Chapter 10: Electrostatics

EXERCISES [PAGES 205 - 206]

Exercises | Q 1. (i) | Page 205

Choose the correct option.
A positively charged glass rod is brought close to a metallic rod isolated from ground. The charge on the side of the metallic rod away from the glass rod will be

1. **same as that on the glass rod and equal in quantity**
2. opposite to that on the glass of and equal in quantity
3. same as that on the glass rod but lesser in quantity
4. same as that on the glass rod but more in quantity

SOLUTION

Same as that on the glass rod and equal in quantity

Exercises | Q 1. (ii) | Page 205

Choose the correct option.
An electron is placed between two parallel plates connected to a battery. If the battery is switched on, the electron will

1. **be attracted to the +ve plate**
2. be attracted to the -ve plate
3. remain stationary
4. will move parallel to the plates

SOLUTION

An electron is placed between two parallel plates connected to a battery. If the battery is switched on, the electron will **be attracted to the + ve plate**

Exercises | Q 1. (iii) | Page 205

Choose the correct option.
A charge of + 7 μC is placed at the centre of two concentric spheres with radius 2.0 cm and 4.0 cm respectively. The ratio of the flux through them will be

1. 1:4
2. 1:2
3. **1:1**
4. 1:16

SOLUTION

1:1

Explanation:
The total flux is independent of shape and radius.

Exercises | Q 1. (iv) | Page 205

Choose the correct option.
Two charges of 1.0 C each are placed one meter apart in free space. The force between them will be

1. 1.0N
2. **9×10^9 N**
3. 9×10^{-9}N
4. 10N

SOLUTION

9×10^9 N

Explanation:

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2} = 9 \times 10^9 \times \frac{1 \times 1}{1} = 9 \times 10^9 \text{ N}$$

Exercises | Q 1. (v) | Page 205

Choose the correct option.
Two point charges of +5 μC are so placed that they experience a force of 8.0×10^{-3}N. They are then moved apart so that the force is now 2.0×10^{-3}N. The distance between them is now

1. 1/4 the previous distance
2. **double the previous distance**
3. four times the previous distance
4. half the previous distance

SOLUTION

double the previous distance

Explanation:

$$F_{coulomb} \alpha \frac{1}{r^2}$$

$$\frac{F_1}{F_2} = \frac{r_2^2}{r_1^2}$$

$$\therefore \frac{r_2^2}{r_1^2} = \frac{8 \times 10^{-3}}{2 \times 10^{-3}}$$

$$\therefore r_2^2 = 4 \times r_1^2$$

$$\therefore r_2 = 2r_1$$

Exercises | Q 1. (vi) | Page 205

Choose the correct option.

A metallic sphere A isolated from ground is charged to +50 µC. This sphere is brought in contact with other isolated metallics sphere B of half the radius of sphere A. The charge on the two-sphere will be now in the ratio

1. 1:2
2. 2:1
3. 4:1
4. **1:1**

SOLUTION

1:1

Explanation:

When two conductors, one charged and the other uncharged are brought in contact with each other, the charge (whether −ve or +ve) under its own repulsion will spread over both the conductors. Thus, the conductors will be charged uniformly with the same sign.

Exercises | Q 1. (vii) | Page 206

Choose the correct option.

Which of the following produces uniform electric field?

1. point charge
2. linear charge
3. **two parallel plates**
4. charge distributed an circular any

SOLUTION

Two parallel plates

Exercises | Q 1. (viii) | Page 206

Choose the correct option.

Two-point charges of A = +5.0 µC and B = -5.0 µC are separated by 5.0 cm. A point charge C = 1.0 µC is placed at 3.0 cm away from the centre on the perpendicular bisector of the line joining the two point charges. The charge at C will experience a force directed towards

1. point A
2. point B

3. **a direction parallel to line AB**
4. a direction along the perpendicular bisector

SOLUTION

A direction parallel to line AB

Explanation:

The situation resembles a point along the equatorial line of a dipole. Therefore, force-directed would be along a direction parallel to line AB.

Exercises | Q 2. (i) | Page 206

Answer the following question.

What is the magnitude of the charge on an electron?

SOLUTION

The magnitude of the charge on an electron is 1.6×10^{-19} C.

Exercises | Q 2. (ii) | Page 206

Answer the following question.

State the law of conservation of charge.

SOLUTION

In any given physical process, ″the charge may get transferred from one part of the system to another, but the total charge in the system remains constant"

OR

For an isolated system, total charge cannot be created nor destroyed.

Exercises | Q 2. (iii) | Page 206

Answer the following question.

Define a unit charge.

SOLUTION

Unit charge (one coulomb) is the amount of charge which, when placed at a distance of one meter from another charge of the same magnitude in a vacuum, experiences a force of 9.0×10^{9} N.

