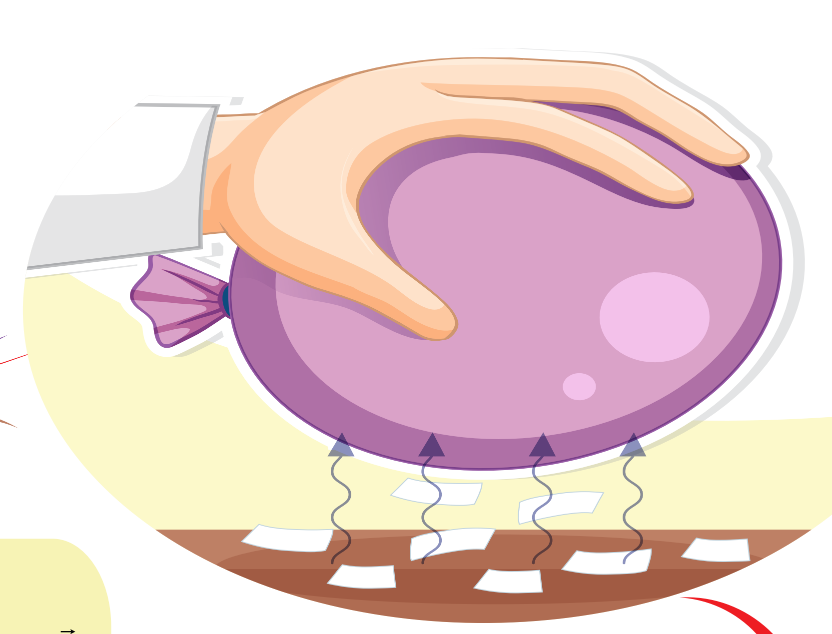
ELECTROSTATICS



QUANTIZATION OF CHARGES

All charges must be integral multiple of e i.e.
$Q = ne$ ($e = 1.6 \times 10^{-19}C$)
where — n = integer

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

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_0 = Permitivity of free space $= 8.854\times10^{-12}\ C^2/Nm^2$

- Forces in vector form

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

- Forces between multiple charges

$$F_{Net} = \frac{q_0}{4\pi\varepsilon_0}\sum_{i=1}^{k}\frac{q_i}{r_{oi}^2}\hat{r}_{oi}$$

ELECTRIC FIELD

- Electric field intensity (E) $\Rightarrow \vec{E} = \lim_{q_0\to0}\frac{\vec{F}}{q_0}$

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 toorigi

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

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

$$E_{\parallel} = \frac{\lambda}{4\pi\varepsilon_0 r}\left[\cos\theta - \cos\frac{\pi}{2}\right]$$

$$E_{\perp} = \frac{\lambda}{4\pi\varepsilon_0 r}\left[\sin\phi_2 + \sin\phi_1\right]$$

(Here, l is linear charge density)

Case(I): E.f due to infinite line charge

$$\phi_1 = \phi_2 = \frac{\pi}{2} \to F_{\perp} = \frac{\lambda}{2\pi\varepsilon_0 r};\ E_{\parallel} = 0$$

Case(II): E.f due to semi-infinite line charge

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

- Electric field due to a charged circular ring at a point on its axis.

$$E_P = \frac{kQx}{(R^2+x^2)^{\frac{3}{2}}}$$

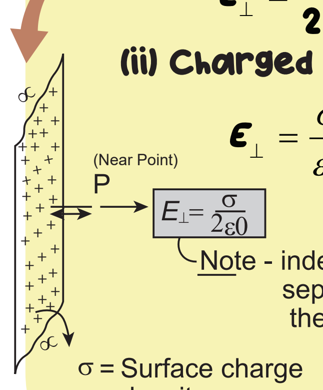
- Electric field due to a plane infinite sheet

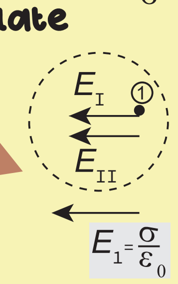
(i) Non-conducting sheet:

