NCERT Solutions for Class 12 Physics Chapter 1 – Electric Charges And Fields

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?

Ans - Given the following information,

Repulsive force of magnitude, f $= 6\times 10^{-3} N$

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 two spheres, $r = 30cm = 0.3m$

Electrostatic force between two spheres is given by Coulomb's law as

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

Where, ε_0 is the permittivity of free space and,

$$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 Nm^2 C^{-2}$$

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

Hence electrostatic force will be $6 \times 10^{-3}\ N$ and since the charges are of the same nature, the force will be repulsive.

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?

Ans - (a) Electrostatic force on first sphere is given to be, $F = 0.2N$

Charge of the first sphere is, $q_1 = 0.4\mu C = 0.4 \times 10^{-6} C$

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

We have the electrostatic force given by Coulomb's law as,

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

$$\Rightarrow r = \sqrt{\frac{q_1 q_2}{4\pi\varepsilon_0 F}}$$

Substituting the given values in the above equation, we get

$$\Rightarrow r = \sqrt{\frac{0.4 \times 10^{-6} \times 8 \times 10^{-6} \times 9 \times 10^{9}}{0.2}}$$

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

$$\therefore r = 0.12m$$

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?

Ans - We are given the ratio, $\frac{ke^2}{Gm_e\, m_p}$

G is gravitational constant which has its unit N $m^2\, kg^{-2}$

m_e and m_p are masses of electron and proton

e is the electric charge in C

k is a constant given by $k = \frac{1}{4\pi\varepsilon_0}$

In the expression for k, ε_0 is the permittivity of free space which has its unit $N\,\mathrm{m}^2 C^{-2}$

Now, we could find the dimension of the given ratio by considering their units as follows:

$$\frac{ke^2}{G\,\mathrm{m}_e m_p} = \frac{\left[N\,\mathrm{m}^2 C^{-2}\right][C]^2}{[N\,\mathrm{m}^2 kg^{-2}][kg][kg]} = M^0L^0T^0$$

Clearly, it is understood that the given ratio is dimensionless.

Now, we know the values for the given physical quantities as,

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

$G = 6.67 \times 10^{-11} N\ m^2\ k\ g^{-2}$

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

$m_p = 1.66 \times 10^{-27} kg$

Substituting these values into the required ratio, we get,

$$\frac{ke^2}{Gm_e m_p} = \frac{9 \times 10^9 \times \left(1.6 \times 10^{-19}\right)^2}{6.67 \times 10^{-11} \times 9.1 \times 10^{-3} \times 1.67 \times 10^{-22}}$$

$$\Rightarrow \frac{ke^2}{Gm_e m_p} \approx 2.3 \times 10^{39}$$

Substituting these values into the required ratio, we get,

$$\frac{ke^2}{Gm_e m_p} = \frac{9 \times 10^9 \times \left(1.6 \times 10^{-19}\right)^2}{6.67 \times 10^{-11} \times 9.1 \times 10^{-3} \times 1.67 \times 10^{-22}}$$

$$\Rightarrow \frac{ke^2}{Gm_e m_p} \approx 2.3 \times 10^{39}$$

We could infer that the given ratio is the ratio of electrical force to the gravitational force between a proton and an electron when the distance between them is kept constant.

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?

Ans – (a) According to the supplied assertion, "Electric charge of a body is quantized," or charged particles are incapable of moving from a single body to a different one within a portion, merely the integral quantity (1,2,3,...,n) of electrons may be exchanged.
Since the electrical charge of a single electron is fundamentally charged in nature, the

energy on any substance is equal to the inherent multiple of the energy upon the electron itself. It can be represented by a mathematical equation known as, $q= \pm ne$.
Here, n is the total amount of electrons exchanged and e is the amount of charge present in a single electron, which can potentially be used to represent the energy of any substance.

(b) The overall amount of electrical charges is equal to the amount of electrical energy that is visibly present on a macroscopic or huge level. Accordingly, electrical charges are seen to be continuous hence quantification is negligible at the macroscopic level.

