CHAPTER - 1 ELECTRIC CHARGES AND FIELDS

Electric Charges & Fields

Electric charges

- Two kinds of charges + ve and – ve
- S.I unit is coulomb (C)
  1 C = charge flowing through a wire in 1 sec if current in it is 1A
  $1e = 1.602 \times 10^{-19}C$

Quantization of charge

All charges must be integral multiple of e. i.e.
$Q = ne$
where n = integers

Conservation of charge

It is not possible to create or destroy net charge of an isolated system.

Coulomb's Law

In 1985, Charles Augustin de Coulomb gave Coulomb's law

- Force between two charged particles

$$\vec{F} = \frac{k q_1 q_2 \vec{r}}{r^3} = \frac{k q_1 q_2 \hat{r}}{r^2}$$, force is attractive when q_1 and q_2 are of opposite sign, otherwise repulsive

$$|\vec{F}| = \frac{k q_1 q_2}{r^2}$$

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

- Force between multiple charges

$$\vec{F}_1 = \vec{F}_{12} + \vec{F}_{13} + \vec{F}_{14} + \vec{F}_{15} + \ldots\ldots = \frac{q_1}{4\pi\varepsilon_0} \sum_{i=2}^{n} \frac{q_i}{r_{1i}^2} \hat{r}_{1i}$$

where $\hat{r}_{1i}$ is the unit vector along charge particle under consideration
$\hat{r}_{1i}$ = distance between I and i^{th} particle

"The electric force with which two charges attract or repel one another are not affected by the presence of other charges". It is known as Superposition Principle.

Electric flux

$\Delta\phi = \vec{E}\Delta\vec{S}$, $\Delta\vec{S}$ = area vector
$\vec{E}$ = electric field
$\phi = \int \vec{E}.\vec{ds}$

Gauss's Theorem

$\oint \vec{E}.\vec{ds} = q_{in}/\varepsilon_0 = \phi$

where, q_{in} = net charge enclosed
ϕ = flux through a closed surface

Application of Gauss's Law

- Field due to linear charge distribution
  $E = \lambda/2\pi\varepsilon_0 r$,
  λ = linear charge density
- Field due to a plane sheet of charge
  $E = \sigma/2\varepsilon_0$,
  σ = charge per unit area
- Field due to a charged conducting plate
  $E = \sigma/\varepsilon_0$,
  σ = charge per unit area
- Field inside a conductor = 0
- Electric field due to a thin spherical shell at a point
  Outside the shell, $E = Q/4\pi\varepsilon_0 r^2$
  Inside the shell, $E = 0$
  On the surface $E = Q/4\pi\varepsilon_0 R^2$

Electric field due to uniformly charged sphere at an

- Outside point
  $E = Q/4\pi\varepsilon_0 r^2$
- Internal point
  $E = Q/4\pi\varepsilon_0 R^3$
- On the surface
  $E = Q/4\pi\varepsilon_0 R^2$

Electric Field

Electric field due to point charge

$$\vec{E} = \frac{\vec{F}}{q} = k\frac{Q}{r^2} \text{ (N/C)}$$

$\because$ unit = N/C

- Due to discrete distribution of charges
  $$\vec{E} = \sum_{i}^{n} \vec{E_i}$$
- Due to continuous distribution of charges
  $$\vec{E} = k\int \frac{dQ}{r^2}\hat{r}$$
  $$|\vec{E}| = k\int \frac{dQ}{r^2}$$

Electric field lines

- Always normal to conducting surface
- Lines originating from +ve charge
- Terminating at –ve charge
- Never intersect each other
- Never form closed loop
- Are imaginary lines.

Electric Dipole moment, $\vec{p} = q\vec{d}$

Electric field due to dipole at axial position

$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\left(\frac{2p}{r^3}\right)\hat{r}$$

Electric field due to dipole at equatorial position

$$|E| = \frac{1}{4\pi\varepsilon_0}\left(\frac{p}{r^3}\right)$$

Torque on an electric dipole placed in an electric field $(\vec{E})$

$$\vec{\tau} = \vec{p} \times \vec{E} = p E \sin\theta$$