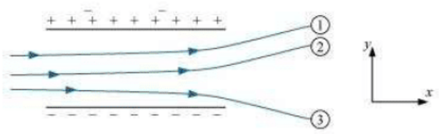


Answer:

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 **E** = 3 × 10^3 î 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:

(a) Electric field intensity, $\vec{E}$ = 3 × 10^3 î N/C

Magnitude of electric field intensity, $|\vec{E}|$ = 3 × 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,

$\Phi = |\vec{E}| A\cos\theta$

= 3 × 10^3 × 0.01 × cos0°

= 30 N m^2/C

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

Flux, $\Phi = |\vec{E}| A\cos\theta$

= 3 × 10^3 × 0.01 × cos60°

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

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:

(a) Net outward flux through the surface of the box, Φ = 8.0 × 10^3 N m^2/C

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

$$\phi = \frac{q}{\epsilon_0}$$

ϵ_0 = Permittivity of free space

= 8.854 × 10^{-12} $N^{-1}C^2 m^{-2}$

q = $\epsilon_0\Phi$

= 8.854 × 10^{-12} × 8.0 × 10^3

= 7.08 × 10^{-8}

= 0.07 μC

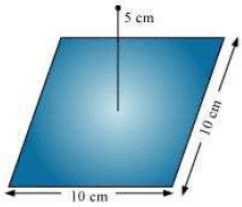
Therefore, the net charge inside the box is 0.07 μC.

(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:

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.

$$\phi_{\text{Total}} = \frac{q}{\epsilon_0}$$

Hence, electric flux through one face of the cube i.e., through the square, $\phi = \frac{\phi_{\text{Total}}}{6}$

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

Where,

ϵ_0 = Permittivity of free space

= 8.854 × 10^{-12} $N^{-1}C^2 m^{-2}$

q = 10 μC = 10 × 10^{-6} C

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

= 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:

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

$$\phi_{\text{Net}} = \frac{q}{\epsilon_0}$$

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

$$\therefore \phi_{\text{Net}} = \frac{2\times10^{-6}}{8.854\times10^{-12}}$$

= 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:

(a) Electric flux, Φ = −1.0 × 10^3 N m^2/C

Radius of the Gaussian surface,

r = 10.0 cm

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 m²/C.

(b) Electric flux is given by the relation,

$$\phi = \frac{q}{\epsilon_0}$$

Where,

q = Net charge enclosed by the spherical surface

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

$$\therefore q = \phi \epsilon_0$$

= −1.0 × 10^3 × 8.854 × 10^{-12}

= −8.854 × 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:

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

$$E = \frac{q}{4\pi \epsilon_0 d^2}$$

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, $\frac{1}{4\pi \epsilon_0}$ = 9 × 10^9 N m² C^{-2}

$$\square\, q = E(4\pi \epsilon_0)d^2$$

$$= \frac{1.5\times10^3\times(0.2)^2}{9\times10^9}$$

= 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/m². (a) Find the charge on the sphere. (b) What is the total electric flux leaving the surface of the sphere?

Answer:

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

Radius of the sphere, r = 1.2 m

Surface charge density, σ = 80.0 μC/m² = 80 × 10^{-6} C/m²

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,

$$\phi_{\text{TOtal}} = \frac{Q}{\epsilon_0}$$

Where,

$\square_0$ = Permittivity of free space

= 8.854 × 10^{-12} $N^{-1}C^2 m^{-2}$

Q = 1.447 × 10^{-3} C

$$\phi_{\text{Total}} = \frac{1.44\times10^{-3}}{8.854\times10^{-12}}$$

= 1.63 × 10^8 N C^{-1} m²

Therefore, the total electric flux leaving the surface of the sphere is 1.63 × 10^8 N C^{-1} m².

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:

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

$$E = \frac{\lambda}{2\pi \in_0 d}$$

$$\lambda = 2\pi \in_0 dE$$

Where,

d = 2 cm = 0.02 m

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

$\square_0$ = Permittivity of free space

$$\frac{1}{4\pi \in_0} = 9 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$$

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

= 10 μC/m

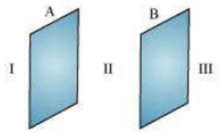
Therefore, the linear charge density is 10 μC/m.