1.5

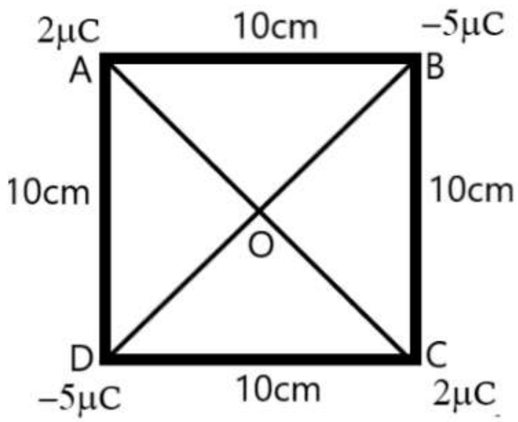
When a glass rod is rubbed with a silk cloth, charges appear on both. A similar phenomenon is observed with many other pairs of bodies. Explain how this observation is consistent with the law of conservation of charge.

Ans – When two separate objects are rubbed together, electrical charges of opposing type and similar magnitude are created on both surfaces. This occurs as a result of electrical charges being generated in tandem. We refer to this phenomenon as charging via friction. However, because opposing forces of identical size destroy one another, the system's net value stays unchanged. The rule of conservation of energy is therefore shown to be compatible with the fact that scratching a metal rod with a silky fabric produces opposing forces with identical intensity on each of these objects.

1.6

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

Ans: Consider a square of side length 10cm with four charges at its corners and let O be its centre.



From the figure we find the diagonals to be

$AC = BD = 10\sqrt{2}cm$

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

Now the repulsive force at O due to charge at A

$$F_{AO} = k\ \frac{q_A q_O}{O\ A^2} = k\ \frac{(+2\mu C\ )(1\mu C\ )}{\left(5\sqrt{2}\right)^2} \qquad \cdots\left(1\right)$$

And the repulsive force at O due to charge at D

$$F_{DO} = k\ \frac{q_D q_O}{O\ D^2} = k\ \frac{(+2\mu C\ )(1\mu C\ )}{\left(5\sqrt{2}\right)^2} \qquad \cdots\left(2\right)$$

And the attractive force at O due to charge at B,

$$F_{BO} = k\ \frac{q_B\ q_O}{O\ B^2} = k\ \frac{(-5\mu\ C\ )(1\mu\ C\ )}{\left(5\ \sqrt{2}\right)^2} \qquad \cdots\cdots\left(3\right)$$

And the attractive force at O due to charge at C,

$$F_{CO} = k\ \frac{q_C\ q_O}{O\ C^2} = k\ \frac{(-5\mu\ C\ )(1\mu\ C\ )}{\left(5\ \sqrt{2}\right)^2} \qquad \cdots\left(4\right)$$

We find that (1) and (2) are of same magnitude but they act in the opposite direction and hence they cancel out each other.

Similarly, (3) and (4) are of the same magnitude but in the opposite direction and hence they cancel out each other too.

Hence, the net force on charge at centre O is found to be zero.

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?

Ans – (a) When an electrical charge gets embedded in an electrically charged environment, it feels an ongoing pull, which results in a continuous curve referred to as an electrostatic field vector.
The amount of charge that travels across the sectional area of a wire of electricity carrying one ampere of electrical energy in one second is known as the unit charge. The field boundaries won't abruptly break since the electrical charge doesn't bounce from one place to another.

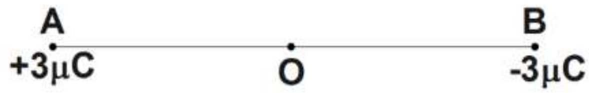
(b) When 2 field paths are observed to pass through across one another at a place, it could indicate that the intensity of the electric field possesses two distinct routes at that particular location, since two separate deviations (indicating the trajectory of electric field intensity around particular spot) may be formed at the area of junction. Meanwhile, 2 separate field lines would never intersect one another because this would not be feasible.

1.8

Two point charges $q_A = 3\mu C$ and $q_B = -3\mu C$ are located 20cm 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 $1.5 \times 10^{-9}C$ is placed at this point, what is the force experienced by the test charge?

Ans - (a) Let O be the midpoint of line AB.



