Potential of earth is taken to be zero.
Any body connected to the earth, will acquire zero potential.

Electrostatics:-

→ $1C = 3 \times 10^9$ esu.

→ $q = \pm ne$ $(e = 1.6 \times 10^{-19} C)$

→ mass of $e^- = 9.1 \times 10^{-31}$ kg.

1. Charging by friction - bodies get oppositely charged.

→ total charge remains zero.

→ charge gained by one body = charge lost by other body.

-ve charge	+ve charge
silk	glass rod
rubber/ebonite rod	animal fur (cat skin)
comb	dry hair
Amber/plastic objects	woollen cloth.

Body with loosely bound e^-s, looses e^-s. Body with tightly bound e^-s, gains e^-s.

2. Charging by conduction - bodies acquire ~~[illegible]~~ like charges.

3. Charging by induction (no contact)

net force is attractive

→ uncharged body (initially) remains uncharged. Electrons and protons only rearrange themselves in the body.

4. $$F = \frac{K q_1 q_2}{r^2} = \frac{K q_1 q_2}{r^2}\hat{r} = \frac{K q_1 q_2}{r^3}\vec{r}.$$

$$\left(K = \frac{1}{4\pi\varepsilon_0} = 9 \times 10^9\ Nm^2/C^2, \quad \varepsilon_0 = 8.85 \times 10^{-12}\ C^2/Nm^2\right)$$

ε_0 – permittivity of free space.

$$F_m = \frac{K q_1 q_2}{r^2} = \frac{q_1 q_2}{r^2\, 4\pi\varepsilon_0\varepsilon_r}$$

$\varepsilon_r = k$ = relative permittivity

(ε_r = dielectric constant)

($\varepsilon_r = 1$ (vacuum/air))

$$\therefore F_{medium} = \frac{F_{vacuum/air}}{K} = \frac{F_{vacuum/air}}{\varepsilon_r}.$$

Principle of superposition is applicable to F.

when linear size of body is smaller (much smaller) than the distance under consideration, the object can be treated as a point charge.

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5. Electric Field -

→ electrostatic force experienced by unipositive charge.

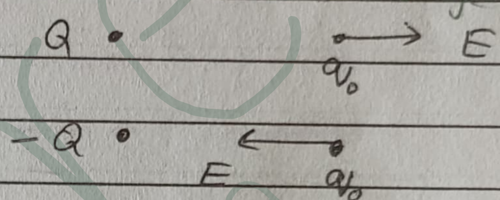
→ $\vec{E} = \frac{KQ}{r^2}\hat{r} = \frac{KQ}{r^3}\vec{r}$.

→ $\vec{F} = q\vec{E}$ (q = charge placed in external field $\vec{E}$)

Due to +ve charge ⇒ $\vec{E}$ is away from the charge.

Due to −ve charge ⇒ $\vec{E}$ is towards the charge.

Principle of superposition applicable to $\vec{E}$.



	Object	$\vec{E}$ (due to object)
(i)	point charge	$\vec{E} = \frac{Kq}{r^2}\hat{r}$
(ii)	infinitely long line charge	$\vec{E} = \frac{2K\lambda}{r}\hat{r}$ λ = charge per unit length.
(iii)	infinite non-conducting thin sheet. ($\sigma = q/A$)	$\vec{E} = \frac{\sigma}{2\varepsilon_0}\hat{n}$ σ = surface charge density, $\hat{n}$ = unit normal vector
(iv)	infinite conducting sheet ($\sigma = q/2A$).	$\vec{E} = \frac{\sigma}{\varepsilon_0}\hat{n}$
(v)	uniformly charged ring	$\vec{E} = \frac{KQx}{(R^2+x^2)^{3/2}}$ x = point on the axis of the ring. $\vec{E}_{centre} = 0$ E_{max} at $x = \frac{R}{\sqrt{2}}$
(vi)	uniformly charged hollow and solid conducting sphere.	$E_{in} = 0$, $E_{out} = \frac{KQ}{r^2}\hat{r}$.
(vii)	uniformly charged solid non-conducting sphere.	$E_{out} = \frac{KQ}{r^2}\hat{r}$, $E_{in} = \frac{KQr}{R^3}\vec{r}$.

Surface area of sphere $= 4\pi R^2$
The corner of a cube is shared by 8 other cubes.

