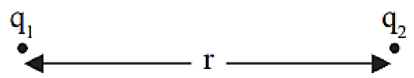
2024 – 25

## ELECTRIC CHARGES AND FELDS

### Coulomb' Law

Force between two charges $\vec{F} = \frac{1}{4\pi \in_0 \in_0} \frac{q_1 q_2}{r^2} \hat{r}, \in_r$ =dielectric constant




### Principle of superposition

Force on a point charge due to many charges if given by

$\vec{F} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + ..........$

**Notes**: The force due t one charge is not affected by the presence of other charges.

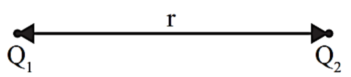
### Electric field of Electric Field Intensity (Vector Quantity)

$\vec{F} = \frac{\vec{F}}{q}$, Units is N/C or V/m

### Electric point for two charges

$$\vec{F} = \lim_{q_0 \to 0} \frac{\vec{F}}{q} = \frac{1}{4\pi \in_0 r^2} \frac{Q}{r^2} \hat{r}$$

### Null point for two charges




If $|Q_1| > |Q_2|$

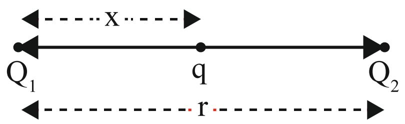
$\Rightarrow$ Null point near $Q_2$

$x = \frac{\sqrt{Q_1} r}{\sqrt{Q_1} + \sqrt{Q_2}}; x \to$ Distance of null Point $Q_1$ Charge

(+) For like charges

(-) For unlike charges

### Equilibrium of three point charges



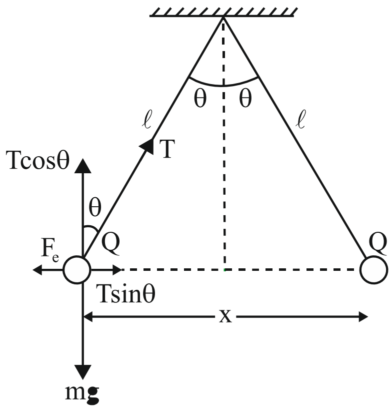

(i) Two charges must be of like nature.

(ii) Third charge should be of unlike nature.

$$x = \frac{\sqrt{Q_1}}{\sqrt{Q_1} + \sqrt{Q_1}} r \text{ and } q = \frac{-Q_1 Q_2}{\left(\sqrt{Q_1} + \sqrt{Q_1}\right)^2}$$

## Equilibrium of Suspended Point Charge System

For equilibrium position

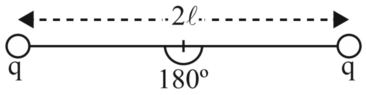



T cosθ = mg & T sinθ = $F_e$

$$\Rightarrow \tan\theta = \frac{F_e}{mg} = \frac{kQ^2}{x^2 mg}$$

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

If whole set up is taken into an artificial satellite (geff ; 0)



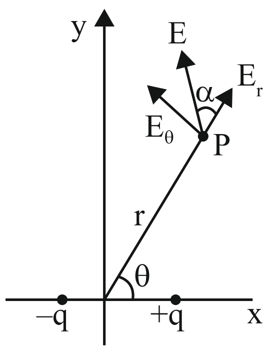

$$\Rightarrow T = F_e = \frac{kq^2}{4\ell^2}$$

## Electric Dipole

❖ Electric dipole moment p = qd

❖ Torque on dipole placed in uniform electric field $\vec{\tau} = \vec{p} \times \vec{E}$

❖ At a point which is at a distance r from dipole midpoint and making angle q with dipole axis.




