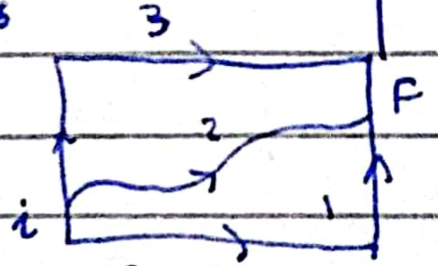
Chapter # 28

ELECTRIC POTENTIAL ENERGY AND ELECTRIC POTENTIAL

∴ Conservative (Initial and final dependent)

Electrostatic force	Gravitational force
1- $F = K \frac{q_1 q_2}{r^2}$	1- $F = G \frac{m_1 m_2}{r^2}$
2- Conservative field/force	2- Conservative field/force
$W = \int_a^b \bar{F} \cdot d\bar{s}$	↓
$\Delta U = -\int_a^b \bar{F} \cdot d\bar{s}$	P.E can be defined

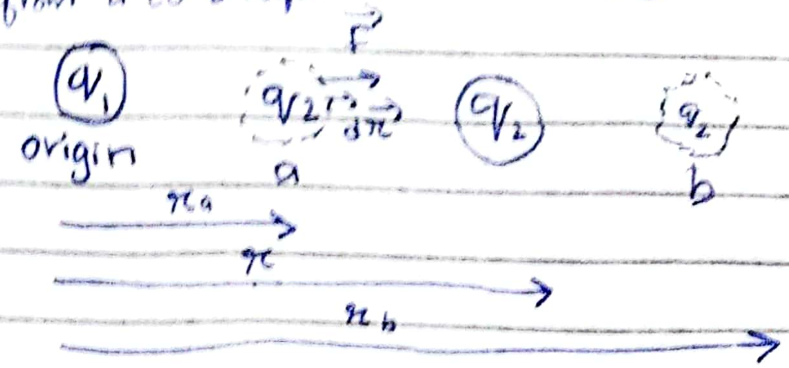


$$W = \int_i^f \bar{F} \cdot d\bar{r}$$

$$\Delta U = -W \rightarrow \Delta U = -G m_1 m_2 \left(\frac{1}{r_f} - \frac{1}{r_i} \right)$$

⊙ Electric Potential Energy:

(Energy from a to b required)



$\Delta U > 0$
$\Delta U < 0$
$\Delta U = 0$

$r_a < r_b$

$ds = dr$

⊙ $$F = \frac{1}{4\pi\epsilon_0} \cdot \frac{q_1 q_2}{r^2} \quad \text{—— (2)}$$

$$\vec{F} \cdot d\vec{r} = F\,dr \qquad (\theta = 0^\circ)\,(\text{parallel})$$

$$\Delta U = -\int_a^b F\,dr \quad \text{—— (1)}$$

$$\Delta U = -\int_a^b \frac{1}{4\pi\epsilon_0} \cdot \frac{q_1 q_2\,dr}{r^2}$$

$$\Delta U = -\frac{1}{4\pi\epsilon_0} q_1 q_2 \int_a^b \frac{1}{r^2}\,dr$$

$\because \int x^n dx = \frac{x^{n+1}}{n+1}$

$\because \int \frac{1}{r^2}\,dr$

$$\int r^{-2}\,dr = \frac{r^{-2+1}}{-2+1} = \frac{r^{-1}}{-1} = -\frac{1}{r}$$

$$\Delta U = -\frac{1}{4\pi\epsilon_0} q_1 q_2 \left| -\frac{1}{r} \right|_{r_a}^{r_b}$$

$$\boxed{\Delta U = \frac{1}{4\pi\epsilon_0} q_1 q_2 \left(\frac{1}{r_b} - \frac{1}{r_a} \right)}$$

$\because \frac{1}{r_b} - \frac{1}{r_a} = -ve$

$\because x_a < x_b$ (+ve)

$q_1 q_2$ same

$\because \frac{1}{r_a} > \frac{1}{r_b}$ $\Delta U(-ve)$

⊙ Like charges:

$r_a > r_b$ $\quad \Delta U > 0$

⊙ Unlike charges:

$r_a > r_b$ $\quad \Delta U < 0$

$r_a < r_b$ $\quad \Delta U > 0$

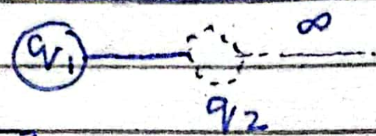
⊙ **Absolute**

$$\Delta U = U_b - U_a \to 0$$

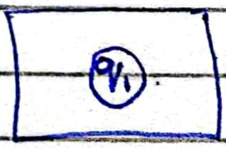
$U_a = 0$ if $r_a \to \infty$

$$\boxed{U = \frac{1}{4\pi\epsilon_0}\cdot\frac{q_1 q_2}{r}}$$

$r_a \to \infty$

:- 

:- Electric force & Electric Potential Energy shows interaction.