→ E due to arc / E due to line charge } – $E_x = \frac{k\lambda}{r}[\sin\alpha + \sin\beta]$

$E_y = \frac{k\lambda}{r}[\cos\alpha - \cos\beta]$.

α and β are measured in opposite sense.

6. Electric lines of force (ELOF) –
→ ELOF originate at +ve charge and terminate at –ve charge.
→ ELOF never form closed loops, never intersect.
→ ELOF per unit area $\propto$ strength/magnitude of $\vec{E}$.
→ No. of ELOF originating/terminating at a charge is proportional to the magnitude of charge.
→ ELOF are $\perp$ to surface of conductor. ELOF never enter into the conductor ($E_{inside} = 0$).

7. Electric flux (ϕ) –

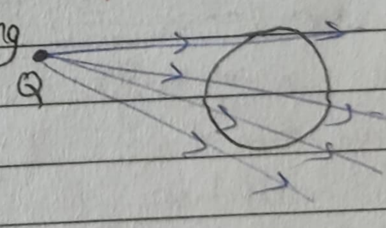
$$\phi = \oint \vec{E} \cdot d\vec{A}$$

($\vec{A}$ is always perpendicular to surface under consideration).

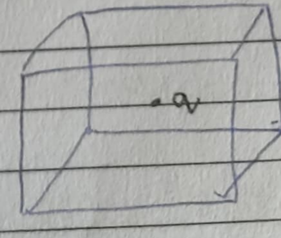
→ Gauss' law ⇒ $\phi = \oint \vec{E} \cdot d\vec{A} = \frac{q_{in}}{\varepsilon_0}$.

Flux through gaussian surface is independent of shape. &

→ ELOF entering = ELOF leaving



$\therefore \phi = 0$. ($q_{in} = 0$)
but $\vec{E} \neq 0$.



$\phi_{Total} = \frac{q}{\varepsilon_0}$.

$\phi_{each\ surface} = \frac{q}{6\varepsilon_0}$

physical meaning of flux = no. of ELOF passing through a given surface.

& and independent of position of charge inside the surface.

$W_{ext} + W_{ef} = \Delta KE.$

$1 ev = 1.6 \times 10^{-19} J.$

__/__/____

8. **Electric Potential** (scalar) = work done by external agent in bring unit +ve charge from reference point (∞) to the given point. ($V_\infty = 0$)

→ $V = -\int_{\infty}^{r} \vec{E} \cdot d\vec{r}$ $\qquad V_f - V_i = -\int_{r_i}^{r_f} \vec{E} \cdot dr.$

(i) Point charge - $V = \frac{KQ}{r}$

(ii) Uniformly/Non-uniformly charged Ring/Arc (at centre) $V = \frac{Kq}{R}.$

(iii) V_{axis} of a ring. - $V = \frac{Kq}{\sqrt{R^2+x^2}}.$

(iv) Spherical shell - $V_{outside} = \frac{KQ}{r}$ $\qquad V_{in} = \frac{KQ}{R}.$

(v) Solid sphere - $V_{outside} = \frac{KQ}{r}$ $\qquad V_{in} = \frac{KQ}{2R^3}[3R^2 - r^2].$

→ $(W_{ext})_{A\to B} = q(V_B - V_A)$

$(W_{ef})_{A \to B} = q(V_A - V_B).$

→ $V_B - V_A = -\vec{E} \cdot \vec{r}_{AB} = -Ed$

d = displacement along the $\vec{E}$.

$\perp$ to $\vec{E}$, V does not change ($\because d = 0$).

In direction of $\vec{E}$, V decreases.

→ Equipotential surfaces $\perp$ $\vec{E}$.

9. **Potential Energy (Electric)** -

→ $U = \frac{KQq_0}{r} = Vq_0.$

U_{system} = Work done to make the system.

For n point charges – no of combination $= \frac{n(n-1)}{2}$

→ $U_{net} = \frac{U_1 + U_2 + U_3 + \dots U_n}{2}$ for n symmetrically arranged charges –

U_1 = work done to make system when charge 1 is fixed and all other particles are brought individually in its presence.

