CHAPTER 1 Electric Charges and Fields

EXERCISES PAGE:42

Question1 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 the air?

Solution :

The formula used to find the force, F is given as, $F = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}$ ...(1)

Where, q1 and q2 are the charges.
r is the distance between the charges.
$\frac{1}{4\pi\epsilon_0}$ is a constant and its value is 9×10^{9} N m^2 C^{-2}
ϵ_0 is the permittivity of free space. Its value is 8.85×10^{-12} (F/m)

Since, both the charges are positive, thus, the nature of force will be repulsive.
F12 is the force on charge q1 caused by charge q2.
Now, Given:

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
Putting the values in equation (1), we get,

$$F = \frac{(9\times10^{9}\ N\,m^2\,C^{-2})\times(2\times10^{-7}\ C)\times(3\times10^{-7}\ C)}{0.3m\times0.3m}$$

$$F = 6\times10^{-3}\ N$$

Hence, the force between the given charged particles will be 6×10^{-3} N. Since the nature of the charges is the same i.e. they are both positive. Hence, the force will be repulsive.

Question2. 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?

Solution :

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

Charge on this sphere, q1 = 0.4 μC = 0.4 × 10−6 C

Charge on the second sphere, q2 = − 0.8 μC = − 0.8 × 10−6 C

Electrostatic force between the spheres is given by the relation,

$$F = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2} \quad \frac{1}{4\pi\epsilon_0}$$

Where, ∈0 = Permittivity of free space

$$r^2 = \frac{q_1 \times q_2}{4 \times \pi \times \epsilon_0 \times F}$$

$$\Rightarrow r^2 = \frac{0.4 \times 10^{-6}\, C \times -0.8 \times 10^{-6}\, C \times 9 \times 10^{9}\, N\, m^2 C^{-2}}{0.2\, N}$$

$\Rightarrow r^2 = 144 \times 10^{-4}\ m^2$

Taking square root both the sides,

$\Rightarrow r = \sqrt{144 \times 10^{-4}}$

r = 0.12 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 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?

Solution :

The given ratio is $\frac{ke^2}{G\,m_e m_p}$.

Where,

G = Gravitational constant

Its unit is N m2 kg−2.

me and mp = Masses of electron and proton.

Their unit is kg.

e = Electric charge.

Its unit is C.

K is a constant = $\frac{1}{4\pi\epsilon_0}$

∊0 = Permittivity of free space

Its unit is N m2 C−2.

$$\frac{ke^2}{G\,m_e m_p} = \frac{Nm^2C^{-2} \times C^2}{Nm^2kg^{-2} \times kg \times kg}$$

Hence, the given ratio is dimensionless.

e = 1.6 × 10−19 C

G = 6.67 × 10-11 N m2 kg-2

me= 9.1 × 10-31 kg

mp = 1.66 × 10-27 kg

Hence, the numerical value of the given ratio is

On substituting these values into the ratio, we get

$$\Rightarrow \frac{ke^2}{G\, m_e m_p} = \frac{9 \times 10^9 \times (1.6 \times 10^{-19})^2}{6.67 \times 10^{-11} \times 9.1 \times 10^{-31} \times 1.67 \times 10^{-27}}$$

$$\Rightarrow \frac{ke^2}{G\, m_e m_p} \approx 2.3 \times 10^{40}$$

Note:

$$\Rightarrow \frac{\text{electric force}}{\text{gravitational force}} \approx 10^{40}$$

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

Question4. (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?

Solution :

(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.

Question5. 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.

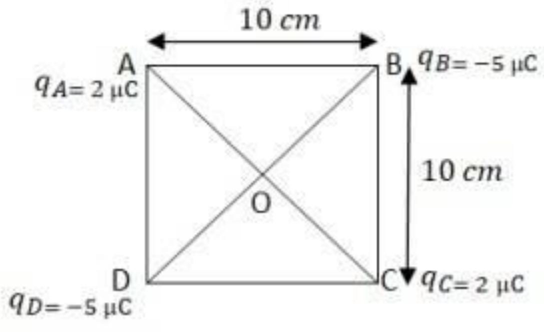
Solution :

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.

Question6. Four point charges qA = 2 μC, qB = −5 μC, qC = 2 μC, and qD = −5 μC 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?

Solution :

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 cm

AO = OC = DO = OB = $(10\sqrt{2})/2$ cm = $5\sqrt{2}$cm 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.

