres, r = 50 cm = 0.5 m

Force of repulsion between the two spheres

$$F = \frac{1}{4\pi\varepsilon_0} . \frac{q_A q_B}{r^2}$$

Where, ε_0 = Permittivity of free space and $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \text{ Nm}^2\text{C}^{-2}$

Therefore,

$$F = \frac{9 \times 10^9 \times (6.5 \times 10^{-7})^2}{(0.5)^2}$$

$$= 1.52 \times 10^{-2} \text{ N}$$

Therefore, the force between the two spheres is 1.52×10^{-2} N.

(b) After doubling the charge,

Charge on sphere A, $q_A = 1.3 \times 10^{-6}$ C

Charge on sphere B, $q_B = 1.3 \times 10^{-6}$ C

The distance between the spheres is halved.

$$\therefore r = \frac{0.5}{2} = 0.25 \ m$$

Force of repulsion between the two spheres,

$$F = \frac{1}{4\pi\varepsilon_0} . \frac{q_A q_B}{r^2} = \frac{9 \times 10^9 \times 1.3 \times 10^{-6} \times 1.3 \times 10^{-6}}{(0.25)^2}$$

$= 16 \times 1.52 \times 10^{-2}$

= 0.243 N

Therefore, the force between the two spheres is 0.243 N.

Question 1.13:

Suppose the spheres A and B in Exercise 1.12 have identical sizes. A third sphere of the same size but uncharged is brought in contact with the first, then brought in contact with the second, and finally removed from both. What is the new force of repulsion between A and B?

Answer 1.13:

Distance between the spheres, A and B, r = 0.5 m

Initially, the charge on each sphere, $q = 6.5 \times 10^{-7}$ C

When sphere A is touched with an uncharged sphere C, q/2 amount of charge from A will transfer to sphere C. Hence, charge on each of the spheres, A and C, is q/2.

When sphere C with charge q/2 is brought in contact with sphere B with charge q, total charges on the system will divide into two equal halves given as,

$$\frac{1}{2}\left(q + \frac{q}{2}\right) = \frac{3q}{4}$$

Hence, charge on each of the spheres, C and B, is $\frac{3q}{4}$.

Force of repulsion between sphere A having charge q/2 and sphere B having charge $\frac{3q}{4}$ is

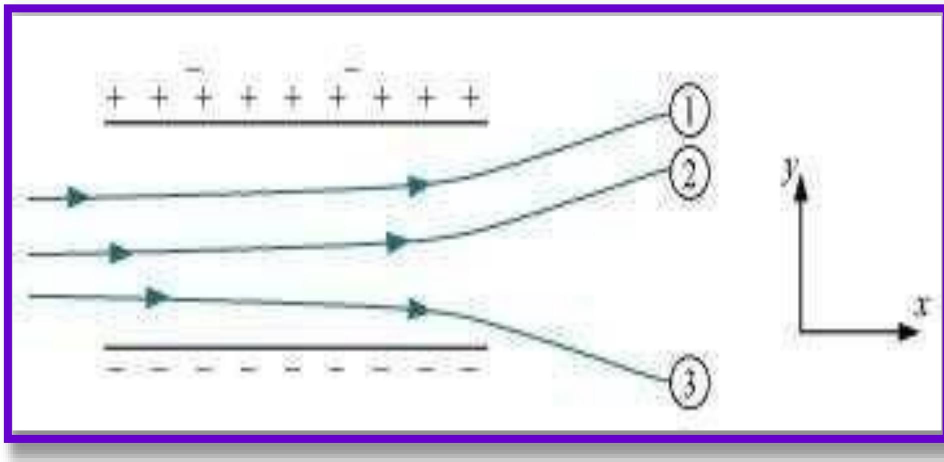
$$F = \frac{1}{4\pi\varepsilon_0} . \frac{q_A q_B}{r^2} = \frac{1}{4\pi\varepsilon_0} . \frac{\frac{q}{2} \times \frac{3q}{4}}{r^2}$$

$$= \frac{1}{4\pi\varepsilon_0} . \frac{3q^2}{8r^2} = \frac{9 \times 10^9 \times 3 \times (6.5 \times 10^{-7})^2}{8 \times (0.5)^2} = 5.703 \times 10^{-3} \text{ N}$$

Therefore, the force of attraction between the two spheres is 5.703×10^{-3} N.