:- 

$U = 0$

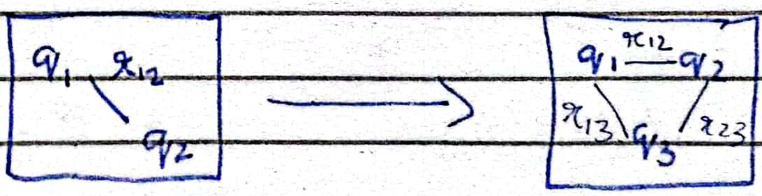
:- It can't be defined for single charge.

$$F = k\frac{q_1 q_2}{r^2}$$

$$U = \frac{1}{4\pi\epsilon_0}\cdot\frac{q_1 q_2}{r}$$

:- Electric force (Vector)

:- Electric potential (Scalar)

⊙ 

$$U = \frac{1}{4\pi\epsilon_0}\cdot\frac{q_1 q_2}{r_{12}}$$

$$U = \frac{1}{4\pi\epsilon_0}\cdot\frac{q_1 q_2}{r_{12}} + \frac{1}{4\pi\epsilon_0}\frac{q_1 q_3}{r_{13}} + \frac{1}{4\pi\epsilon_0}\frac{q_2 q_3}{r_{23}}$$

8/3/23

★ Electric field & Electric potential a field or effect of single charge.

$$W = \int_a^b \vec{F}\cdot d\vec{s}$$

$$\Delta U = W = -\int_a^b \vec{F}\cdot d\vec{s}$$

$$\Delta U = \frac{1}{4\pi\epsilon_0}\cdot q q_0\left(\frac{1}{r_b} - \frac{1}{r_a}\right)$$

* Electrical Potential: (work done per unit charge)

$$U = \frac{1}{4\pi\epsilon_0} \cdot \frac{q\,q_0}{r}$$

$\therefore W = \int_a^b F \cdot d\bar{s}$

$$\Delta V = \frac{\Delta U}{q_0}$$

$\therefore \Delta U = -W = -\int_a^b \bar{F} \cdot d\bar{s}$

$\therefore \Delta U = -W = -\int_a^b \bar{F} \cdot d\bar{s}$

$$\Delta V = \frac{-\int_a^b F \cdot d\bar{s}}{q_0}$$

$\Delta U = -W = \frac{1}{4\pi\epsilon_0} q q_0 \left(\frac{1}{r_b} - \frac{1}{r_a}\right)$

$$\Delta V = \frac{1}{4\pi\epsilon_0} \cdot q\left(\frac{1}{r_b} - \frac{1}{r_a}\right)$$

$\therefore U = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r}$

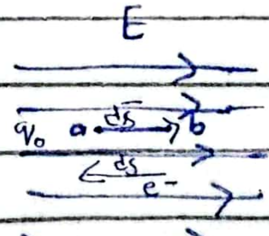
$$V = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r}$$

$\therefore 1\,eV = 1.6 \times 10^{-19}\,J$

$r_a \to \infty$

Calculating potential from the field:
Let we have a uniform electric field.

$$\Delta V = \frac{\Delta U}{q_0}$$



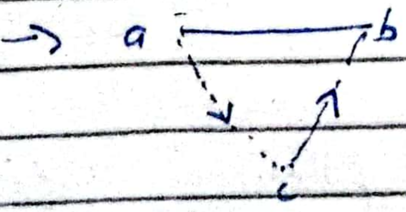
$$\Delta V = \frac{-\int_a^b \bar{F} \cdot d\bar{s}}{q_0}$$

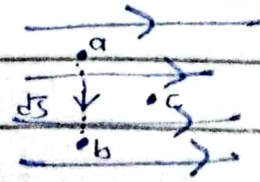
$$\Delta V = -\int \bar{E} \cdot d\bar{s}$$

$\leftarrow \vec{F} = q_0 \vec{E}$

* Sample problem 28.5:-

$\therefore$ '−' negative sign shows test charge moves from high potential to low potential.