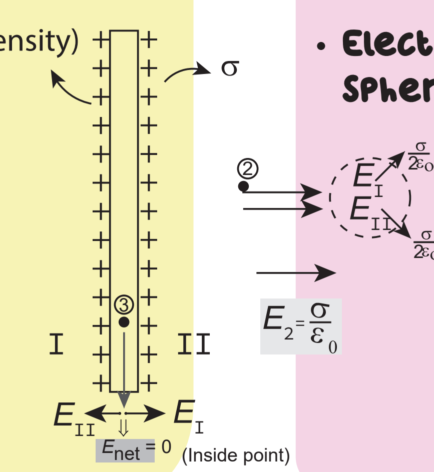
$$E_{\perp} = \frac{\sigma}{2\varepsilon_0}$$

(ii) Charged conducting plate

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

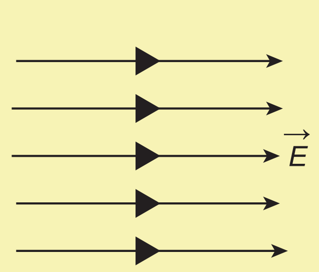




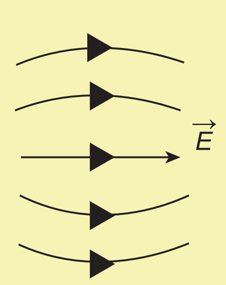


ELECTRIC FIELD LINES

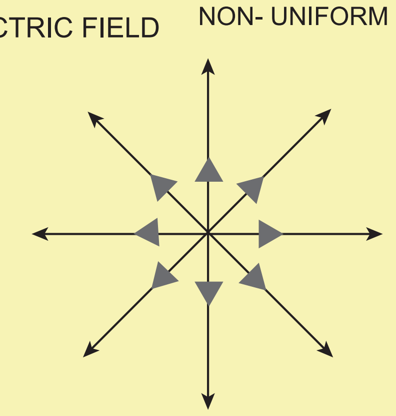
- Aways normal to conducting surface.
- Lines originating from +ve charge
- Terminating at -ve charge
- Never intersect each other.
- Never form closed loop.
- Electric field lines are imaginary.
  - (i) Uniform Electric field
  - (ii) Non-Uniform E.F.
  - (iii) Radial Electric field



UNIFORM ELECTRIC FIELD



NON- UNIFORM ELECTRIC FIELD



RADIAL ELECTRIC FIELD

ELECTRIC DIPOLE

A pair of equal and opposite point charges repeated by fix distance

Electric Dipole Moment

$\vec{P} = q(2a)\ cm$

- Electric field due to Electric Dipole
  - (i) Electric field (E.F.) on the axis of dipole at a distance r from center of dipole:

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

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

$$E_{Net} = \frac{-kP}{(r^2+a^2)^{\frac{3}{2}}}$$

- Electrical potential due to electric dipole:

(i) Axial $\to V_P = \frac{KP}{(r^2-a^2)}$

(ii) Equatorial $\to V_P = 0$

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

Force $\to \vec{F}_{Net} = qE - qE = 0$

Torque $\to \vec{\iota} = PESin\theta = \vec{P}\times\vec{E}$

Work Done in Rotating Dipole

$\to W = PE(\cos\theta_1 - \cos\theta_2)$

- Potential Energy $\to U = -PE\cos\theta = \vec{P}.\vec{E}$

ELECTRIC FLUX

Total number of electric field lines passing normally throng an area

$-\phi = \oint \vec{E}.\vec{dS}$

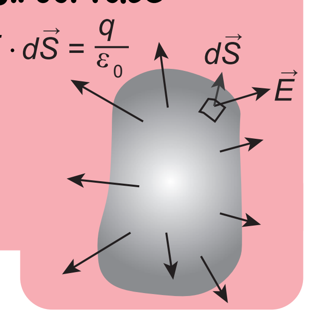
Electric flux $(\phi) = |\vec{E}||\vec{dS}|\cos\theta$

GAUSS LAW

It states, total flux of an E.F. through a closed surface is equal to times of total charge enclosed by the surface.