Question 1.14:

Figure shows tracks of three charged particles in a uniform electrostatic field. Give the signs of the three charges. Which particle has the highest charge to mass ratio?



Answer 1.14:

Opposite charges attract each other and same charges repel each other. It can be observed that particles 1 and 2 both move towards the positively charged plate and repel away from the negatively charged plate. Hence, these two particles are negatively charged. It can also be observed that particle 3 moves towards the negatively charged plate and repels away from the positively charged plate. Hence, particle 3 is positively charged.

The charge to mass ratio (emf) is directly proportional to the displacement or amount of deflection for a given velocity. Since the deflection of particle 3 is the maximum, it has the highest charge to mass ratio.

Question 1.15:

Consider a uniform electric field $\mathbf{E} = 3 \times 10^3\ \hat{\mathbf{i}}$ N/C.

(a) What is the flux of this field through a square of 10 cm on a side whose plane is parallel to the yz - plane?

(b) What is the flux through the same square if the normal to its plane makes a 60° angle with the x-axis?

Answer 1.15:

(a) Electric field intensity, $\mathbf{E} = 3 \times 10^3\ \hat{\mathbf{i}}$ N/C

Magnitude of electric field intensity, $|\mathbf{E}| = 3 \times 10^3$ N/C

Side of the square, s = 10 cm = 0.1 m

Area of the square, $A = s^2 = 0.01\ m^2$

The plane of the square is parallel to the y-z plane. Hence, angle between the unit vector normal to the plane and electric field, θ = 0°

Flux (ϕ) through the plane is given by the relation,

$\phi = |\mathbf{E}| A \cos\theta$

$= 3 \times 10^3 \times 0.01 \times \cos 0°$

$= 30\ N\ m^2/C$

(b) Plane makes an angle of 60° with the x – axis. Hence, θ = 60°

Flux, $\phi = |\mathbf{E}| A \cos\theta$

$= 3 \times 10^3 \times 0.01 \times \cos 60°$

$= 30 \times \frac{1}{2}$

$= 15\ N\ m^2/C$

Question 1.16:

What is the net flux of the uniform electric field of Exercise 1.15 through a cube of side 20 cm oriented so that its faces are parallel to the coordinate planes?

Answer 1.16:

All the faces of a cube are parallel to the coordinate axes. Therefore, the number of field lines entering the cube is equal to the number of field lines piercing out of the cube. As a result, net flux through the cube is zero.

Question 1.17:

Careful measurement of the electric field at the surface of a black box indicates that the net outward flux through the surface of the box is 8.0×10^3 N m^2/C.

(a) What is the net charge inside the box?

(b) If the net outward flux through the surface of the box were zero, could you conclude that there were no charges inside the box? Why or Why not?

Answer 1.17:

(a) Net outward flux through the surface of the box, $\phi = 8.0 \times 10^3$ N m^2/C

For a body containing net charge q, flux is given by the relation,

$$\phi = \frac{q}{\varepsilon_0}$$

ε_0 = Permittivity of free space

$= 8.854 \times 10^{-12}\ N^{-1}C^2\ m^{-2}$

$q = \varepsilon_0 \phi$

$= 8.854 \times 10^{-12} \times 8.0 \times 10^3\ C = 7.08 \times 10^{-8}\ C = 0.07\ \mu C$

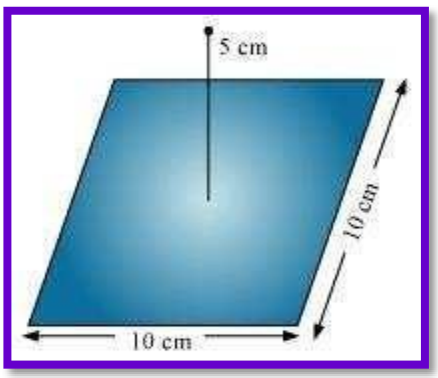
Therefore, the net charge inside the box is 0.07 µC.