$E \cdot ds = 0$
$\theta = 90°$

$\therefore 1J = (1V)(1C)$

$\therefore$ for electron it is positive

$\therefore$ a & b are perpendicular to field
so $\theta = 90°$
$\boxed{\cos 90° = 0}$

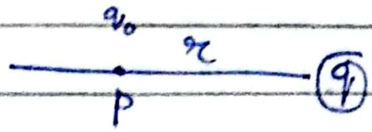
$\therefore \Delta U = q_0 \Delta V$

KeV or eV, e, V

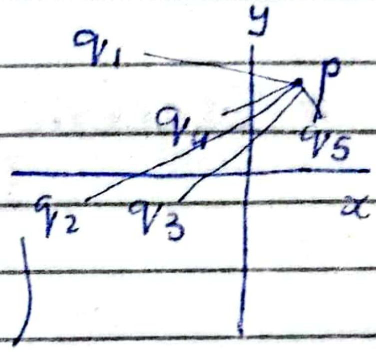
$1\,eV = 1.6 \times 10^{-19}\,J$

* Electric Potential Due To a Point Charge:

$$U = \frac{1}{4\pi\epsilon_0} \frac{q q_0}{r}$$



$$V = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r}$$



Total potential at P

$$V = V_1 + V_2 + V_3 + V_4 + V_5$$

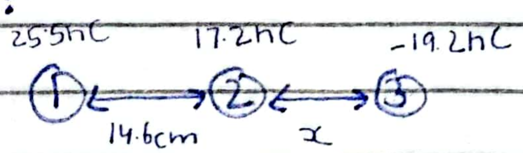
$$V = \frac{1}{4\pi\epsilon_0}\left(\frac{q_1}{r_1} + \frac{q_2}{r_2} + \frac{q_3}{r_3} + \frac{q_4}{r_4} + \frac{q_5}{r_5}\right)$$

Generally for 'n' charges

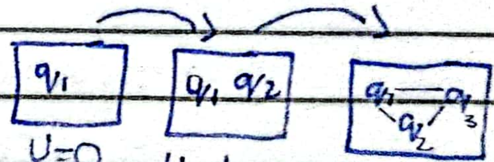
$$V = \frac{1}{4\pi\epsilon_0} \sum_{n=1}^{n} \frac{q_n}{r_n}$$

:- Ex #2
Pg: 655
(Homework)

Ex 4:



Find x if potential energy of system is zero.



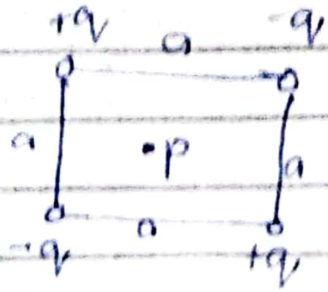
$U = 0$

$$U = \frac{1}{4\pi\epsilon_0} \cdot \frac{q_1 q_2}{r}$$

$$U = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_3}{r_{13}} + \frac{1}{4\pi\epsilon_0} \frac{q_2 q_3}{r_{23}} + \frac{1}{4\pi\epsilon_0} \frac{q_2 q_3}{r_{23}}$$

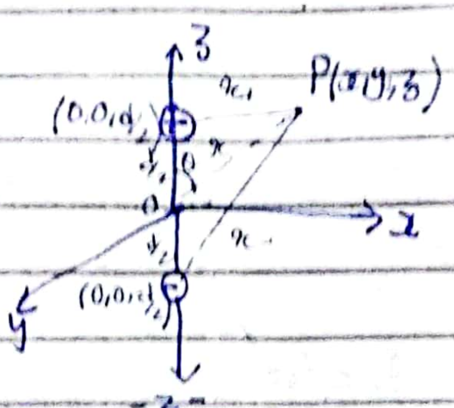
⊛ Problem:

Find total potential at centre of square



Ans: At center = 0 V because from center distance is same

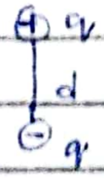
* Electric Potential Due To a Dipole



Total Potential at P

$$V = V_+ + V_- \quad \text{---(1)}$$

$$V = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{r_+} + \frac{1}{4\pi\epsilon_0} \frac{(-q)}{r_-}$$



$$V = \frac{1}{4\pi\epsilon_0} \cdot q\left(\frac{1}{r_+} - \frac{1}{r_-}\right)$$

$$V = \frac{1}{4\pi\epsilon_0} \cdot q\left(\frac{r_- - r_+}{r_- r_+}\right) \quad \text{---(2)}$$

