ELECTROSTATICS

QUANTIZATION OF CHARGES

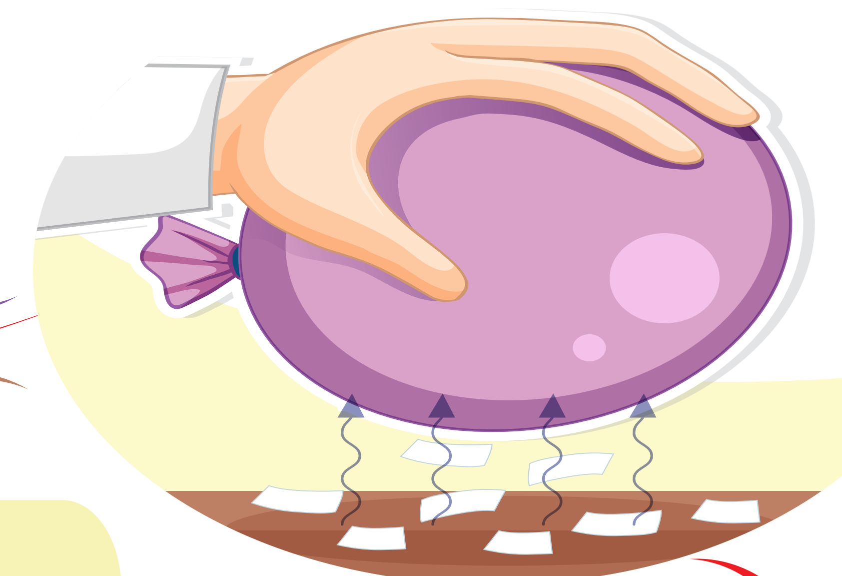
All charges must be integral multiple of e i.e.
$Q = ne$ ($e = 1.6 \times 10^{-19}C$)
where — n = integer

CONSERVATION OF CHARGES

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

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)



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 $\rightarrow V_P = \frac{KP}{(r^2-a^2)}$
  - (ii) Equatorial $\rightarrow V_P = 0$
- Force and Torque on dipole in uniform external (E.F.)
  - Force $\rightarrow F_{net} = qE - qE = 0$
  - Torque $\rightarrow \tau = PE\sin\theta = \vec{P} \times \vec{E}$
- Work Done in Rotating Dipole
  $\rightarrow W = PE(\cos\theta_1 - \cos\theta_2)$
- Potential Energy $\rightarrow U = -PE\cos\theta = \vec{P}.\vec{E}$

ELECTRIC FLUX

Total number of electric field lines passing normally throng an area

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

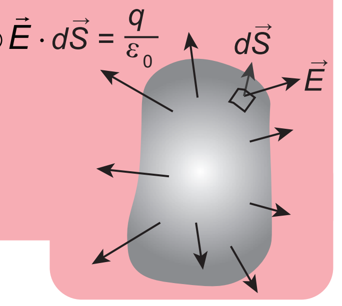
Electric flux $(\phi) = |\vec{E}||\vec{dS}|\cos\theta$

