ELECTRIC CHARGES AND FIELDS

Basic Properties of Charges

Quantization of charge : Total charge on a body is always an integral multiple of a basic unit of charge denoted by e and is given by $q = ne$.

Conservation of charge : Total charge of an isolated system remains unchanged with time.

Additivity of charge : Total charge of a system is the algebraic sum (*i.e.* sum taking into account with proper signs) of all individual charges in the system.

Coulomb's Law

$\vec{F}_{21} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^3}\vec{r}_{12}$ for like charges

$\vec{F}_{21} = \frac{q_1 q_2}{4\pi\varepsilon_0 r^3}\vec{r}_{21}$ for unlike charges

using Superposition principle

- The vector sum of forces would give us the total force.
- Force between two charges is unaffected by the presence of the other charges.

Electric Field

Electric Field : Electric field intensity at a point distant r from a point charge q in air is $\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$.

Basic characteristics

- Field lines start from positive charges and end at negative charges.
- Electrostatic field lines do not form any closed loops.
- Two field lines can never cross each other.

Electric Dipole

Electric Dipole : Every dipole is associated with a dipole moment $\vec{p}$ whose magnitude is equal to the product of the magnitude of either charge (q) and the distance $2a$ between the charges, *i.e.*, $\vec{p} = q \times (2\vec{a})$.

Dipole in an external field experiences

Torque

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

Electric field due to dipole

On Equatorial line (Broad on position)

$E = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^3}$

On Axial line (End on position)

$E = \frac{2p}{4\pi\varepsilon_0 r^3}$

Electric Flux

Electric Flux : Electric flux over an area in an electric field represents the total number of electric field lines crossing this area.

Gauss's Theorem : Total normal electric flux over a closed surface S in vacuum is $1/\varepsilon_0$ times the charge (Q) contained inside the surface. $\phi_E = \oint_S \vec{E}.d\vec{S} = \frac{Q}{\varepsilon_0}$.

Applications

volume charge density, $\rho = \frac{q}{V}$

Electric field due to **a uniformly charged thin spherical shell**

At a point outside the shell *i.e.*, $r > R$, $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2} = \frac{\rho R^3}{3\varepsilon_0 r^2}$

On the surface $r = R$, $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{R^2}$

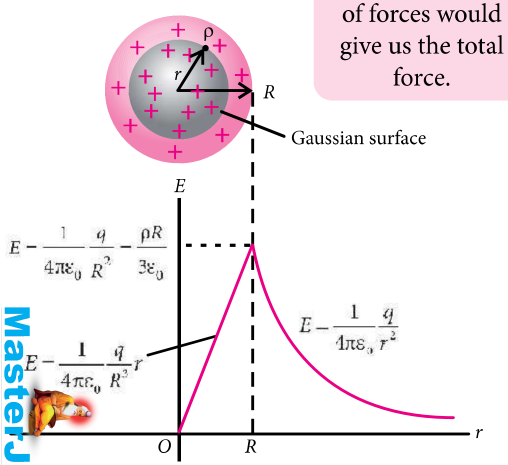
Inside the shell *i.e.*, $r < R$, $E = 0$

surface charge density, $\sigma = \frac{q}{A}$

Electric field due to **a uniformly charged infinite thin plane sheet,** $E = \frac{\sigma}{2\varepsilon_0}$.

linear charge density, $\lambda = \frac{q}{l}$

Electric field due to **an infinitely long thin uniformly charged straight wire,** $E = \frac{\lambda}{2\pi\varepsilon_0 r}$.



For uniformly charged solid sphere