Total flux through surface

$(\phi) = \frac{q_{enclosed}}{\varepsilon_0}$ $\oint \vec{E}\cdot d\vec{S} = \frac{q}{\varepsilon_0}$



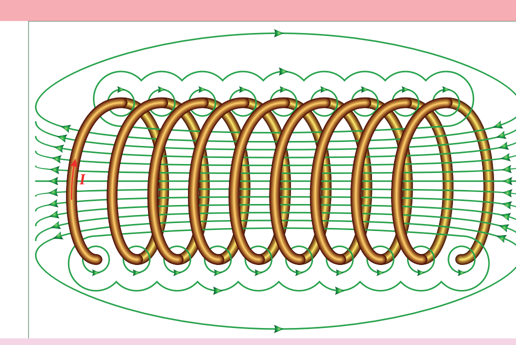
THEORY OF CONDUCTOR

A material having free electrons in its valence shell is called conductor.

- Inside a conductor, the net electrostatic field is zero
- At the surface of a charged conductor, the electrostatic field must be normal to the surface at every point
- The interior of a conductor can have no excess charge in the static situation i.e. excess charge reside only on the outer surface of conductor.
- Electric field at the ssurface of a charged conductor

$\left[E = \frac{\sigma}{\varepsilon_0}\right]$ where, σ is surface charge density.

$$\left(\sigma = \frac{1}{\text{radius of curvature}}\right)$$



- Electric field due to charged spherical shell or conducting sphere

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

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

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

- Electric field due to a solid non-conducting sphere - (f = volume charge density)

$$E = (r<R) = \frac{kQr}{R^3} = \frac{fr}{3\varepsilon_0}$$

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

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

ELECTRIC POTENTIAL & ELECTRIC POTENTIAL ENERGY

- Work done by external charge to move from postion 1 to 2 in static electric field E.

$$W_{ext} = \int \vec{F}.\vec{dl} = -q\int_1^2 \vec{E}.\vec{dl}$$

- Electric potential

$$\to V_P = \frac{W_{ext}(\infty\to P)}{q} = -\int_\infty^P \vec{E}.\vec{dl}$$

- Electric potential due to a point charge in its surrounding: $\to V_P = \frac{Kq}{r}$

- Electric potential due to a point charged ring at its center:

$$V = \int dv = \int\frac{Kdg}{R} = \frac{K\theta}{R}$$

- Electric potential due to conducting and non-conducting sphere:

(i) Inside ($r<R$)
(ii) Outside ($r>R$)
(iii) At surface ($r=R$)

Hollow conducting

$V_P = \frac{Kq}{R}$

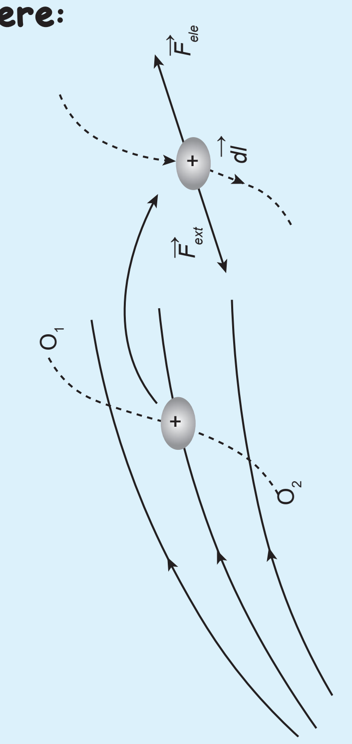
$V_P = \frac{Kq}{r}$

$V_P = \frac{Kq}{R}$

Solid Non-Conducting

$V_P = \frac{Kq}{2R^3}[3R - r^2]$

$V_P = \frac{Kq}{r}$ $V_P = \frac{Kq}{R}$



- Electric potential energy: Amount of work done(w) required to be done to move a charge from infinity to any given point inside the field.

$$U_A = W_{\infty\to A} = -q\int_{-\infty}^{A}\vec{E}.\vec{dl} = qV_A$$

- Work done in moving charge from A to B will be:

$$W_{ext} = \Delta U = (U_B - U_A) = q(V_B - V_A)$$

- Electric potential energy due to two point charges:

$$U = \frac{Kq_1q_2}{r}$$

- Electric potential energy of a system of charges:

$$U_{(Total)} = kq_1q_2\frac{1}{r_{12}} + kq_2q_3\frac{1}{r_{23}} + \frac{kq_3q_4}{r_{34}} + \dots$$

- Relation between electric field and potential:

Electric field at a point is negative of potential gradient

Potential gradient $\to \left[E = \frac{-dV}{dr}\right]$

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