Question7. (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?

Solution **:**
(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.

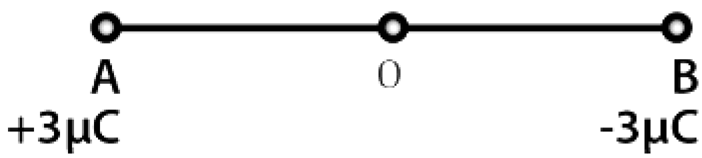
(b) If two field lines cross each other at a point, then electric field intensity will show two directions at that point. This is not possible. Hence, two field lines never cross each other.

Question 8 Two point charges q_A = 3 μC and q_B= −3 μC are located 20 cm apart in a vacuum.

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

(ii) 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?

Solution **:**
(i) 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,

$$E_A = \frac{3 \times 10^{-6}\,C}{4\pi\epsilon_0 \times (0.1m)^2}$$

E1 = $\Rightarrow E_A = \frac{9 \times 10^{9}\,N\,m^2\,C^{-2} \times 3 \times 10^{-6}\,C}{\times (0.1m)^2}$ along OB

Where,

ϵ_0 = Permittivity of free space

Its value is 8.85×10^{-12} (F/m)

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

E2 = $\frac{-3 \times 10^{-6}\,C}{4\pi\epsilon_0 \times (0.1m)^2}$ = $\frac{9 \times 10^{9}\,N\,m^2\,C^{-2} \times -3 \times 10^{-6}\,C}{\times (0.1m)^2}$ along OB

$E_{net} = E_A + E_B$

$\Rightarrow E_{net} = 2E_A$

$$\Rightarrow Enet = 2 \times \frac{9 \times 10^{9}\,N\,m^2\,C^{-2} \times -3 \times 10^{-6}\,C}{\times (0.1m)^2}$$

$= 5.4 \times 10^6 NC^{-1}$
along OB

Therefore, the electric field at midpoint O is

$5.4 \times 10^6 NC^{-1}$
along OB.

(ii) A test charge with a charge potential of

$1.5 \times 10^{-9}\ C$
is placed at midpoint O.

$q = 1.5 \times 10^{-9}\ C$
Let the force experienced by the test charge be F

Therefore, F = qE

=

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

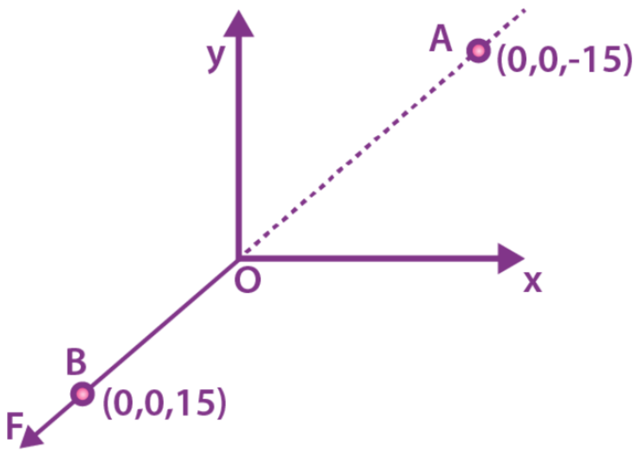
$= 8.1 \times 10^{-3}\ N$
The force is directed along line OA because the negative test charge is attracted towards point A and is repelled by the charge placed at point B. As a result, the force experienced by the test charge is

$q = 8.1 \times 10^{-3}\ N$
along OA.

Question9 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?

Solution : The charges which are located at the given points are shown in the coordinate system as:



At point A, the total charge amount,

$q_A = 2.5 \times 10^{-7}\ C$

At point B, the total charge amount,

$q_B = –2.5 \times 10^{-7}\ C$

The total charge of the system is,

$q_A + q_B = 2.5 \times 10^{-7}\ C – 2.5 \times 10^{-7}\ C = 0$

Distance between two charges at points A and B,

d = 15 + 15 = 30 cm = 0.3 m

The 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

$7.5 \times 10^{-8}\ C$

m along the positive z-axis.

Question 10 An electric dipole with dipole moment

$4 \times 10^{-9}\ Cm$
is aligned at 30° with the direction of a uniform electric field of magnitude
$5 \times 10^{4}\ NC^{-1}$
. Calculate the magnitude of the torque acting on the dipole.