Exercises | Q 2. (iv) | Page 206

Answer the following question.

Two parallel plates have a potential difference of 10V between them. If the plates are 0.5 mm apart, what will be the strength of the electric charge.

SOLUTION

Given: V = 10 V, d = 0.5 mm = 0.5×10^{-3} m

To find: Strength of electric field (E)

Formula: $E = \frac{V}{d}$

Calculation: From the formula,

$$E = \frac{10}{0.5 \times 10^{-3}}$$

$= 20 \times 10^{3}$ V/m

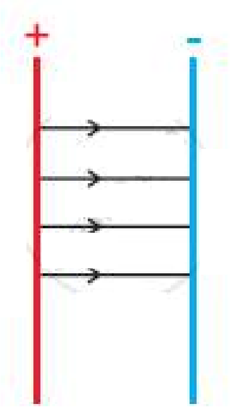
The strength of the electric field will be **20×10^{3} V/m**

Exercises | Q 2. (v) | Page 206

Answer the following question.
What is a uniform electric field?

SOLUTION

A uniform electric field is a field whose magnitude and direction are the same at all points.
For example, the field between two parallel plates is shown in the diagram.



Uniform electric field

Exercises | Q 2. (vi) | Page 206
Answer the following question.
If two lines of force intersect of one point. What does it mean?

SOLUTION

If two lines of force intersect of one point, it would mean that the electric field has two directions at a single point.

Exercises | Q 2. (vii) | Page 206

Answer the following question.

State the units of linear charge density.

SOLUTION

SI unit of λ is (C/m).

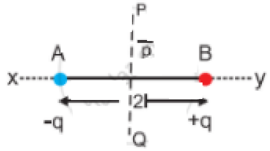
Exercises | Q 2. (viii) | Page 206

Answer the following question.

What is the unit of dipole moment?

SOLUTION

1. Strength of a dipole is measured in terms of a quantity called the dipole moment.



2. Let q be the magnitude of each charge and $2\vec{l}$ be the distance from the negative charge to the positive charge. Then, the product $q\left(2\vec{l}\right)$ is called the dipole moment $\vec{p}$.
3. Dipole moment is defined as $\vec{p} = q\left(2\vec{l}\right)$
4. A dipole moment is a vector whose magnitude is q (2l) and the direction is from the negative to the positive charge.
5. The unit of dipole moment is coulomb-meter (C m) or debye (D).

Exercises | Q 2. (ix) | Page 206

Answer the following question.

What is relative permittivity?

SOLUTION

1. Relative permittivity or dielectric constant is the ratio of the absolute permittivity of a medium to the permittivity of free space. It is denoted as K or ε_r.

   i.e., K or $\varepsilon_r = \frac{\varepsilon}{\varepsilon_0}$

2. It is the ratio of the force between two point charges placed a certain distance apart in free space or vacuum to the force between the same two-point charges when placed at the same distance in the given medium.

   i.e., K or $\varepsilon_r = \frac{F_{vacuum}}{F_{medium}}$

3. It is also called a specific inductive capacity or dielectric constant.

Exercises | Q 3. (i) | Page 206

Solve numerical example.

Two small spheres 18 cm apart have equal negative charges and repel each other with the force of 6×10^{-8} N. Find the total charge on both spheres.

SOLUTION

Given: $F = 6 \times 10^{-8}$ N, $r = 18$ cm $= 18 \times 10^{-2}$ m

To find: Total charge $(q_1 + q_2)$

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

Calculation: From the formula,

$F = \frac{1}{4\pi\varepsilon_0}\frac{q^2}{r^2}$ .....(Given: $q_1 = q_2 = q$)

$\therefore q^2 = \frac{4\pi\varepsilon_0}{1} \times Fr^2$

$$= \frac{6 \times 10^{-8} \times \left(18 \times 10^{-2}\right)^2}{9 \times 10^9} \text{.........} \left[\because \frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \text{SI units}\right]$$

$q^2 = 21.6 \times 10^{-20}$

Taking square roots from log table,

$\therefore q = -4.648 \times 10^{-10}$ C ...($\because$ the charges are negative)

Total charge = $q_1 + q_2 = 2q$

$= 2 \times (-4.648) \times 10^{-10}$

Exercises | Q 3. (ii) | Page 206

Solve numerical example.
A charge +q exerts a force of magnitude -0.2 N on another change -2q. If they are separated by 25.0 cm, determine the value of q.