Eg – For a hexagon (6 charges on the corners)

$U_{net} = \frac{U_1 + U_2 + U_3 + U_4 + U_5 + U_6}{2} = \frac{6U_1}{2} = 3U_1$

$(U_1 = U_{12} + U_{13} + U_{14} + U_{15} + U_{16})$

→ Self energy – $U_{shell} = \frac{KQ^2}{2R}$

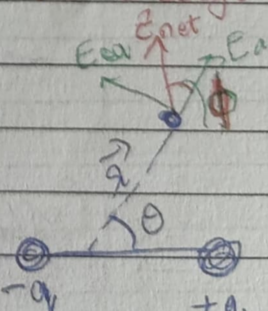
$U_{solid\ sphere} = \frac{3KQ^2}{5R}$

→ Energy density $= \frac{U}{Volume} = \frac{1}{2}\varepsilon E^2$. $(\varepsilon = \varepsilon_0 \varepsilon_r)$

$\vec{E} = -\frac{dV}{dr}\hat{r} = -\left(\frac{\partial V}{\partial x}\hat{i} + \frac{\partial V}{\partial y}\hat{j} + \frac{\partial V}{\partial z}\hat{k}\right)$

10\. Electric dipole –

$\vec{p} = q \times r$ direction P is from –ve charge to +ve charge.



→ $\vec{E}_{axis} = \frac{2K\vec{P}}{r^3}$ $\vec{E}_{equatorial} = \frac{-K\vec{P}}{r^3}$

E at general point – $E = \frac{KP}{r^3}\sqrt{3\cos^2\theta + 1}$.

$\left(\tan\phi = \frac{\tan\theta}{2}\right)$

→ $V_{axial} = \frac{KP}{r^2}$ $V_{eq} = 0$

$V_{general\ point} = \frac{KP\cos\theta}{r^2} = \frac{K\vec{P}\cdot\vec{r}}{r^3}$.

$U = -\int \tau \cdot d\theta = -\int F_c \cdot dr$

$\rightarrow \vec{\tau} = \vec{P} \times \vec{E}$

$\rightarrow U = -\vec{P} \cdot \vec{E}$

} for uniform $\vec{E}$.

$\tau = -I\alpha$

moment of inertia

For non-uniform $\vec{E}$ — $F_{net} = P\left(\frac{dE}{dx}\right)$.

11. Movement of charge in uniform $\vec{E}$.

$q_1 = +ve$.

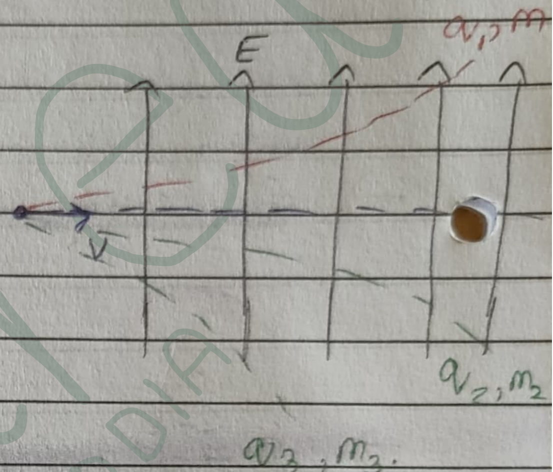
$q_2, q_3 = -ve$.

$a_3 > a_2$

$\therefore m_2 > m_3$.

$\vec{F} = q\vec{E}$

$\vec{a} = \frac{q\vec{E}}{m}$

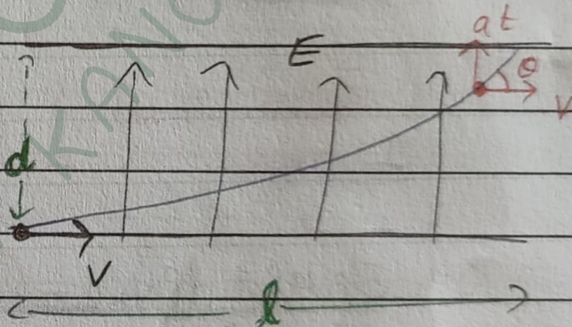


$\rightarrow t = \frac{l}{v}$

$\rightarrow d = \frac{1}{2}at^2 = \frac{1}{2}\frac{qE}{m}\left(\frac{l}{v}\right)^2$

$\rightarrow \tan\theta = \frac{at}{v} = \frac{al}{v^2}$

$= \frac{qEl}{mv^2}$.