Soln.:

Electric dipole moment,

$p = 4 \times 10^{-9}\ Cm$
Angle made by p with a uniform electric field,

$\theta = 30^{\circ}$
Electric field,

$E = 5 \times 10^{4}\ NC^{-1}$
The torque acting on the dipole is given by the relation,

$\tau = pE \sin\theta$

$= 4 \times 10^{-9} \times 5 \times 10^{4} \times \sin 30 = 20 \times 10^{-5} \times \frac{1}{2} = 10^{-4}\ Nm$
Therefore, the magnitude of the torque acting on the dipole is

$10^{-4}\ Nm$

Question 11 A polythene piece rubbed with wool is found to have a negative charge of

$3 \times 10^{-7}\ C$
.

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

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

Soln.:

(i) Since the wool is positively charged and the polythene is negatively charged, we can say that few amounts of electrons are transferred from wool to polythene.

Charge on the polythene, q =

$3 \times 10^{-7}\ C$

.

Amount of charge on an electron,

$e = -1.6 \times 10^{-19}\ C$

Let the number of electrons transferred from wool to polythene be n

So, by using the given equation, we can calculate the value of n,

q = ne

$\Rightarrow n = \frac{q}{e} = \frac{-3\times10^{-7}}{-1.6\times10^{-19}} = 1.87 \times 10^{12}$

Therefore, the number of electrons transferred from wool to polythene is

1.87×10^{12}

(ii) Yes,

Mass is also transferred as an electron is transferred from wool to polythene and an electron particle has some mass.

Mass of an electron,

$m_e = 9.1 \times 10^{-31} kg$

Total mass transferred , m =

$m_e \times n$

$= 9.1 \times 10^{-31} \times 1.87 \times 10^{12}$

$= 1.701 \times 10^{-18}\ kg$

Here, the mass transferred is too low that it can be neglected.

Question 12 (i) Two insulated charged copper spheres, A and B, have their centres separated by a distance of 50 cm. What is the mutual force of electrostatic repulsion if the charge on each is $6.5 \times 10^{-7}\ C$

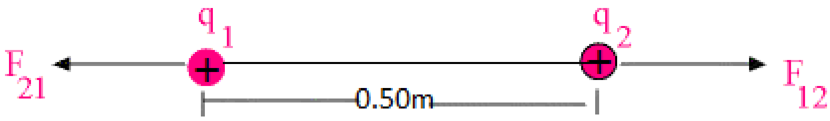
The radii of A and B are negligible compared to the distance of separation.

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

Solution:

a) Charge on sphere A, qA = Charge on sphere B, qB = 6.5×10^{-7} C

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



Force of repulsion between the two spheres,

$$F = \frac{1}{4\pi\epsilon_0} \times \frac{q_1 q_2}{r^2}$$

Where,

∈0 = Free space permittivity

$\frac{1}{4\pi\epsilon_0}$ = $F = 9 \times 10^9 \mathrm{Nm^2C^{-2}}$;

∴ $F = 9 \times 10^9 \mathrm{Nm^2C^{-2}} \times \frac{(6.5\times10^{-7}\mathrm{C})^2}{(0.5\mathrm{m})^2}$

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

Therefore, the force between the two spheres is

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

(b) After doubling the charge, charge on sphere A, qA = Charge on sphere B, qB = $1.3 \times 10^{-6}\ C$

The distance between the spheres is halved.