∵ distance small

$$r_- - r_+ \approx d\cos\theta$$

$$r_- r_+ \approx r^2$$

$$V = \frac{1}{4\pi\epsilon_0} \frac{qd\cos\theta}{r^2}$$

$$V = \frac{1}{4\pi\epsilon_0} \cdot \frac{p\cos\theta}{r^2}$$

$\because p = qd$

∴ (x_1, y_1, z_1)

(x_2, y_2, z_2)

$\therefore r = \sqrt{(x_2-x_1)^2 + (y_2-y_1)^2 + (z_2-z_1)^2}$

$(0,0,d/2)$, (x,y,z)

$$r_+ = \sqrt{(x-0)^2 + (y-0)^2 + (z-d/2)^2}$$

$$r_- = \sqrt{(x-0)^2 + (y-0)^2 + (z+d/2)^2}$$

$\therefore r = \sqrt{x^2+y^2+z^2}$

$r^2 = x^2+y^2+z^2$

$r_- = \sqrt{x^2+y^2+z^2+\frac{d^2}{4}+zd}$

d is very small

$r^2 = x^2+y^2+z^2$ $\qquad \frac{d^2}{4} \to 0$

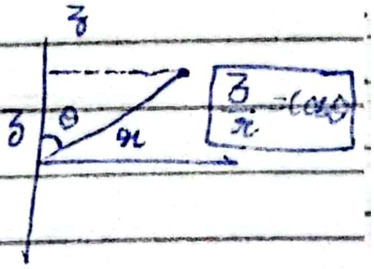
$r_- = \left[r^2\left(1+\frac{zd}{r^2}\right)\right]^{1/2}$ $\qquad \because (1+x)^n = 1+nx+\dots$

$x \ll 1$

$n \to$ fraction

$r_- \approx r\left[1+\frac{z\,d}{r^2}\right]^{1/2}$

$r_- = r\left[1+\frac{1}{2}\frac{z\,d}{r^2}\right]$



$r_- = r + \frac{zd}{2r}$

From figure:

$\frac{z}{r} = \cos\theta$

∵ 'θ' angle is along ~~z-axis~~

∵ along z-axis (potential maximum)

∵ along x y axis (zero)

$r_- \approx r + \frac{d}{2}\cos\theta$

Similarly

$r_+ \approx r - \frac{d}{2}\cos\theta$

$\therefore r_- r_+ \approx r^2 - \frac{d^2}{4}\cos^2\theta$

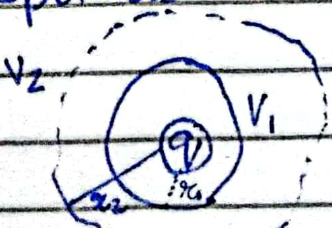
$r_- r_+ = r^2$

d is very small

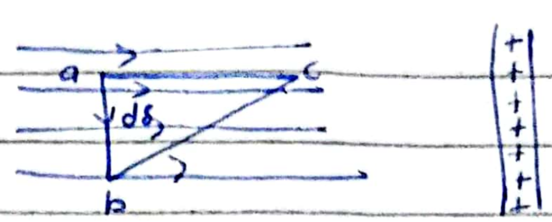
$r_- - r_+ = (d\cos\theta)$

*** Equipotential Surface:** (28.17, 28.18, 28.19)

Potential over one surface remains same and over other surface it is equal to work done. It depends on initial and final state.



:- pg #652 (MCQ's)

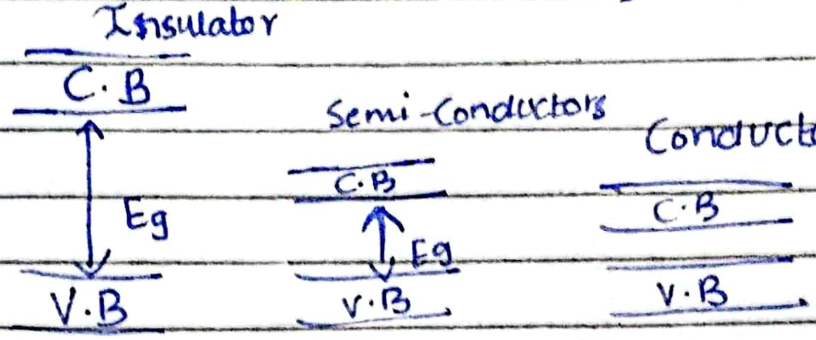


$\therefore \Delta V = \int_a^b \vec{E}\, d\vec{s}$

CHAPTER # 29

ELECTRICAL PROPERTIES OF MATERIALS

(*)

