ELECTRIC CHARGES AND FIELDS

ELECTRIC CHARGES

- Charge is an intrinsic property of matter by virtue of which it experience Electric & Magnetic Effect.
- Two kinds of charges +ve and -ve
- S.I. Unit Coulomb (C)

Conservation of Charges

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

Quantization of Charges

All charges must be integral multiple of e.

i.e $Q = \pm ne$ ($e = 1.6 \times 10^{-19}$C)

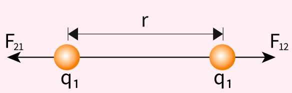
Where — n = integer

COULOMB'S LAW

- **Force between two charged particles**

$$\vec{F} = \frac{Kq_1q_2\vec{r}}{r^3} = \frac{Kq_1q_2\hat{r}}{r^2}$$

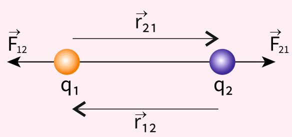
$$K = \frac{1}{4\pi\varepsilon_0} = 9\times10^9 Nm^2c^{-2}$$



ε_o = Permitivity of Free Space = $8.854 \times 10^{-12}\ C^2 / Nm^2$

- **Forces In Vector Form**

$$\vec{F}_{12} = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{|r_1 - r_2|^3}(\vec{r}_1 - \vec{r}_2)$$



- **Forces between Multiple Charges**

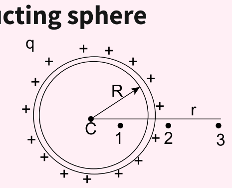
$$F_{Net} = \frac{\vec{q}_0}{4\pi\varepsilon_0}\sum_{i=1}^{n}\frac{q_i}{r_{oi}^2}\hat{r}_{oi}$$

- **Electric field due to charged spherical shell or conducting sphere**

$E = 0$ when $(r < R)$

$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$ when $(r > R)$

$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R^2}$ when $(r = R)$



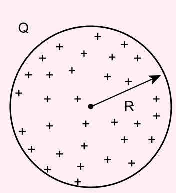
Charged Conducting shell

- **Electric field due to a solid non-conducting sphere - (f = Volume charge density) shell or conducting sphere.**

$E = \frac{1}{\mu\pi\varepsilon_0}\frac{qr}{R^3}$ $(r < R)$

$E = \frac{1}{\mu\pi\varepsilon_0} = \frac{Q}{r^2}$ $(r > R)$

$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R^2}$ when $(r = R)$



Charged Non-Conducting Shell

ELECTRIC FIELD

- **Electric field intensity (E)** $\Rightarrow \vec{E} = \lim_{q_0 \to 0}\frac{\vec{F}}{q_0}$

In vector Form - $\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}\hat{r}$

S.I Unit – $\frac{N}{C} = \frac{V}{m}$

- **Electric Field Intensity due to point charge Q**

$$(E) = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$$

- **Net Electric Field with respect to origin**

$$E_{Net} = \frac{1}{4\pi\varepsilon_0}\sum_{i=1}^{n}\frac{q_i}{r_{oi}^2}\hat{r}_{oi}$$

- **Electric field due to finite length line charge at distance r from conductor**

$$E_{\parallel} = \frac{\lambda}{4\pi\varepsilon_0 r}[\cos 0 - \cos\frac{\pi}{2}] \qquad E_{\perp} = \frac{\lambda}{4\pi\varepsilon_0 r}[\sin\phi_2 + \sin\phi_1]$$

(Here, λ is linear charge density)

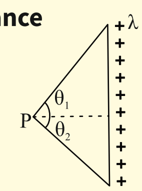
Case(I): E.F due to Infinite line charge

$$\phi_1 = \phi_2 = \frac{\pi}{2} \rightarrow F_1 = \frac{\lambda}{2\pi\varepsilon_0 r}\ : E_{\parallel} = 0$$

Case(II): E.F due to semi-Infinite line charge

$$\phi_1 = \frac{\pi}{2}, \phi_2 = 0 \rightarrow E_{\parallel} = F_{\perp} = \frac{\lambda}{4\pi\varepsilon_0 r}$$

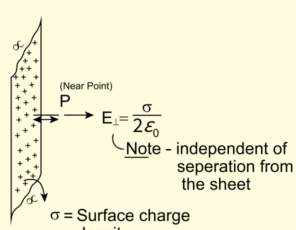
- **Electric field due to finite line charge at perpendicular distance**



$$E = \frac{1}{4\pi\varepsilon_0}\frac{\lambda}{r}(\sin\theta_1 + \sin\theta_2)$$