$Q_1 = 2\times q$
$Q_2 = 2\times q$
$R = 0.5 \times r$
∴

Force of repulsion between the two spheres,

Using Coulomb's law, we get,

$$F = \frac{1}{4\pi\epsilon_0} \times \frac{q_1 q_2}{r^2} \ldots(1)$$

where, $\frac{1}{4\pi\epsilon_0} = 10^9 Nm^2C^{-2}$

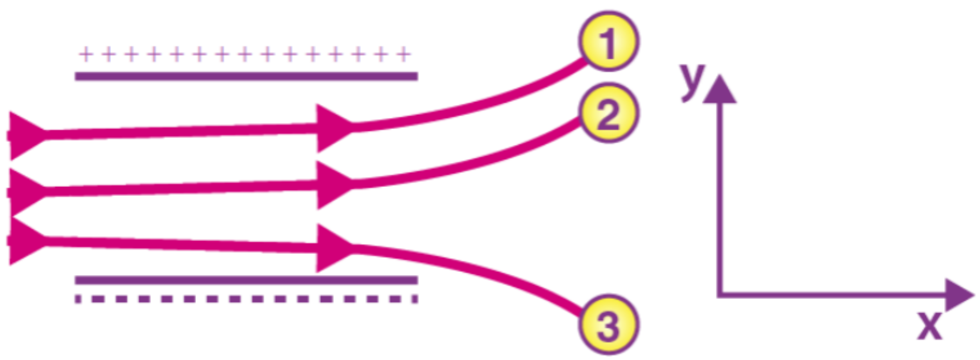
Where, ε_0 is the permittivity of the free space.

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

= 0.243 N

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

Question13. Figure 1.30 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?



Solution : 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.

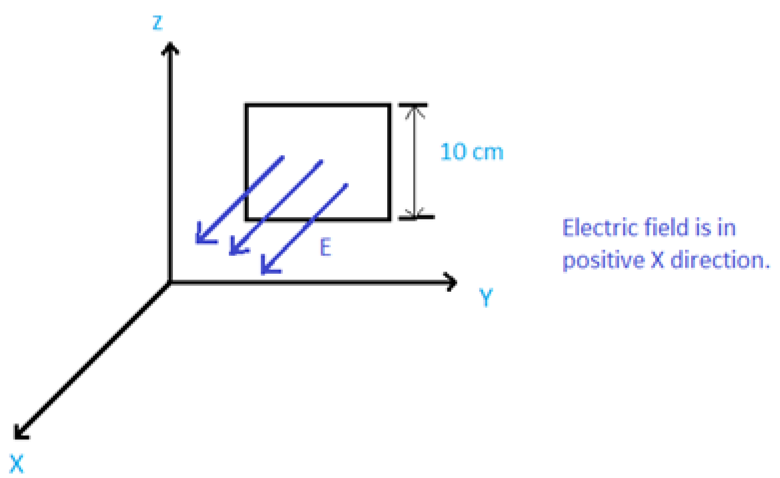
The charge to mass ratio (emf) is directly proportional to the displacement or amount of deflection for a given velocity. Since the deflection of particle 3 is the maximum, it has the highest charge to mass ratio.

Question14. Consider a uniform electric field E = 3 × 10^3îN/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?

Solution : Given:

Electric field E = 3× 10^3 N/C

Side of square, s = 10 cm



a) Flux of field through square whose plane is parallel to yz plane.

We understand that the normal to the plane is parallel to the direction of field.

So, θ = 0°

Ø = E . A

Ø = E × A× cos(θ) ...(1)

Where, E = Electric field

A = Area through which we have to calculate flux

θ = Angle between normal to surface and the Electric field

$A = s^2$

$A = .01\ m^2$

Plugging values, of E, A and θ in equation (1)

$\varnothing = 3\times 10^3\ NC^{-1}\times 0.01m^2\times \cos 0°$

$\varnothing = 30\ Nm^2C^{-1}$

b) If normal to its (square's) plane makes 60° with the X axis.

θ = 60°

$\varnothing = E \times A\times \cos(\theta)$

$\varnothing = 3\times 10^3\ NC^{-1}\times 0.01m^2 \times \cos 60°$

$\varnothing = 15\ Nm^2C^{-1}$

Question15. What is the net flux of the uniform electric field of Exercise 1.14 through a cube of side 20 cm oriented so that its faces are parallel to the coordinate planes?

Solution : 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 16)

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?

Solution : Given:

a) $\varnothing = 8.0\times 10^{3}\ Nm^{2}C^{-1}$

Let net charge inside the box = q

We know that,

Flux, $\varnothing = q/\varepsilon_0$ ..(1)