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

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

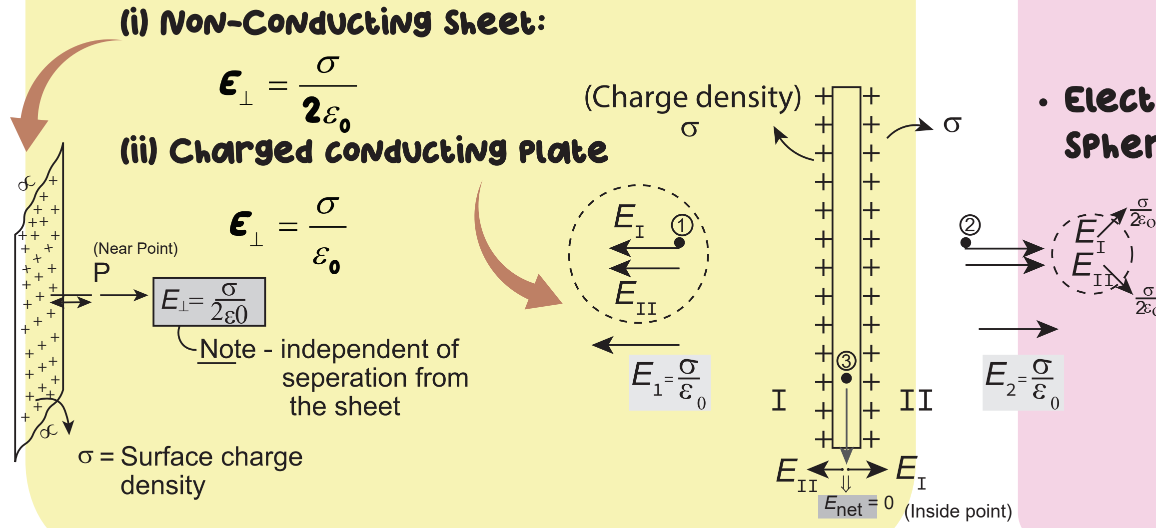


COULOMB'S LAW

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

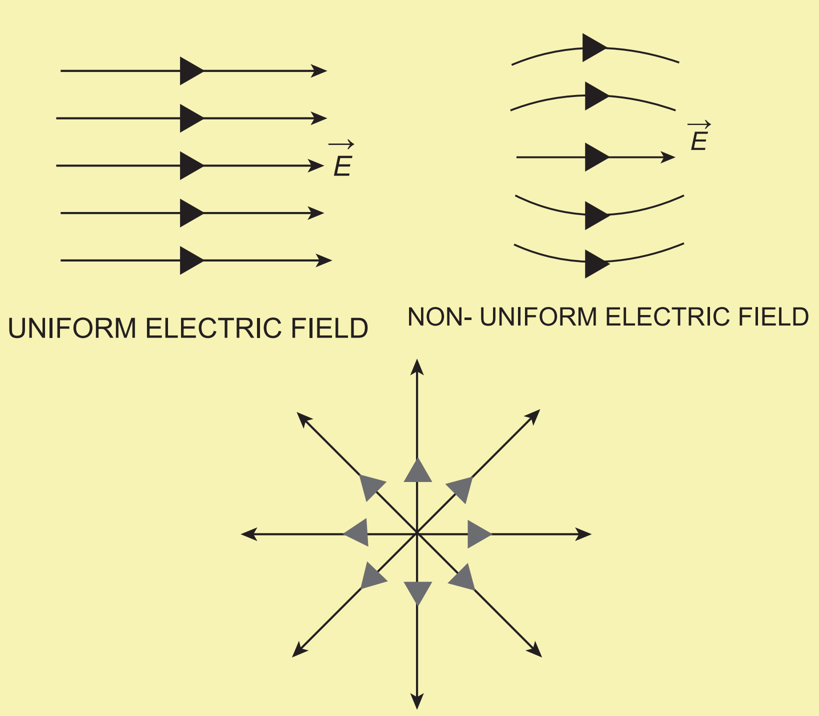
ELECTRIC FIELD

- 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
  $$E_{\parallel} = \frac{\lambda}{4\pi\varepsilon_0 r}\left[\cos0 - \cos\frac{\pi}{2}\right]$$
  $$E_{\perp} = \frac{\lambda}{4\pi\varepsilon_0 r}\left[\sin\phi_2 + \sin\phi_1\right]$$
  (Here, l is linear charge density)
  Case(I): E.F due to infinite line charge
  $$\phi_1 = \phi_2 = \frac{\pi}{2} \rightarrow F_1 = \frac{\lambda}{2\pi\varepsilon_0 r};\ E_{\parallel} = 0$$
  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 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



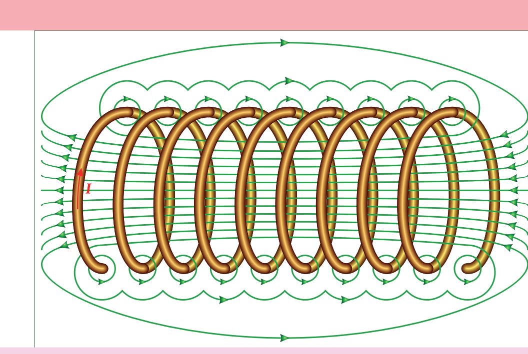
THEORY OF CONDUCTOR

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.

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

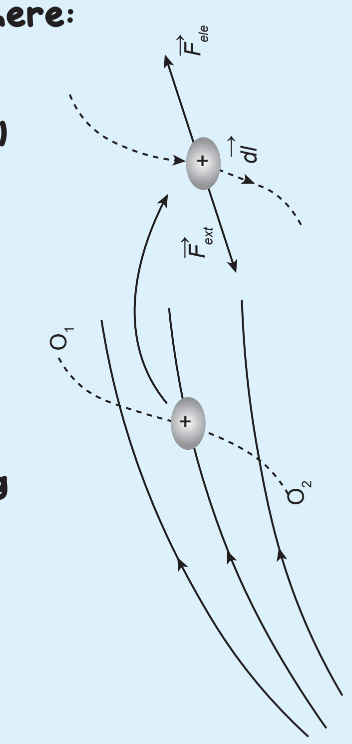


- Electric field due to charged spherical shell or conducting sphere
  $$E = (r<R) = 0$$
  $$E = (r>R) = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$$
  $$E = (r=R) = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R^2}$$
- Electric field due to a solid non-conducting sphere - (f = volume charge density)
  $$E = (r<R) = \frac{kQr}{R^3} = \frac{fr}{3\varepsilon_0}$$
  $$E = (r>R) = \frac{kQ}{r^2} = \frac{1Q}{4\pi\varepsilon_0 r^2}$$
  $$E = (r=R) = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R^2}$$

ELECTRIC POTENTIAL & ELECTRIC POTENTIAL ENERGY

- Work done by external charge to move from postion 1 to 2 in static electric field E.
  $$W_{ext} = \int_1^2 \vec{F}.\vec{dl} = -q\int_1^2 \vec{E}.dl$$
- Electric potential
  $$\rightarrow V_P = \frac{W_{ext}(\infty\rightarrow P)}{q} = -\int_{\infty}^{P}\vec{E}.\vec{dl}$$
- Electric potential due to a point charge in its surrounding: $\rightarrow V_P = \frac{Kq}{r}$
- Electric potential due to a point charged ring at its center:
  $$V = \int dv = \int\frac{Kdq}{R} = \frac{K\theta}{R}$$
- 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
  $$V_P = \frac{Kq}{2R^3}\left[3R - r^2\right]$$
  $$V_P = \frac{Kq}{r} \qquad V_P = \frac{Kq}{R}$$



- 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.
  $$U_A = W_{\infty\rightarrow A} = -q\int_{-\infty}^{A}\vec{E}.\vec{dl} = qV_A$$
- 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 $\rightarrow \left[E = \frac{-dV}{dr}\right]$