

Chapter 01

ELECTRIC CHARGES AND FIELDS

SYNOPSIS:

Electric Charge:

a) Positive charge:

When a body loses electrons, it is said to acquire positive charge.

b) Negative charge:

When a body gains electrons, it is said to acquire negative charge.

c) Quantization of charge:

$$Q = \pm ne$$

e = charge of electron = 1.6×10^{-19} Coulombs.

n = Integer

$$1 \text{ coulomb} = \frac{1}{1.6 \times 10^{-19}} = 6.25 \times 10^{18} \text{ electrons.}$$

d) Linear charge density(λ):

It is the charge per unit length.

$$\lambda = \frac{\text{Charge}}{\text{Length}} \quad (\text{or}) \quad \lambda = \frac{q}{l}$$

S.I unit : Coulomb/m.

e) Surface charge density(σ):

It is the charge per unit surface Area.

$$\sigma = \frac{\text{Charge}}{\text{Area}} \quad (\text{or}) \quad \sigma = \frac{q}{A}$$

S.I unit : Coulomb/m².

f) Volume charge density(ρ):

It is the charge per unit volume.

$$\rho = \frac{\text{Charge}}{\text{Volume}} \quad (\text{or}) \quad \rho = \frac{q}{V}$$

S.I unit : Coulomb / m³.

Coulom's Inverse square Law:

The force of attraction (or) repulsion between two stationary point charges Q_1 and Q_2 which are seperated by a distance 'd' in air (or) Vaccum is given by

$$F_{\text{air}} = \frac{1}{4\pi\epsilon_0} \frac{Q_1 Q_2}{r^2}$$

Where $\frac{1}{4\pi\epsilon_0} = 9 \times 10^9$

Sl. Unit: $Nm^2 C^{-2}$.

ϵ_0 = Permittivity of free space (or) air

$$\epsilon_0 = 8.85 \times 10^{-12} C^2 / N - m^2$$

$$F_{\text{Medium}} = \frac{1}{4\pi\epsilon} \frac{Q_1 Q_2}{r^2} \quad (\text{or}) \quad F_{\text{Medium}} = \frac{1}{4\pi\epsilon_0 K} \frac{Q_1 Q_2}{r^2}$$

Where 'K' is dielectric constant.

Dielectric constant(K):

$$K = \epsilon_r = \frac{\epsilon}{\epsilon_0} \quad \text{and} \quad K = \frac{F_{\text{air}}}{F_{\text{Medium}}}$$

Where,

ϵ_r = Relative permittivity

ϵ = Permittivity of Medium

ϵ_0 = Permittivity of free space (or) air.

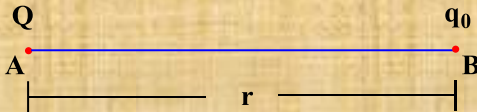
Electric field(E):

Electric field Intensity at any point in an electric field is defined as the force experienced by a unit positive charge placed at that point.

$$\vec{E} = \frac{\vec{F}}{q_0} \quad (\text{or}) \quad \vec{F} = \vec{E}q_0$$

S.I unit : N/C (or) volt / meter.

a) Electric field intensity due to an Isolated point Charge:



$$E_{\text{air}} = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2} \quad \text{and} \quad E_{\text{Medium}} = \frac{1}{4\pi\epsilon} \frac{Q}{r^2} \quad \text{and}$$

$$E_{\text{Medium}} = \frac{E_{\text{air}}}{K}$$

b) Motion of a charged particle in uniform Electric field:

- i. A charged body of mass 'm' and charge 'q' is initially at rest in a uniform electric field 'E'.