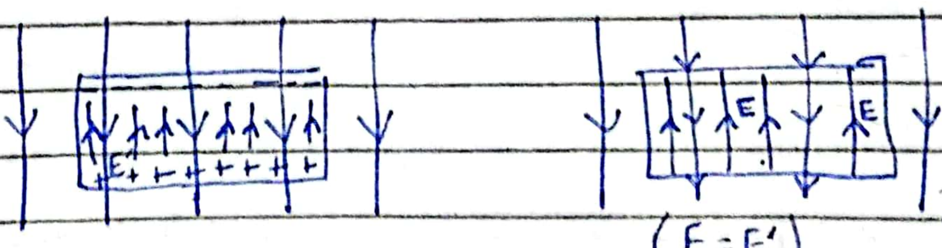


$\therefore$ Eg (Energy gap)

(*) superconductors (Resistivity zero at 0K).

(*) Conductor in an electric field.

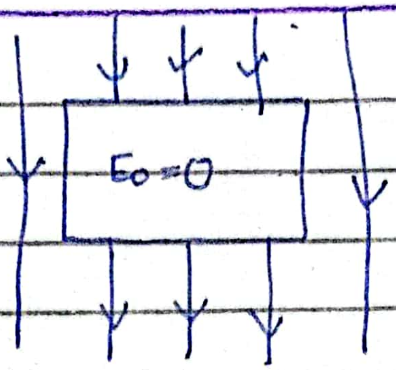
* Conductor In An Electric Field:



(E = E')

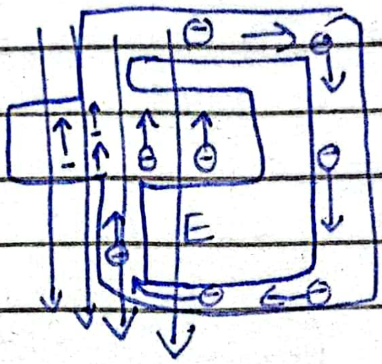
where $\vec{E}_0 = \vec{E} + \vec{E}'$

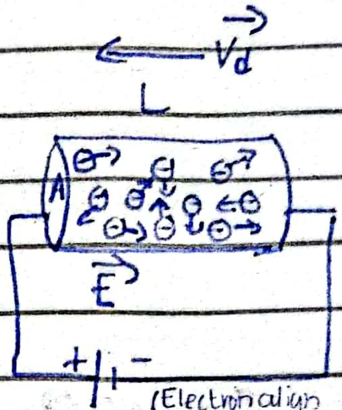
(*) When we place conductor in external or uniform ions are moved towards electrons (negative potential) and electrons move towards positive potential and electric is induced (positive) which is in opposite direction of electric field. E' (E prime)



⊛ If we develop mechanism and apply electric field and extracting electrons and injecting at other electric field.

Dynamic condition.

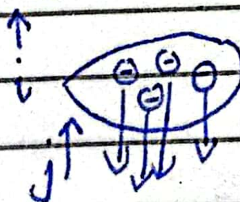




(Electron align after potential)

$$i = \frac{dq}{dt}$$ ((conventional direction)

⊙ Current Density:



$j = i/A$ (same direction as i)

⊛ Electron align in application of current in the opposite direction is called drift velocity. ($\vec{V_d}$)

⊛ Volume of conductor

$V = A \times L$

N = number of electrons in the conductor

$= nAL$ —(1)

$j = i/A$ .... (2)

$$q = nALe$$

$$i = q/t = \frac{nALe}{t}$$

$$V_d = \frac{L}{t}$$

$$t = L/V_d$$

$$i = \frac{nALe}{L/V_d}$$

$$i = nA\vec{V_d}e \longrightarrow (3)$$

: Sample Problem (1 & 2)
: pg 615

So eq (2) becomes

$$j = ne\vec{V_d}$$

$$\vec{j} = -ne\vec{V_d}$$

∴ current density & drift velocity are opposite in direction

Ex : 29-1 (1, 2, 3) (complete all)

$$q = i \times t = (4.82)(4.60 \times 60)$$
$$= 1330\ C$$

$$q = ne$$
$$n = q/e = \frac{1330}{1.6 \times 10^{-19} C}$$
$$= 8.31 \times 10^{21} \text{ electrons.}$$