(b) No

Net flux piercing out through a body depends on the net charge contained in the body. If net flux is zero, then it can be inferred that net charge inside the body is zero. The body may have equal amount of positive and negative charges.

Question 1.18:

A point charge +10 μC is a distance 5 cm directly above the centre of a square of side 10 cm, as shown in Fig. 1.34. What is the magnitude of the electric flux through the square? (Hint: Think of the square as one face of a cube with edge 10 cm.)



Answer 1.18:

The square can be considered as one face of a cube of edge 10 cm with a centre where charge q is placed. According to Gauss's theorem for a cube, total electric flux is through all its six faces.

$$\phi_{Total} = \frac{q}{\varepsilon_0}$$

Hence, electric flux through one face of the cube i.e., through the square is

$$\phi = \frac{\phi_{Total}}{6} = \frac{1}{6} . \frac{q}{\varepsilon_0}$$

Where,

ε_0 = Permittivity of free space = 8.854×10^{-12} $N^{-1}C^2$ m^{-2}

q = 10 μC = 10×10^{-6} C

$$\therefore \phi = \frac{1}{6} \cdot \frac{10 \times 10^{-6}}{8.854 \times 10^{-12}}$$

= 1.88×10^5 N m^2 C^{-1}

Therefore, electric flux through the square is 1.88×10^5 N m^2 C^{-1}.

Question 1.19:

A point charge of 2.0 μC is at the centre of a cubic Gaussian surface 9.0 cm on edge. What is the net electric flux through the surface?

Answer 1.19:

Net electric flux (ϕ_{Net}) through the cubic surface is given by

$$\phi_{Net} = \frac{q}{\varepsilon_0}$$

Where,

ε_0 = Permittivity of free space = 8.854×10^{-12} $N^{-1}C^2$ m^{-2}

q = Net charge contained inside the cube = 2.0 μC = 2×10^{-6} C

$$\therefore \phi_{Net} = \frac{2 \times 10^{-6}}{8.854 \times 10^{-12}}$$

= 2.26×10^5 N m^2 C^{-1}

The net electric flux through the surface is 2.26×10^5 N m^2C^{-1}.

Question 1.20:

A point charge causes an electric flux of -1.0×10^3 Nm^2/C to pass through a spherical Gaussian surface of 10.0 cm radius centered on the charge.

(a) If the radius of the Gaussian surface were doubled, how much flux would pass through the surface?

(b) What is the value of the point charge?

Answer 1.20:

(a) Electric flux, $\Phi = -1.0 \times 10^3$ N m^2/C

Radius of the Gaussian surface, r = 10.0 cm

Electric flux piercing out through a surface depends on the net charge enclosed inside a body. It does not depend on the size of the body. If the radius of the Gaussian surface is doubled, then the flux passing through the surface remains the same i.e., -10^3 N m^2/C.

(b) Electric flux is given by the relation

$$\phi = \frac{q}{\varepsilon_0}$$

Where,

ε_0 = Permittivity of free space = 8.854×10^{-12} $N^{-1}C^2$ m^{-2}

q = Net charge enclosed by the spherical surface $= \phi\varepsilon_0$

$= -1.0 \times 10^3 \times 8.854 \times 10^{-12}$

$= -8.854 \times 10^{-9}$ C

$= -8.854$ nC

Therefore, the value of the point charge is -8.854 nC.

Question 1.21:

A conducting sphere of radius 10 cm has an unknown charge. If the electric field 20 cm from the centre of the sphere is 1.5×10^3 N/C and points radially inward, what is the net charge on the sphere?

Answer 1.21:

Electric field intensity (E) at a distance (d) from the centre of a sphere containing net charge q is given by the relation,

$$E = \frac{1}{4\pi\varepsilon_0} . \frac{q}{d^2}$$

Where, q = Net charge = 1.5×10^3 N/C

d = Distance from the centre = 20 cm = 0.2 m

ε_0 = Permittivity of free space and $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \text{ Nm}^2\text{C}^{-2}$

Therefore,

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

= 6.67×10^9 C

= 6.67 nC

Therefore, the net charge on the sphere is 6.67 nC.