We are given:

AB = 20m

$AO = OB \ = 10cm$

Take E to be the electric field at point O, then

Electric field at point O due to charge would be,

$$E_1 = \frac{3 \times 10^{-6}}{4\pi\varepsilon_0 (AO)^2} = \frac{3 \times 10^{-6}}{4\pi\varepsilon_0 \left(10 \times 10^{-2}\right)^2} NC^{-1} \text{ along OB}$$

The electric field at point O due to charge-would be

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

The net electric field

$$\Rightarrow E = E_1 + E_2$$

$$\Rightarrow E = 2 \times \frac{9 \times 10^9 \times 3 \times 10^{-6}}{\left(10 \times 10^{-2}\right)^2}$$

$$\Rightarrow E = 5.4 \times 10^6 \ N\ C^{-1}$$

(b) We have a test charge of magnitude 1.5×10^{-9} C placed at mid-point O and we found the electric field at this point to be $E = 5.4 \times 10^6$ NC^{-1}.

Force experienced by the test charge F will be,

F = qE

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

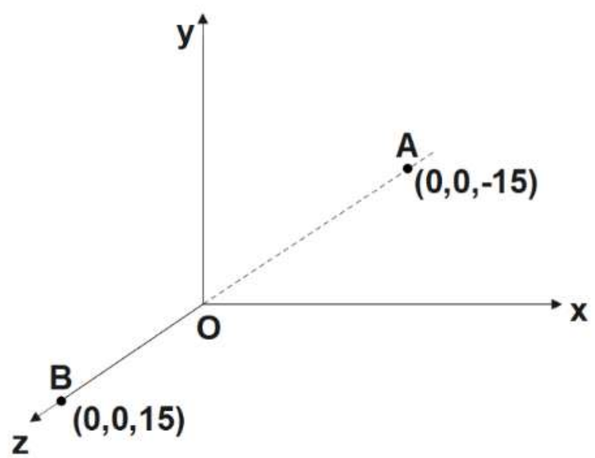
$\Rightarrow F = 8.1 \times 10^{-3}$ N

This force will be directed along OA since like charges repel and unlike charges attract.

1.9

A system has two charges $q_A = 2.5 \times 10^{-7}$ C and $q_B =$ -2.5×10^{-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?

Ans - System mentioned in the question can be represented as,



Charge at point A, $q_A = 2.5 \times 10^{-7}$ C

Charge at point B, $q_B = -2.5 \times 10^{-7}$ C

Then, net charge would be,

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

Distance between two charges at A and B would be,

$d = 15 + 15 = 30$ cm

$d = 0.3$ m

Electric dipole moment of system could be given by,

$P = q_A \times d = qB \times d$

$\Rightarrow P = 2.5 \times 10^{-7} \times 0.3$

$\therefore P = 7.5 \times 10^{-8}$ Cm along the +z axis.

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 NC^{-1}. Calculate the magnitude of the torque acting on the dipole.

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

Angle made by $\vec{p}$ with uniform electric field, $\theta = 30^o$

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

Torque acting on the dipole is given by

$\tau = pEsi\,n\ \theta$

Substituting the given values, we get,

$\Rightarrow \tau = 4 \times 10^{-9} \times 5 \times 10^4 \times sin30^\circ$

$\Rightarrow \tau = 20 \times 10^{-5} \times \frac{1}{2}$

$\therefore \tau = 10^{-4} Nm$

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?

Ans – (a) A specific amount of charged particles undergo conversion from genuine wool to polythene whenever the two different materials are massaged together. This causes polythene to transform into a negatively charged element when it gains electrons & woollen element to gain a positive charge when it loses them.

As we all know,

The electrical charge present across the polyethylene piece would be, q = -3×10^{-7} C

Meanwhile, the charge of an electron is represented as, e = -1.6×10^{-19} C Assuming n is the number of electron particles that are moved from wool to polythene, we may infer through the quantization characteristic that,

$q = ne$

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

$\Rightarrow n = 1.87 \times 10^{12}$

Consequently, the total amount of electrons being carried through wool to polythene might constitute 1.87×10^{12}.

(b) Yes. During the transfer of electrons from wool to polythene, mass is also exchanged along with charge. Let m be the mass transferred and m_e be mass of the electron,

$$m = m_e \times n$$

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

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

Hence, we determined that a negligible quantity of mass is transferred from wool to polythene.