Where, q = net charged enclosed

ε_0 = permittivity of free space

$\varepsilon_0 = 8.85\times 10^{-12}\ N^{-1}m^{-2}C^{2}$

Plugging values of $\varnothing$ and ε_0 in equation (1) we get,

$q = \varnothing \times \varepsilon_0$

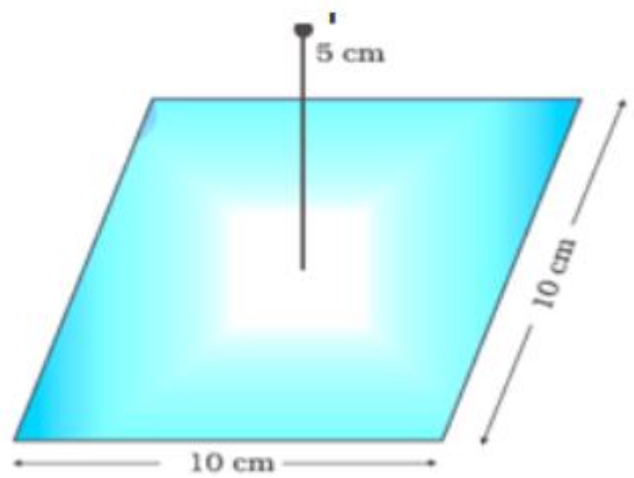
$\Rightarrow q = 8.0 \times 10^{3}\ Nm^{2}C^{-1}\times 8.85\times 10^{-12}N^{-1}C^{2}m^{-2}$

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

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

(b) No, we cannot conclude that the body doesn't have any charge. The flux is due to the Net charge of the body. There may still be equal amount of positive and negative charges. So, it is not necessary that if flux is zero then there will be no charges.

Question17. 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. 1.31. 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.)



Solution : Given:

q = + 10

s = 10 cm

Assume the charge to be enclosed by a cube, where the square is one of its sides.

Now, let us find the total flux through the imaginary cube.

We know that,

Flux, $\varnothing = q/\varepsilon$ ...(1)

Where, q = net charged enclosed

ε_0 = permittivity of free space

$\varepsilon_0 = 8.85 \times 10^{-12}\ N^{-1} m^{-2} C^2$

Now plugging the values of q and ε_0 in equation (2)

$\Rightarrow \varnothing = 11.28 \times 10^5\ Nm^{-2}C^{-1}$

We understand that flux through all the faces of cube will be equal;

Let flux through the square = $\varnothing_a$

Hence,

$\varnothing_a = \varnothing/6$

Explanation: The net flux will be distributed equally among all 6 faces of the cube. Hence, the square will have one sixth of the total flux.

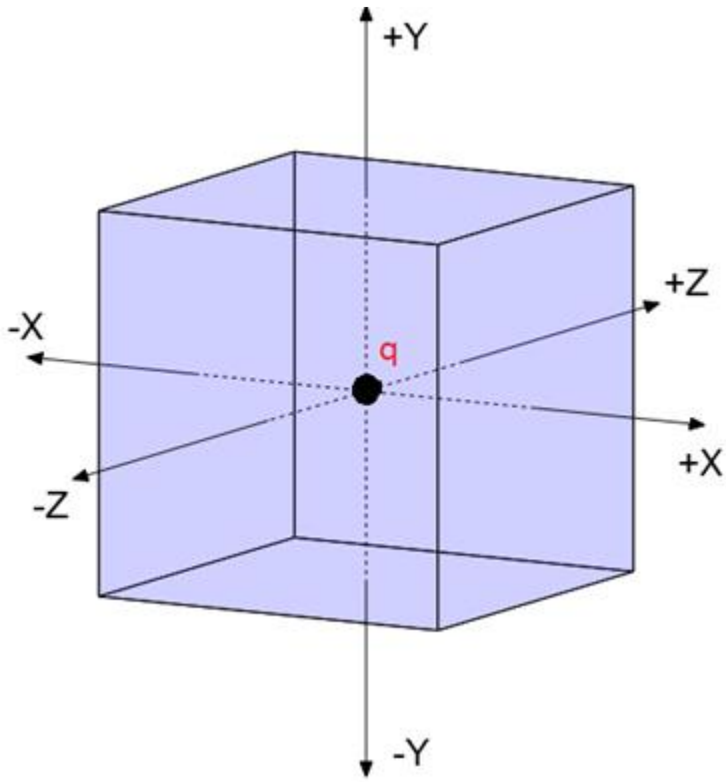
$\varnothing_a = 1.88\ Nm^{-2}C^{-1}$

Question18. 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?