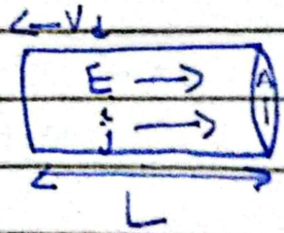
20/3/23

*** Ohmic Material:**

The material which obeys Ohm's law.

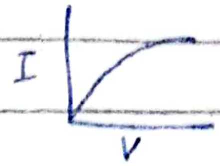
$$j \propto E$$
$$j = \sigma E \quad \ldots\ldots (i)$$

σ is conductivity :- Unit: Siemen

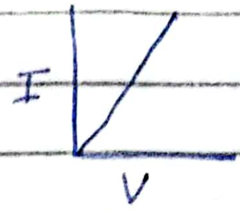


$$\sigma = \frac{1}{\rho}$$

$\because$ ρ is resistivity

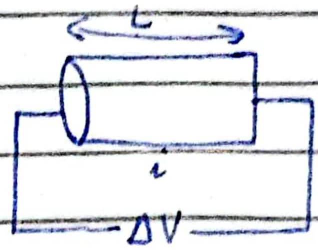


$$j = \frac{1}{\rho} E$$



$$\boxed{E = \rho j}$$

$$\boxed{\rho = \frac{E}{j}} \quad \ldots\ldots (1)$$



$$\because j = i/A \quad \ldots\ldots (2)$$

$$E = \frac{\Delta V}{L} \quad \ldots\ldots (3)$$

eq. (1) becomes:

$$\rho = \frac{\Delta V / L}{i/A}$$

$$\rho = \frac{\Delta V}{i} \frac{A}{L}$$

$\because$ Resistivity unit (ρ) (ohm.meter) (Ωm)

$$\boxed{\rho = \frac{RA}{L}}$$

where $R = \Delta V / i$

(*) ρ_0 (initial), T_0 (initial)

↓ increase

ρ , T

$\because$ Temperature changes resistivity increases (ohmic material)

$\boxed{\Delta\rho}$ $\rho - \rho_0 \propto \rho_0$

$T - T_0 \propto (\rho - \rho_0)$

$\Delta T \propto \Delta\rho$

$\rho - \rho_0 \propto \rho_0 (T - T_0)$

$\rho - \rho_0 = \alpha_{av} \rho_0 (T - T_0)$

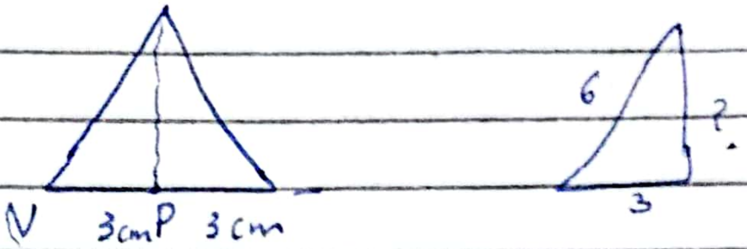
$\because$ α_{av} is temperature coefficient of resistivity.

$$\rho = R\frac{L}{A} \qquad \therefore \rho = \frac{RA}{L}$$

$$\therefore \rho_0 = \frac{R_0 A}{L}$$

$$\rho_0 = R_0\frac{L}{A} \qquad \boxed{R - R_0 = \alpha_{av} R_0 \Delta T}$$

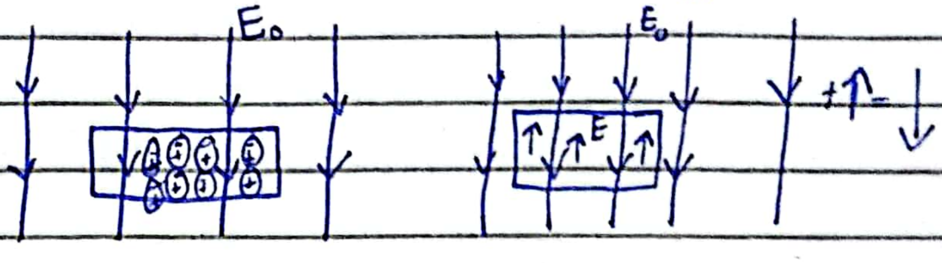
⊙ Quiz :