1.12

(a) 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 6.5×10^{-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?

Ans - (a) Charges on spheres and are equal

$q_A = q_B = 6.5 \times 10^{-7} C$

Distance between the centres of the spheres is given as.

$r = 50cm = 0.5m$

It is known that the force of repulsion between the two spheres would be given by Coulomb's law as

$F = \frac{q_A q_B}{4\pi e_0 r^2}$

Where, ϵ_0 is the permittivity of the free space

Substituting known values into above expression, we get

$$F = \frac{9 \times 10^9 \times \left(6.5 \times 10^{-7}\right)^2}{(0.5)^2} = 1.52 \times 10^{-2} N$$

Thus, mutual force of electrostatic repulsion between the two spheres is found to be

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

(b) Given that the charges on both spheres are doubled and distance between centres of the spheres is halved. i.e.

$q'_A = q'_B = 2 \times 6.5 \times 10^{-7} = 13 \times 10^{-7} C$

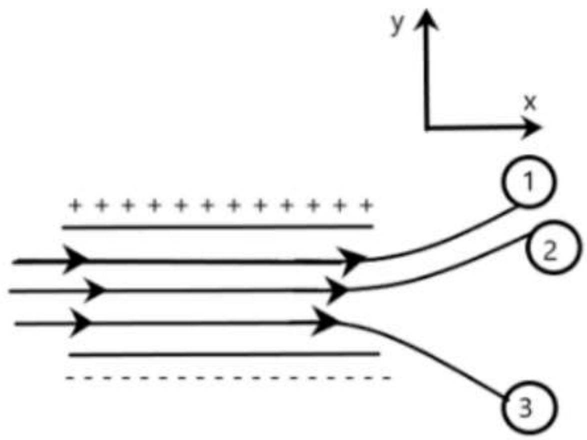
$r' = \frac{1}{2}(0.5) = 0.25m$

Substitute these values in Coulomb's law to get

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

$$\Rightarrow F = \frac{9 \times 10^9 \times \left(13 \times 10^{-7}\right)^2}{(0.25)^2}$$

Figure below shows tracks taken by three charged particles in a uniform electrostatic field. Give the signs of the three charges and also mention which particle has the highest charge to mass ratio?



Ans – We may infer from the established features of electrical charges that similar ones oppose one another and contrasting charges draw one another. Accordingly, components 1 and 2 could become negatively charged if they moved in the direction of the plate that was positively charged despite repelling back from the negatively charged surface, and component 3 would ultimately become positively charged if they moved in the opposite direction of the negatively charged surface and repelled aside over the positively charged surface.

As we are well aware of the fact that, for any specific velocity, the change in displacement or quantity of deflection has become directly proportional to the charge-to-mass proportion, or electromagnetic field (emf). Element 3 is likely to have the largest charge-to-mass proportion as its deviation is the greatest between the 3 existing components.

1.14

Consider a uniform electric field $E = 3 \times 10^3\ \hat{i}$ 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?

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

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

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

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

Since the plane of square is parallel to y-z plane, the normal to its plane would be directed in x direction. So, angle between normal to plane and the electric field would be, $\theta = 0°$

We know that the flux through a surface is given by the relation.

$\phi = |E||A|cos\theta$

Substituting the given values, we get,

$\Rightarrow \phi = 3 \times 10^3 \times 0.01 \times cos0°$

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

b) $\phi = |E|\,|A|cos\theta$

$\Rightarrow \phi = 3 \times 10^3 \times 0.01 \times cos60°$

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

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

1.15

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?

Ans – Each of the cube's edges has been demonstrated to be parallel with their respective coordinate axes. There are exactly as many field lines entering the cube as there are field lines exiting the cube. Consequently, there would be no net flow within the cube.

1.16

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 Nm^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?