Solution : Given:

Total charge inside the cube, q = 2.0 μC

Edge length of Cube, a = 9.0 cm



We know that,

Flux, $\varnothing = q/\varepsilon_0$

Where, q = net charged enclosed

ε_0 = permittivity of free space

$\varepsilon_0 = 8.85\times 10^{-12}\ N^{-1}\ m^{-2}C^2$

$$\varnothing = \frac{2\times10^{-6}\ C}{8.85\times10^{-12}N^{-1}C^2m^{-2}}$$

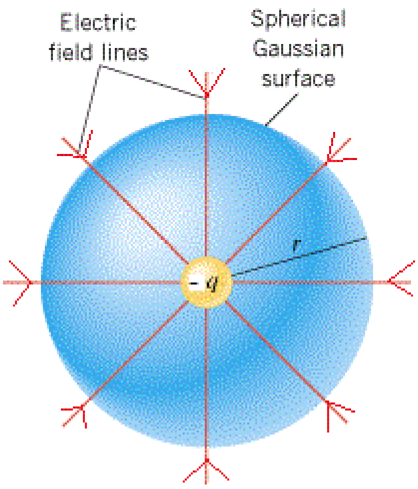
$$\Rightarrow \varnothing = 2.26 \times 10^5\ Nm^2C^{-1}$$

Question19. A point charge causes an electric flux of $-1.0 \times 10^3\ N\ m^2/C$ 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?

Solution : Given:

$Ø = -1.0 \times 10^3\ Nm^2C^{-1}$

r-$_1$ = 10.0 cm.



a) Flux if the radius of the Gaussian surface is doubled.

If the radius is doubled then the flux would remain same i.e. $-1.0 \times 10^3\ Nm^2C^{-1}$.

The geometry of the Gaussian surface doesn't affect the total flux through it. The net charge enclosed by Gaussian surface determines the net flux.

b) Let value of point charge enclosed by Gaussian surface = q

We know that,

Flux, $Ø = q/\varepsilon_0$ ...(1)

Where, q = net charged enclosed

ε_0 = permittivity of free space

$\varepsilon_0 = 8.85 \times 10^{-12}\ N^{-1}m^{-2}C^2$

Now plugging, the values Ø and ε_0 in equation (1).

$q = Ø \times \varepsilon_0$

$\Rightarrow q = -1.0 \times 10^3 Nm^2C^{-1} \times 8.85 \times 10^{-12} N^{-1}m^{-2}C^2$

⇒ $q = -8.85 \times 10^{-9}$ C

The charge enclosed by the surface is -8.85×10^{-9} C.

Question 20

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?

Solution : Given:

Radius of charged sphere, r = 10 cm

Electric field, 20 cm away from centre of sphere, $E = 1.5\times 10^{3} NC^{-1}$

We know that, electric field intensity at a point P, located at a distance R, due to net charge q is given by,

...(1)

Now plugging the values of q and R in equation (1)

$q = 4\times \pi\times \varepsilon_0\times R^2\times E$

⇒ $q = 4\times 3.14\times 8.85\times 10^{-12} N^{-1}m^{-2}C^{-2}\times (0.2m)^2 \times 1.5\times 10^{3}C$

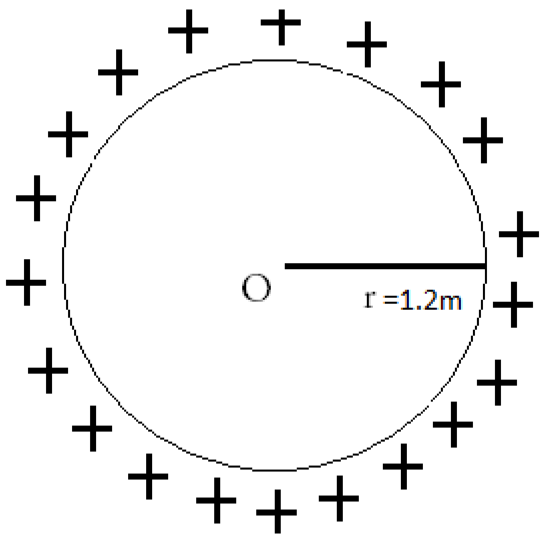
⇒ $q = 6.67\times 10^{-9}C$

The net charge on the sphere is $-6.67\times 10^{-9}C$. Since the electric field points radially inwards, we can infer that charges on sphere are negative.

Question21. A uniformly charged conducting sphere of 2.4 m diameter has a surface charge density of 80.0 μC/m2. (a) Find the charge on the sphere. (b) What is the total electric flux leaving the surface of the sphere?