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:

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,

$$E = \frac{\sigma}{\in_0}$$

Where,

$\square_0$ = Permittivity of free space = 8.854×10^{-12} N^{-1}C^2 m^{-2}

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

= 1.92×10^{-10} N/C

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

Question 1.25:

An oil drop of 12 excess electrons is held stationary under a constant electric field of 2.55×10^4 N C^{-1} in Millikan's oil drop experiment. The density of the oil is 1.26 g cm^{-3}. Estimate the radius of the drop. (g = 9.81 m s^{-2}; $e = 1.60 \times 10^{-19}$ C).

Answer:

Excess electrons on an oil drop, n = 12

Electric field intensity, $E = 2.55 \times 10^4$ N C^{-1}

Density of oil, ρ = 1.26 gm/cm^3 = 1.26×10^3 kg/m^3

Acceleration due to gravity, g = 9.81 m s^{-2}

Charge on an electron, $e = 1.6 \times 10^{-19}$ C

Radius of the oil drop = r

Force (F) due to electric field E is equal to the weight of the oil drop (W)

$F = W$

$Eq = mg$

$$Ene = \frac{4}{3}\pi r^3 \times \rho \times g$$

Where,

q = Net charge on the oil drop = ne

m = Mass of the oil drop

= Volume of the oil drop × Density of oil

$$= \frac{4}{3}\pi r^3 \times \rho$$

$$\therefore r = \sqrt[3]{\frac{3Ene}{4\pi\rho g}}$$

$$= \sqrt[3]{\frac{3\times 2.55\times 10^{4}\times 12\times 1.6\times 10^{-19}}{4\times 3.14\times 1.26\times 10^{3}\times 9.81}}$$

$$= \sqrt[3]{946.09\times 10^{-21}}$$

$$= 9.82\times 10^{-7}\ \text{m}$$

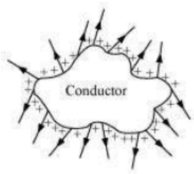
= 9.82×10^{-4} mm

Therefore, the radius of the oil drop is 9.82×10^{-4} mm.

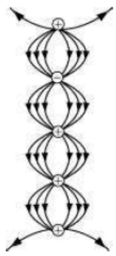
Question 1.26:

Which among the curves shown in Fig. 1.35 cannot possibly represent electrostatic field lines?

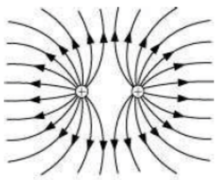
(a)



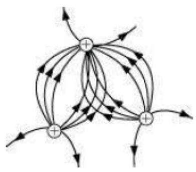
(b)



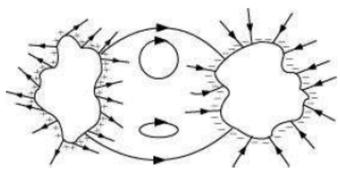
(c)



(d)



(e)



Answer:

(a) The field lines showed in (a) do not represent electrostatic field lines because field lines must be normal to the surface of the conductor.

(b) The field lines showed in (b) do not represent electrostatic field lines because the field lines cannot emerge from a negative charge and cannot terminate at a positive charge.

(c) The field lines showed in (c) represent electrostatic field lines. This is because the field lines emerge from the positive charges and repel each other.

(d) The field lines showed in (d) do not represent electrostatic field lines because the field lines should not intersect each other.

(e) The field lines showed in (e) do not represent electrostatic field lines because closed loops are not formed in the area between the field lines.

Question 1.27:

In a certain region of space, electric field is along the z-direction throughout. The magnitude of electric field is, however, not constant but increases uniformly along the positive *z*-direction, at the rate of 10^{5} NC^{-1} per metre. What are the force and torque experienced by a system having a total dipole moment equal to 10^{-7} Cm in the negative *z*-direction?

Answer:

*********** END **********