Question 1.22:

A uniformly charged conducting sphere of 2.4 m diameter has a surface charge density of 80.0 μC/m^2.

(a) Find the charge on the sphere.

(b) What is the total electric flux leaving the surface of the sphere?

Answer 1.22:

(a) Diameter of the sphere, d = 2.4 m

Radius of the sphere, r = 1.2 m
Surface charge density, σ = 80.0 μC/m^2 = 80 × 10^{-6} C/m^2

Total charge on the surface of the sphere,

Q = Charge density × Surface area

$$= \sigma \times 4\pi r^2$$

= 80 × 10^{-6} × 4 × 3.14 × (1.2)^2

= 1.447 × 10^{-3} C

Therefore, the charge on the sphere is 1.447 × 10^{-3} C.

(b) Total electric flux (ϕ_{Total}) leaving out the surface of a sphere containing net charge Q is given by the relation,

$$\phi_{Total} = \frac{Q}{\varepsilon_0}$$

Where,

ε_0 = Permittivity of free space

= 8.854 × 10^{-12} N^{-1}C^2 m^{-2}

Q = 1.447 × 10^{-3} C

$$\therefore \phi_{Total} = \frac{1.447 \times 10^{-3}}{8.854 \times 10^{-12}}$$

= 1.63 × 10^8 N C^{-1} m^2

Therefore, the total electric flux leaving the surface of the sphere is 1.63 × 10^8 N C^{-1} m^2.

Question 1.23:

An infinite line charge produces a field of 9×10^4 N/C at a distance of 2 cm. Calculate the linear charge density.

Answer 1.23:

Electric field produced by the infinite line charges at a distance d having linear charge density λ is given by the relation,

$$E = \frac{\lambda}{2\pi\varepsilon_0 d}$$

$$\Rightarrow \lambda = 2\pi\varepsilon_0 dE$$

Where, d = 2 cm = 0.02 m

E = 9×10^4 N/C

ε_0 = Permittivity of free space and $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9\ \mathrm{Nm^2C^{-2}}$

Therefore,

$$\lambda = \frac{0.02 \times 9 \times 10^4}{2 \times 9 \times 10^9}$$

= 10 μC/m

Therefore, the linear charge density is 10 μC/m.

Question 1.24:

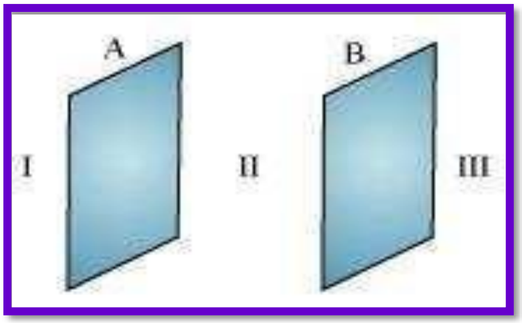
Two large, thin metal plates are parallel and close to each other. On their inner faces, the plates have surface charge densities of opposite signs and of magnitude 17.0×10^{-22} C/m^2. What is E:

(a) in the outer region of the first plate,

(b) in the outer region of the second plate, and (c) between the plates?

Answer 1.24:

The situation is represented in the following figure.



A and B are two parallel plates close to each other. Outer region of plate A is labelled as I, outer region of plate B is labelled as III, and the region between the plates, A and B, is labelled as II.

Charge density of plate A, $\sigma = 17.0 \times 10^{-22}$ C/m^2

Charge density of plate B, $\sigma = -17.0 \times 10^{-22}$ C/m^2

In the regions, I and III, electric field E is zero. This is because charge is not enclosed by the respective plates.

Electric field E in region II is given by the relation,

$$E = \frac{\sigma}{\varepsilon_0}$$

Where,

ε_0 = Permittivity of free space = 8.854×10^{-12} N^{-1}C^2 m^{-2}

$$E = \frac{17.0 \times 10^{-22}}{8.854 \times 10^{-12}}$$

= 1.92×10^{-10} N/C

Therefore, electric field between the plates is 1.92×10^{-10} N/C.