Solution : Given: radius of sphere, $r = 1.2$ m

Surface charge density, $\sigma = 80.0\ \mu C/m^2$



a) Let charge on sphere = q

We understand that,

Total charge, Q = Surface charge density× surface area.

Surface area of sphere, $S = 4\pi r^2$

$S = 18.08\ m^2$

$Q = 80\times 10^{-6} Cm^{-2}\times 18.08 m^{-2}$

$\Rightarrow Q = 1.447 \times 10^{-3} C$

b) Let total electric flux leaving the surface of sphere =

We know that,

Flux, $\varnothing = q/\varepsilon_0$ ...(1)

Where, Q = net charged.

ε_0 = permittivity of free space

$\varepsilon_0 = 8.85\times 10^{-12}\ N^{-1} m^{-2} C^2$

By, plugging the values of q and ε_0 in equation (1), we get,(b)

$$\Rightarrow \varnothing = \frac{1.447\times10^{-3}C}{8.85\times10^{-12}N^{-1}C^2m^{-2}}$$

$$\Rightarrow \varnothing = 1.63\times 10^8\ Nm^2C^{-1}$$

The total flux through the sphere is $1.63\times 10^8\ Nm^2C^{-1}$.

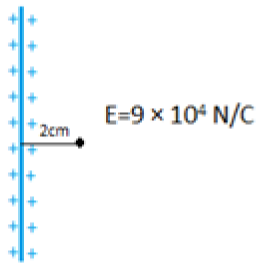
Question22 An infinite line charge produces a field of 9 × 10 ⁴ N/C at a distance of 2 cm. Calculate the linear charge density.

Solution : Given:

$E = 9\times 10^4\ NC^{-1}$

d = 2 cm

Let the linear charge density = λ Coulomb/metre



We know that, Electric field produced by a line charge with a linear charge density σ, at a distance d is given by,

$$E = \frac{\lambda}{2\pi\epsilon_0 d} \qquad ...(1)$$

Where, λ = linear charge density.

ε_0 = permittivity of free space

$\varepsilon_0 = 8.85\times 10^{-12}\ N^{-1}m^{-2}C^2$

d = distance

From equation (1) we have,

$\Rightarrow \lambda = E\times 2\times \pi\times \varepsilon_0\times d$

$\Rightarrow \lambda = 9\times 10^4\ NC^{-1}\times 2\times \pi\times 8.85\times 10^{-12}\ N^{-1}m^{-2}C^2\times 0.02m$

$\Rightarrow \lambda = 10\ \mu\ Cm^{-1}$

The linear charge density is $10\ \mu\ Cm^{-1}$.

Question23 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 magnitude $17.0 \times 10^{-22}\ C/m^2$

What is E:

(a) In the outer region of the first plate?

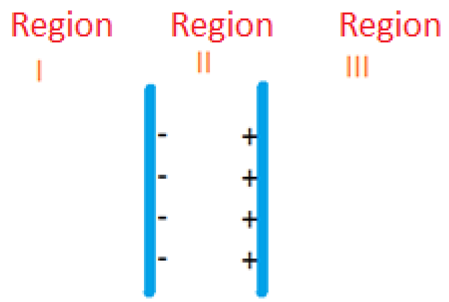
(b) In the outer region of the second plate and (c) between the plates?

Solution : Given:

Surface charge density on plate A, $\sigma_A = -17.0 \times 10^{-22}$ Cm^{-2}

Surface charge density on plate B, $\sigma_B = 17.0 \times 10^{-22}$ Cm^{-2}

The arrangement of plates are as shown:



Let electric field in region 1 = E_1

Region 2 = E_2

Region 3 = E_3

The electric field in region I and region III is zero because no charge is present in these regions.

$E_1 = 0$

$E_2 = 0$

We know that,

$E_3 = \sigma/\varepsilon_0$ ...(1)

Where, σ Surface charge density

ε_0 = permittivity of free space

$\varepsilon_0 = 8.85 \times 10^{-12}\ N^{-1} m^{-2} C^2$

Now, plugging the Values in equation (1).

$\Rightarrow E_3 = 1.92 \times 10^{-10}\ NC^{-1}$

The electric field in the region enclosed by the plates is found to be $1.92 \times 10^{-10}\ NC^{-1}$.

The electric field in region III is $1.92 \times 10^{-10}\ NC^{-1}$.