Ans - (a) Net outward flux through surface of the box,

$$\phi = 8.0 \times 10^3 Nm^2/C$$

For a body containing of net charge, flux could be given by

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

Where, $\varepsilon_0 = 8.854 \times 10^{-12}$ $N^{-1}C^2m^{-2}$ Permittivity of free space

Therefore, the charge is given by

$$q = \phi\ \varepsilon_0$$

$$\Rightarrow q = 8.854 \times 10^{-12} \times 8.0 \times 10^3$$

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

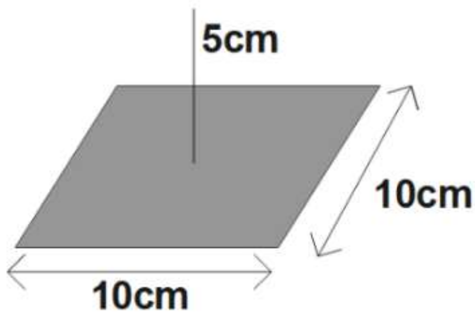
$$\Rightarrow q = 0.07C$$

(b) No. According to Gauss's law, it clearly states that the net flow leaving an object is determined by the amount of charge inside it. Therefore, it may be concluded that the amount of remaining charge within the material is zero when the net flow is considered to have the value zero.

Nevertheless, we are unable to infer that there were indeed no charges present within the enclosed space since the body's overall charge of zero just indicates that there are a comparable amount of both positive & negative charges available inside the element itself.

1.17

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



Ans - Consider the square as one face of a cube of edge length 10cm with a charge q at its centre, according to Gauss's theorem for a cube, total electric flux is through all its six faces.

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

The electric flux through one face of the cube could be now given by $\phi = \frac{\phi_{total}}{6}$

$$\phi = \frac{1}{6}\frac{q}{\varepsilon_0}$$

$\varepsilon_0 = 8.854 \times 10^{-12} N^{-1}C^2m^{-2}$ Permittivity of free space

The net charge enclosed would be, $q = 10\mu C = 10 \times 10^{-6} C$

Substituting the values given in the question, we get,

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

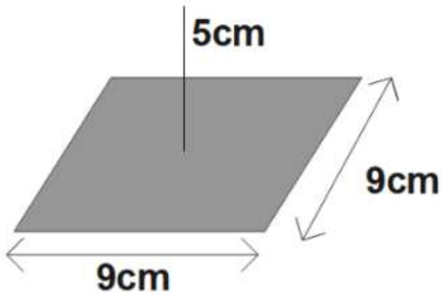
$$\therefore \phi = 1.88 \times 10^5 N\ m^2 C^{-1}$$

1.18

A point charge of 2.0μC is kept at the centre of a cubic Gaussian surface of edge length 9cm. What is the net electric flux through this surface?

Ans - Let us consider one of the faces of the cubical Gaussian surface considered (square).

Since a cube has six such square faces in total, we could say that the flux through one surface would be one-sixth the total flux through the gaussian surface considered.



Net flux through cubical Gaussian surface by Gauss's law is given by,

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

So, the electric flux through one face of the cube would be, $\phi = \frac{\phi_{total}}{6}$

$$\Rightarrow \phi = \frac{1}{6}\frac{q}{\varepsilon_0} \qquad \ldots\ldots(1)$$

$\varepsilon_0 = 8.854\times10^{-12} N^{-1} m^{-2}$

Charge enclosed, $q = 10\mu C = 10\times10^{-6} C$

Substituting the given values in (1) we get,

$$\phi = \frac{1}{6} \times \frac{10\times10^{-6}}{8.854\times10^{-12}}$$

$$\Rightarrow \phi = 1.88\times10^{5}\ Nm^2C^{-1}$$

1.19

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 centred 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?

Ans – (a) As we all know from the above statement:

The total amount of electrical flux because of the mentioned point charge would be,
$\phi = -1.0 \times 10^3\ Nm^2/C$

Meanwhile, the radius of the Gaussian element containing the point charge is considered to be,
r=10.0 cm

Due to Gauss's law, the amount of electrical flux that pierces an object is determined based on the total charge that the material encloses. Subsequently, this effect is not influenced depending on the size of the arbitrary area that is thought to encapsulate this electrical charge. Therefore, the amount of energy flowing through the Gaussian field stays identical if its outer diameter is increased by twofold. i.e., $-10^3\ Nm^2/C$.