SOLUTION

Given: $q_1 = +q$, $q_2 = -2q$, $F = -0.2$ N, $r = 25$ cm $= 25 \times 10^{-2}$ m

To find: Charge (q)

Formula: $F = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$

Calculation: From formula,

$$-0.2 = \frac{9 \times 10^9 \times q \times (-2q)}{\left(25 \times 10^{-2}\right)^2}$$

$$\therefore q^2 = \frac{0.2 \times \left(25 \times 10^{-2}\right)^2}{9 \times 10^9 \times 2}$$

$$= \frac{2 \times 10^{-1} \times 25 \times 25 \times 10^{-4}}{9 \times 10^9 \times 2}$$

$$= \frac{25 \times 25 \times 10^{-14}}{9}$$

$$\therefore q = \sqrt{\frac{25 \times 25 \times 10^{-14}}{9}}$$

$$= \frac{5 \times 5 \times 10^{-7}}{3}$$

$= 0.833 \times 10^{-6}$ C $= 0.833$ μC

The value of 'q' is **0.833 μC**

Exercises | Q 3. (iii) | Page 206

Solve numerical example.

Two charges 5μC and -4μC are kept 5.0 m apart at points A and B respectively. How much work will have to be done to move the charge at A through a distance of 5.0 m further away from point B along the line BA?

SOLUTION

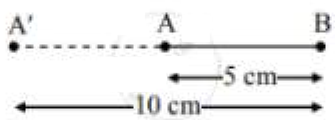
Given: $q_1 = 5$ μC $= 5 \times 10^{-6}$ C, $q_2 = 4$ μC $= -4 \times 10^{-6}$ C, $r_1 = 5$ m

To find: Work done (W)

Formula: i. $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$

ii. $V = \frac{W}{q}$

Calculation:



From formula (i), Potential at point A,

$$V_1 = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r_1}$$

$$= 9 \times 10^9 \times \frac{5 \times 10^{-6}}{5}$$

$$= 9 \times 10^3 \text{ V}$$

Potential at point A′,

$$V_2 = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1}{r_2}$$

$$= 9 \times 10^9 \times \frac{5 \times 10^{-6}}{10}$$

$$= 4.5 \times 10^3 \text{ V}$$

From formula (ii),

Work done to move to move charge at A to A′

$$\therefore V_1 - V_2 = \frac{W}{q_1}$$

$$\therefore W = [9 \times 10^3 - 4.5 \times 10^3] \times 5 \times 10^{-6}$$

$$= 1.8 \times 10^{-2} \text{ J}$$

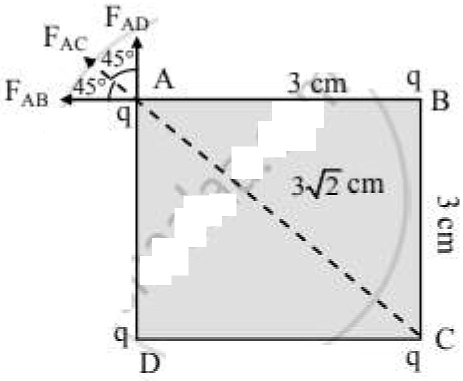
Work done to move the charge is $\mathbf{1.8 \times 10^{-2}}$ **J**

Exercises | Q 3. (iv) | Page 206

Solve numerical example.
Four charges of + 6×10^{-8} C each are placed at the corners of a square whose sides are 3 cm each. Calculate the resultant force on each charge and show in the direction and a diagram drawn to scale.

SOLUTION

Given: $q_A = q_B = q_C = q_D = 6 \times 10^{-8}$ C, a = 3 cm



Magnitude of force on A due to D is,

$F_{AD} = \frac{1}{4\pi\varepsilon_0}\frac{q^2}{r_{AD}^2}$

$= \frac{9 \times 10^9 \times (6 \times 10^{-8})^2}{(3 \times 10^{-2})^2}$

$= 3.6 \times 10^{-2}$ N

Similarly,

$F_{AB} = 3.6 \times 10^{-2}$ N

$F_{AC} = \frac{1}{4\pi\varepsilon_0}\frac{q^2}{r_{AC}^2}$

$= \frac{9 \times 10^9 \times (6 \times 10^{-8})^2}{\left(3\sqrt{2} \times 10^{-2}\right)^2}$

$= 1.8 \times 10^{-2}$ N

∴ Resultant force on 'A'

$= F_{AD} \cos 45 + F_{AB} \cos 45 + F_{AC}$

$$= \left(3.6 \times 10^{-2} \times \frac{1}{\sqrt{2}}\right) + \left(3.6 \times 10^{-2} \times \frac{1}{\sqrt{2}}\right) + 1.8 \times 10^{-2}$$

$= 6.89 \times 10^{-2}$ N directed along $\vec{F}_{AC}$

The resultant force on each charge will be **6.89×10^{-2} N**

Exercises | Q 3. (v) | Page 206

Solve numerical example.

The electric field in a region is given by $\vec{E}$ = 0.5K N/C. Calculate the electric flux Through a square of side 10.0 cm in the following cases

i. the square is along the XY plane

ii. The square is along XZ plane
iii. The normal to the square makes an angle of 45° with the Z axis.