Force action on it $F = Eq$

- ii. The body travels in straight line path with uniform acceleration

$$a = \frac{F}{m} = \frac{Eq}{m}, \quad u = 0$$

iii. Its final velocity, $v = u + at = \left(\frac{Eq}{m}\right)t$

iv. Displacement, $S = ut + \frac{1}{2}at^2 = \frac{1}{2}\left(\frac{Eq}{m}\right)t^2$

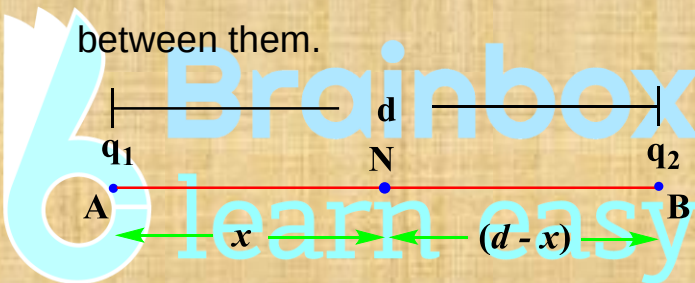
v. Momentum, $P = mv = (Eq)t$

vi. Kinetic Energy, $K.E = \frac{1}{2}mv^2 = \frac{1}{2}\left(\frac{E^2q^2}{m}\right)t^2$

Null point (or) Neutral point:

The point where the resultant electric field intensity becomes zero is called a null point.

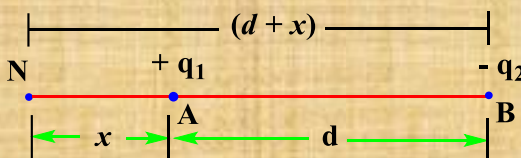
- a) If two like charges q_1 and q_2 are separated by a distance 'd', the null point 'N' will be formed in between them.



$$x = \frac{d}{\sqrt{\frac{q_2}{q_1}} + 1}$$

'x' is from ' q_1 '.

- b) If two unlike charges q_1 and q_2 ($q_1 < q_2$), the null point will be formed outside the system of charges then,



$$x = \frac{d}{\sqrt{\frac{q_2}{q_1}} - 1}$$

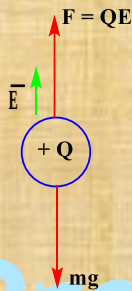
Equilibrium of charge in Electric field:

- i. Freely floating charge in air:

In equilibrium,

$$QE = mg$$

$$E = \frac{mg}{Q}$$



- ii. Suspension of charge from string:

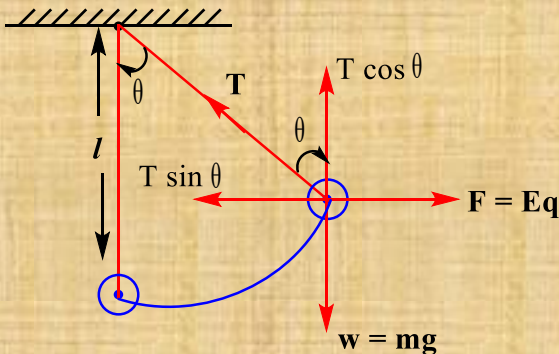
$$T \cos \theta = mg$$

$$T \sin \theta = Eq$$

$$\tan \theta = \frac{Eq}{mg}$$

and

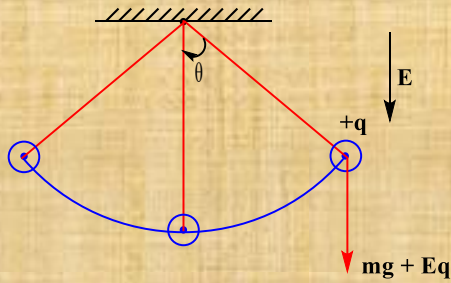
$$T = \sqrt{(Eq)^2 + (mg)^2}$$



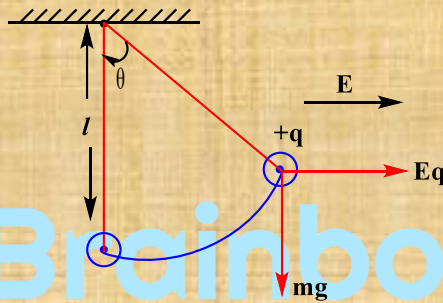
Time period of oscillation of a charged Body:

- i) If electric field is applied in down ward direction.

$$T = 2\pi \sqrt{\frac{l}{\left[g + \left(\frac{Eq}{m} \right) \right]}}$$



ii) If the electric field is applied horizontally then



$$T = 2\pi \sqrt{\frac{l}{\sqrt{g^2 + a^2}}}$$

Where, $a = \frac{Eq}{m}$