(b) Electric flux is given by,

$$\varphi_{total} = \frac{q}{\varepsilon_0}$$

where $\varepsilon_0 = 8.854 \times 10^{-12}\ N^{-1}C^2m^{-2}$

$$\Rightarrow q = \varphi\varepsilon_0$$

$$\Rightarrow q = -1.0 \times 10^3 \times 8.854 \times 10^{-12} = -8.854 \times 10^{-9}\ C$$

$$\Rightarrow q = -8.854\ nC$$

1.20

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?

$$\textbf{Ans} - \quad E = \frac{q}{4\pi\varepsilon_0 d^2} \qquad \cdots\cdots\cdots \left(1\right)$$

Where,

Net charge, $q \quad = 1.5\times\ 10^3\, N/C$

Distance from the centre, $d = 20cm = 0.\mathbf{2}m$

$\varepsilon_0 = 8.854\times10^{-12}\ \mathrm{N^{-1}\ C^2\ m^{-2}}$

Permittivity of free space

$$\frac{1}{4\pi\varepsilon_0} = \quad 9\times10^9\, N\ m^{\ 2}\ C^{-2}$$

From (1), the unknown charge would be,

$$q \quad = E\ \left(4\pi\varepsilon_0\right)\ d^2$$

$\textit{substituting the given values, weget,}$

$$\Rightarrow q = \frac{1.5\times10^3\ \times(0.2)^2}{9\times10^9} = 6.67\times10^{-9}C$$

$$\Rightarrow q = 6.67\ \mathrm{n}C$$

1.21

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?

Ans - (a) Given, diameter of the sphere, d=2.4m.

Radius of the sphere, r=1.2m.

Surface charge density, $\sigma = 80.0\mu C/m^2 = 80\times10^{-6}C/m^2$

Total charge on the surface of the sphere,

Q = Charge density × Surface area

$$\Rightarrow Q = \sigma\times4\pi r^2 = 80\times10^{-6}\ \times4\times3.14\times(1.2)^2$$

$$\Rightarrow Q = 1.447\times10^{-3}C$$

$$\phi_{total} = \frac{Q}{\varepsilon_0} \quad \ldots\ldots \left(1\right)$$

Where, permittivity of free space,

$$\varepsilon_0 = 8.854 \times 10^{-12} N^{-1} C^2 m^{-2}$$

We found the charge on sphere to be, $Q = 1.447 \times 10^{-3} C$

Substituting these in (1), we get,

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

$$\Rightarrow \phi_{total} = 1.63 \times 10^{-8} NC^{-1} m^2$$

1.22

An infinite line charge produces a field of 9 × 10⁴ N/C at a distance of 2 cm. Calculate the linear charge density.

Ans - Electric field produced by the given infinite line charge at a distance d having linear charge density λ could be given by the relation,

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

$$\Rightarrow \lambda = 2\pi\varepsilon_0 E d \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

We are given:

$$d = 2cm = 0.02m$$

$$E = 9 \times 10^4 N/C$$

Permittivity of free space,

$$\varepsilon_0 = 8.854 \times 10^{-12} N^{-1} C^2 m^{-2}$$

Substituting these values in (1) we get,

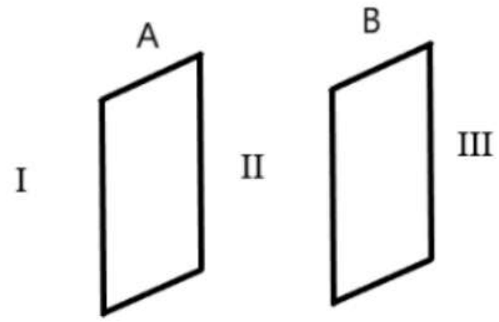
$$\Rightarrow \lambda = 2\pi\left(8.854 \times 10^{-12}\right)\left(9 \times 10^4\right)(0.02)$$

$$\Rightarrow \lambda = 10 \times 10^{-8} C/m$$

1.23

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?

Ans: Given nature of metal plates is represented in the figure below:



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

Given that,

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 with in the respective plates,

Electric field in the region is given by

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

Where,

Permittivity of free space $\varepsilon_0 = 8.854 \times 10^{-12} N^{-1} C^2 m^{-2}$

Clearly

$$E = \frac{17.0 \times 10^{-22}}{8.854 \times 10^{-1.2}}$$

$$\Rightarrow E = 1.92\ 10^{-10} \frac{N}{C}$$