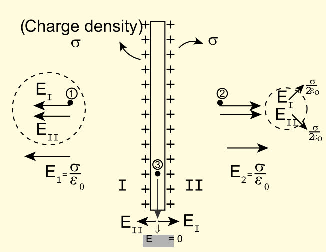
- **Electric field due to a plane Infinite sheet**

(i) Non-Conducting sheet



$$E_{\perp} = \frac{\sigma}{2\varepsilon_0}$$

(ii) Charged conducting plate

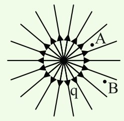


$$E_{\perp} = \frac{\sigma}{\varepsilon_0}$$

Electric Field Lines

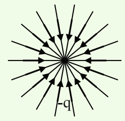
Representation of Electric Lines of Forces Due to Various Configurations

(a) Isolated Positive Charge

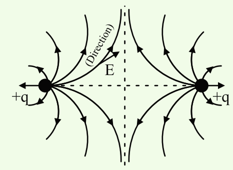


$|E_A| > |E_B|$ as density of field lines at A is greater than at B

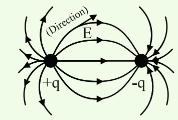
(a) Isolated Negative Charge



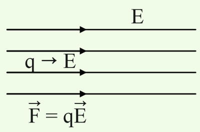
(c) Two Positive Charges



(d) Opposite Charges

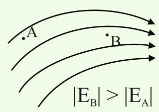


(e) Uniform Electric Field

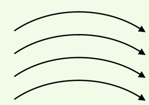


Field lines are parallel, straight and equispaced

(f) Non-Uniform Electric Field



(e) Non-Uniform Field due to direction

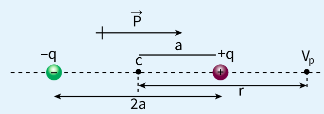


(e) Non-Uniform Field due to change in magnitude

✦ Electric field due to Electric Dipole

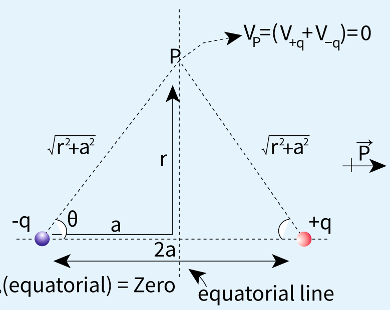
(i) Electric Field (E.F.) on the axis of dipole at a distance r from center of dipole:

$$E = \frac{-kq}{(r-a)^2} + \frac{kq}{(r+a)^2} = \frac{k2qa}{(r^2-a^2)^2}$$



(ii) Electric field at a distance r from centre of dipole on its Equatorial line:

$$E_{net} = \frac{-k\vec{P}}{(r^2+a^2)^{\frac{3}{2}}}$$



✦ Electrical potential due to Electric Dipole:

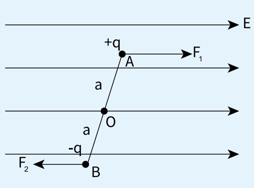
(ii) *Axial* $\rightarrow V_p = \frac{KP}{(r^2-a^2)}$

(iii) Equatorial $\rightarrow V_p = 0$

✦ Force and Torque on dipole in uniform external (E.F.)

Force $\rightarrow \vec{F}_{net} = qE - qE = 0$

Torque $\rightarrow \vec{\tau} = pESin\,\theta = \vec{p} \times \vec{E}$



ELECTRIC FLUX

Total number of electric field lines passing normally through an area.

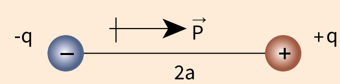
$$\phi = \oint \vec{E}.\vec{ds}$$

Electric Flux (ϕ) = $|E||ds|\cos\theta$

ELECTRIC DIPOLE

A pair of Equal and opposite point charges repeated by fix distance.

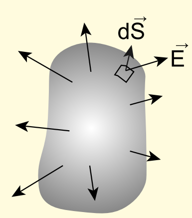
Electric Dipole Moment, $\vec{p} = q(2a)\,cm$



GAUSS LAW

It states, total flux of an E.F. through a closed surface is equal to $\frac{1}{\varepsilon_0}$ times of total charge enclosed by the surface.

Total Flux through surface



$$(\phi) = \frac{q_{enclosed}}{\varepsilon_0}$$

$$\oint \vec{E} \cdot d\vec{s} = \frac{q}{\varepsilon_0}$$