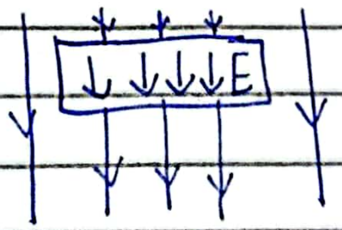


$$V = K\sum_{n=1}^{n}\frac{q_n}{r_n}$$

5|4|23

* Insulator in an electric field:





$$\boxed{E = \frac{E_0}{K_e}}$$

:- K_e is the dielectric constant

:- $K_e > 1$

(V=IR)

⊛ Ex : 12, 13, 15, 16, 17, 19, 23
(pg 676)

13) $A = 56\,cm^2 = 56\times10^{-4}\,m^2$

$L = 11\,km = 11\times10^{3}\,m$ $\qquad R = \rho\frac{L}{A}$

$\rho = 3\times10^{-7}\,\Omega\cdot m$

15)

$L = 4m$

diameter $= 6mm$

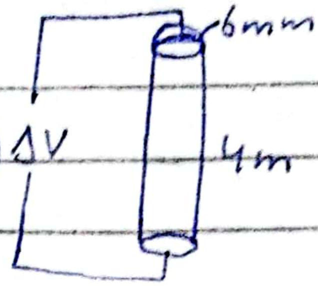
$\Downarrow$

$r = 3\ mm$

$V = 23\ V$

$R = 15 m\Omega = 15 \times 10^{-3}\ \Omega$, $j = ?$

$i = ?$, $\rho = ?$



⊙ $V = IR$

$i = \frac{V}{R}$

⊙ $j = \frac{i}{A}$

$\because A = \pi r^2$

⊙ $\rho = \frac{RA}{L}$

16)

$R_0 = 50\ \Omega$

$T_0 = 20^\circ C$

After one hour working

$R = 58\ \Omega$

$T = ?$

$\alpha_{av} = 4.3 \times 10^{-3} / ^\circ C$

⊙ $R - R_0 = \alpha_{av} R_0 (T - T_0)$

∴ Resistivity (material)

∴ Resistance (object)

⊛ Resistivity depends on material while resistance changes with shape, length, width etc....

19)

(Imp Que (Value changes))

Conductor A	Conductor B
ρ	ρ
L	L

$A_A = \pi (D/2)^2 = \frac{\pi D^2}{4}$

$R_A = \rho \frac{L}{A}$

$R_A = \rho \frac{L}{\pi D^2 / 4}$

Solid wire

$A_B = \pi \left(\frac{2D}{2}\right)^2 - \pi \left(\frac{D}{2}\right)^2$

$= \pi D^2 - \frac{\pi D^2}{4}$

$A_B = \frac{3}{4} \pi D^2$

$R_B = \rho \frac{L}{A_B} = \rho \frac{L}{\frac{3}{4}\pi D^2}$

hollow tube

$\frac{R_A}{R_B} = 3$

:- Sample Problem: 2, 5, 7

$\boxed{R_A = 3 \times R_B}$

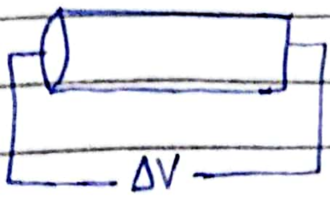
23) $\Delta V = 115\ V$

$L = 9.66\ m$

$j = 1.42\ A/cm^2$

$\delta = ?$

$j = \delta E$



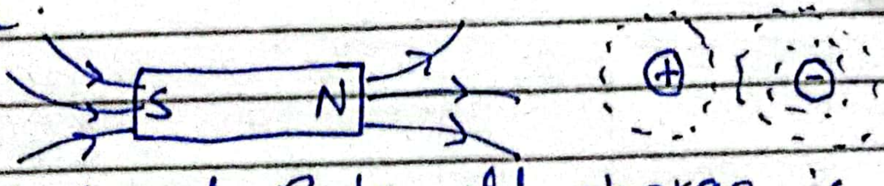
$E = \frac{\Delta V}{L}$

10/4/23

CHAPTER # 32

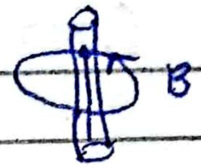
THE MAGNETIC FIELD

* Fundamental property. starts from atom and discovered by Greeks.
* North acts as positive and South acts as positive. Work done depends on path followed.