SOLUTION

Given: $\vec{E}$ = 5K N/C, |E| = 5 N/C, l = 10 cm = 10×10^{-2} m = 10^{-1} m, A = l^2 = $10^{-2} m^2$

To find: Electric flux in three cases.
(Φ_1), (Φ_2), (Φ_3)

Formula: $\Phi = EA \cos\theta$

Calculation:

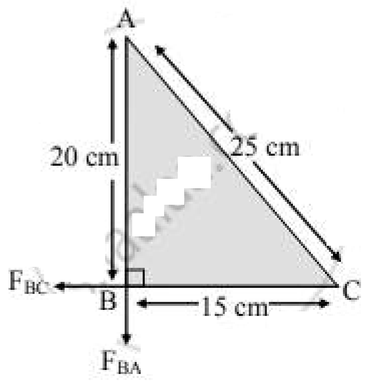
1. **Case I:** When square is along the XY plane,
   $\therefore \theta = 0$
   $\Phi_1 = 5 \times 10^{-2} \cos 0$
   $= 5 \times 10^{-2}$ V m
2. **Case II:** When square is along XZ plane,
   $\therefore \theta = 90°$
   $\Phi_2 = 5 \times 10^{-2} \cos 90° = 0$ V m
3. **Case III:** When normal to the square makes an angle of 45° with the Z axis.
   $\therefore \theta = 45°$
   $\therefore \Phi_3 = 5 \times 10^{-2} \cos 45°$
   $= 3.5 \times 10^{-2}$ V m

Electric flux in the above-mentioned cases are **5×10^{-2} V m**, **0 V m**, and **3.5×10^{-2} V m**.

Exercises | Q 3. (vi) | Page 206
Solve numerical example.
Three equal charges of 10×10^{-8} C respectively, each located at the corners of a right triangle whose sides are 15 cm, 20 cm, and 25cm respectively. Find the force exerted on the charge located at the 90° angle.

SOLUTION

Given: $q_A = q_B = q_C = 10 \times 10^{-8}$ C



Force on B due to A,

$$\vec{F}_{BA} = \frac{1}{4\pi\varepsilon_0}\frac{q_A q_B}{(r_{AB}^2)}$$

$$= 9 \times 10^9 \times \frac{(10 \times 10^{-8})^2}{(20 \times 10^{-2})^2}$$

$= 2.25 \times 10^{-3}$ N

Force on B due to C,

$$\vec{F}_{BC} = \frac{1}{4\pi\varepsilon_0}\frac{q_C q_B}{(r_{BC}^2)}$$

$$= 9 \times 10^9 \times \frac{(10 \times 10^{-8})^2}{(15 \times 10^{-2})^2}$$

$= 4 \times 10^{-3}$ N

∴ Resultant force on point B,

$$|F_B| = \sqrt{F_{BA}^2 + F_{BC}^2 + 2F_{BA}.F_{BC}\cos 90}$$

$$= \sqrt{(2.25 \times 10^{-3})^2 + (4 \times 10^{-3})^2}$$

$= 4.589 \times 10^{-3}$ N

Force exerted on charge at point B is **4.589×10^{-3} N**.

Exercises | Q 3. (vii) | Page 206

Solve numerical example.

A potential difference of 5000 volts is applied between two parallel plates 5cm apart a small oil drop having a charge of 9.6×10^{-19} C falls between the plates. Find

a. electric field intensity between the plates and
b. the force on the oil drop.

SOLUTION

Given: V = 5000 volt, d = 5 cm = 5×10^{-2} m, q = 9.6×10^{-9} C

To find: a. Electric field intensity (E)
b. Force (F)

Formulae: i. $E = \frac{V}{d}$

ii. $E = \frac{F}{q}$

Calculation: From formula (i),

$$E = \frac{5000}{5 \times 10^{-2}} = 10^5 \text{ N/C}$$

From formula (ii)

$F = E \times q$

$= 10^5 \times 9.6 \times 10^{-19}$

$= 9.6 \times 10^{-14}$ N

a. Electric field intensity between the plates is **10^5 N/C**

b. Force on the oil drop is **9.6×10^{-14} N**

Exercises | Q 3. (viii) | Page 206

Solve numerical example.

Calculate the electric field due to a charge of -8.0×10^{-8} C at a distance of 5.0 cm from it.

SOLUTION

Given: $q = -8.0\times10^{-8}$ C, r = 5 cm = 5×10^{-2} m

To find: Electric field (E)

Formula: $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$

Calculation: From formula,

$$E = 9 \times 10^9 \times \frac{(-8 \times 10^{-8})}{(5 \times 10^{-2})^2}$$

$= -2.88 \times 10^5$ N/C

Electric field due to a charge is **-2.88×10^5 N/C**.