Conductors —

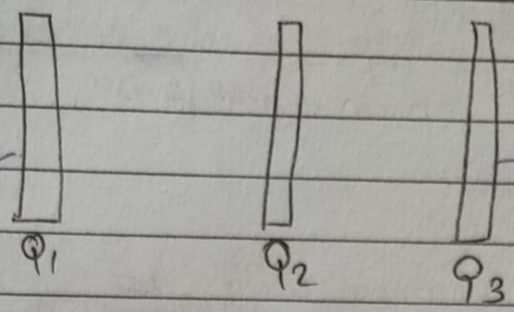
$\rightarrow E_{inside} = 0$. (ELOF never enter into a conductor). always $\perp$ to conducting surface.

$\rightarrow$ E due to conductor — $E = \frac{\sigma}{\varepsilon_0}\hat{n}$.

$\rightarrow$ Electric pressure — $P = \frac{\sigma^2}{2\varepsilon_0}$.

When a conductor is grounded, its $V = 0$

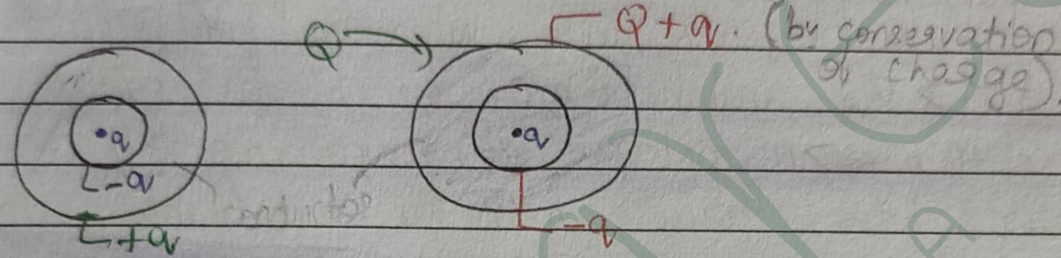
When an isolated conductor is grounded, its charge becomes zero.



$$Q = \frac{Q_1 + Q_2 + Q_3}{2}$$

$$Q = \frac{Q_1 + Q_2 + Q_3}{2}$$

On connecting two conductors with a conducting wire, charge flow occurs till their potentials become equal.



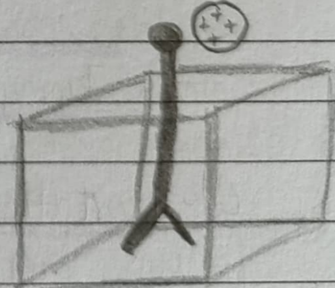
$1\,C = 3 \times 10^{9}$ esu

1 debye $= 10^{-18}$ esu cm $= 3.33 \times 10^{30}$ C-m

1 stat coulomb = 1 franklin $= 3.33 \times 10^{-10}$ C.
= 1 esu

NCERT Points

1. Gold - leaf electroscope is an apparatus used to detect the presence of charge on a body. It consists of a vertical rod housed in a box, with two thin gold leaves attached at the bottom end of the rod. When a charged object touches the metal knob at the top of the rod, the leaves diverge. The degree of divergence indicates the amount of charge.



2. Those substances/materials which allow electricity to pass through them easily are called conductors. They have electric charges (electrons) that are comparatively free to move inside the material.

3. When some charge is transferred to a conductor, it readily gets distributed over the entire surface of the conductor. In contrast, if some charge is put on an insulator, it stays at the same place.

4. The process of sharing charges with the earth is called grounding or earthing.
The electrical wiring in our houses has three wires: live, neutral and earth. The first two carry electric current from the power houses and the third is earthed by connecting it to a buried metal plate. Metallic bodies of electric appliances are connected to the earth wire. When any fault occurs or live wire touches the metallic body, the charge flows to the earth without damaging the appliance or causing injury to humans; this would have otherwise been unavoidable since the human body is a conductor of electricity.

5. Coulomb used a torsion balance to find the force between two charged metallic spheres.

6. The individual forces are unaffected due to the presence of other charges. This is called the principle of superposition.

7. Vectors pointing along the direction of electric field have their lengths proportional to the strength of the field at each point. Joining the vectors in one direction gives electric field lines in that direction.

8. Electrostatic field lines do not form closed loops. This follows from the conservative nature of electric field.

9. When a closed surface S is chosen such that charges are present inside and outside the surface, the electric field on left side of Gauss law is due to all charges, both inside and outside. The term q on right side of Gauss law represents only the charge inside the surface S.

10. Electric field is zero everywhere inside the conductor. This can be taken as the defining property of a conductor.