* Right hand Rule. If charge is moving, magnetic field is associated.

⊛ Magnetic field $(\vec{B})$ (Tesla):



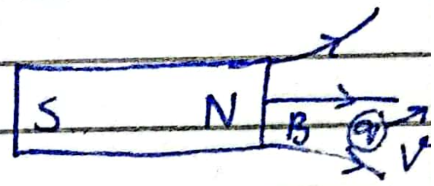
⊙ Magnetic force on a moving Charge:

$F_B \propto q$ —— (1)

$F_B \propto B$ —— (2)

$F_B \propto V$ —— (3)

$F_B \propto \sin\phi$ —— (4)



:- velocity is there but no force (case)

$F_B \propto qVB\sin\phi$

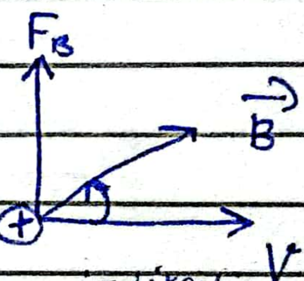
$F_B = KqVB\sin\phi$

if $K = 1$

$F_B = qVB\sin\phi$

$\vec{F_B} = q\vec{V} \times \vec{B}$

: $\vec{V} \times \vec{B} = VB\sin\phi$



$\vec{F_B} = +e\vec{V} \times \vec{B}$ (proton)

$\vec{F_B} = -e\vec{V} \times \vec{B}$ (electron)

:- direction from $\vec{V}$ to $\vec{B}$ gives force.

$B = \dfrac{F}{qV}$:- $\dfrac{1 \text{ Newton}}{1 C \cdot 1 m/s}$

:- $1 N/A\cdot m$

:- Lorentz force:

:- Magnetic + electric

$L_F = F_B + F_E$

$= E + B$

if $L_F = 0$, no effect.

⊙ Lorentz force:

When both electric field $\vec{E}$ and magnetic field $\vec{B}$ act on a charge q, then sum of electric and magnetic force is called Lorentz force.

$\vec{F} = \vec{F_e} + \vec{F_B}$

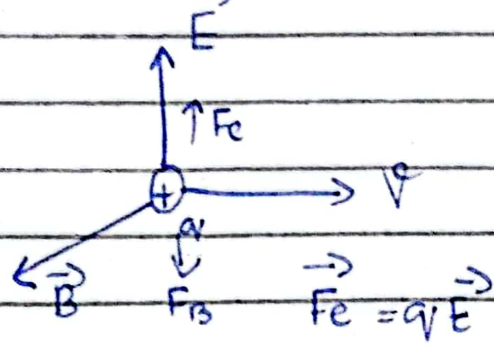
$\vec{F} = q\vec{E} + q\vec{V} \times \vec{B}$

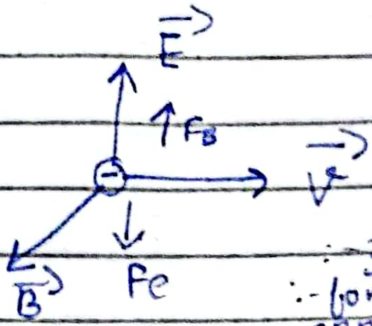
:- $F_e = q\vec{E}$:- $\vec{F_B} = q\vec{V} \times \vec{B}$

Can $\vec{F}$ be zero?

Yes, if $F_e = F_B$ in magnitude and are opposite in direction.

(*)





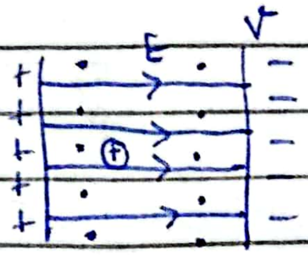
∴ zero
∴ for electron opposite electric field

$$qE = qVB$$

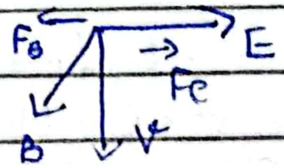
$$\boxed{V = \frac{E}{B}}$$

∴ positive charge moves in electric field

(*)



∴ $V = E/B$



∴ pg 243 (Numerical 2 to 7) (Exercise) (H.W)