Electric field $E = \frac{1}{4\pi\epsilon_0}\frac{p\sqrt{1+3\cos^2\theta}}{r^3}$

Direction $\tan\alpha = \frac{E_\theta}{E_r} = \frac{1}{2}\tan\theta$

❖ Electric field at axial point (or End-on) $\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{2\vec{p}}{r^3}$ of dipole

❖ Electric field at equatorial position (Broad-on) of dipole $\vec{E} = \frac{1}{4\pi\in_0}\frac{(-\vec{p})}{r^3}$

**Electric flux:** $\phi = \int \vec{E} \cdot d\vec{s}$

**Gauss's Law:** $\oint \vec{E} \cdot d\vec{s} = \frac{\Sigma}{\epsilon}$ (Applicable only on closed surface)

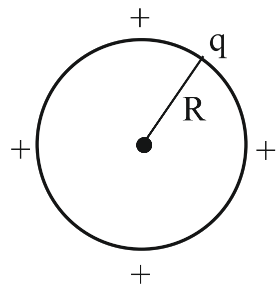
Net flux emerging out of a closed surface is $\frac{q_{en}}{\varepsilon_0}$

$\phi = \oint \vec{E} \cdot d\vec{A} = \frac{q_{en}}{\varepsilon_0}$ where $q_{en}$ = net charge enclosed by the closed surface. $\phi$ does not depend on the

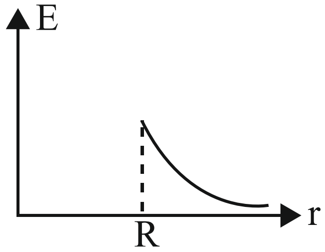
(i) Shape and size of the closed surface

(ii) The charges located outside the closed surface.

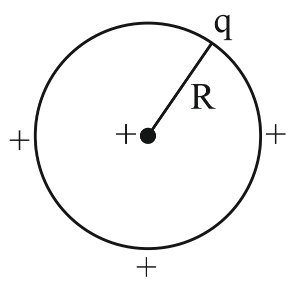
## For a Conducting Sphere



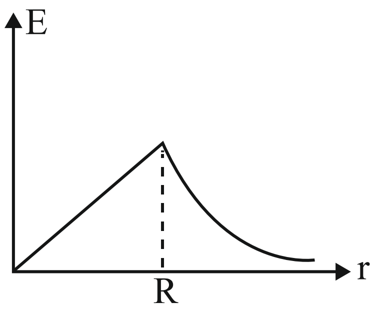

For $r \geq R : E = \frac{1}{4\pi \in_0} \frac{q}{r^2}$ and For $r < R : E = 0$




## For a Non-conducting Sphere



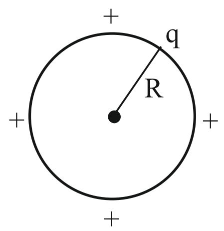

For $r \geq R : E = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2}$




For $r < R : E = \frac{1}{4\pi\epsilon_0} \frac{qr}{R^3}$

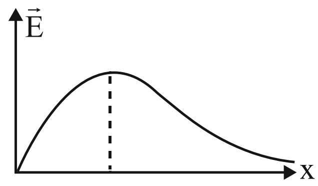
## For a Conducting/Non-conducting Spherical Shell

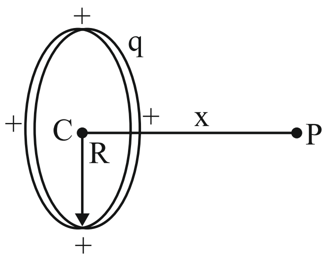
For $r \geq R : E = \dfrac{1}{4\pi\epsilon_0}\dfrac{q}{r^2}$




For $r < R : E = 0$

## For a hanging circular ring




$$E_P = \frac{1}{4\pi\epsilon_0}\frac{qx}{\left(x^2 + R^2\right)^{3/2}}$$

Electric field will be maximum at $x = \pm\dfrac{R}{\sqrt{2}}$

## For a Charged Long Conducting Cylinder

- For $r \geq R : E = \dfrac{q}{2\pi\epsilon_0 r}$
- For $r < R : E = 0$

## Electric Field Intensity at a Point near a Charged Conductor

$$E = \frac{\sigma}{\epsilon_0}$$

## Electric Field for Non-conducting Infinite Sheet of Surface Charged Density $\sigma$

$$E = \frac{\sigma}{2\epsilon_0}$$

## Electric Field for Conducting Infinite Sheet of Surface Charge Density $\sigma$

$$E = \frac{\sigma}{\epsilon_0}$$