12th BOARD HACKER

Current Electricity

Electric current – Rate of flow of charge through wire

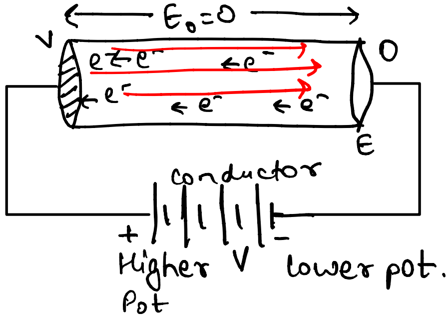
- conductors $\boxed{e^- \; e^- \; e^+}$ free e^-
  ⊕ charges are fixed in conductor

- current will be due to e^- only

- when there is no battery all e^- are in random motion

- no net current in conductor

- when battery is apply, there is force on e^- & they start moving towards (+) terminal.



$$I = \frac{\text{charge flow}}{\text{time}} = \frac{q}{t} \quad \text{unit} = A$$

dimension = [A]

$$\boxed{I = \frac{dq}{dt}, \quad \int dq = \int I.\,dt}$$

- electric field outside a current carrying conductor is zero but inside a conductor is V/L

- $I = (2+3t)A$. charge crossed in first 10 seconds

$$dq = I.dt$$

$$q_T = \int_0^{10} (2+3t).dt = 2[t]_0^{10} + 3\left[\frac{t^2}{2}\right]_0^{10}$$

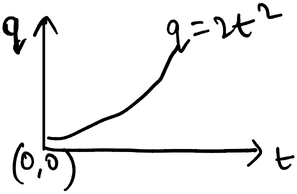
$$= 2(10-0) + \frac{3}{2}(10^2 - 0^2)$$

$$= 20 + \frac{3}{2} \times 100 = \boxed{170C}$$

- $q = 2t^2$

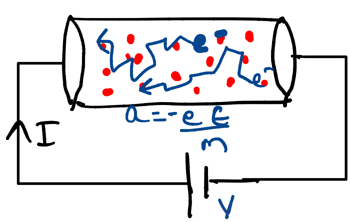
$$I = \frac{dq}{dt} = \frac{d(2t^2)}{dt} = 4t$$

$I = 4t$ at $t = 3 \Rightarrow I = 12A$



Drift velocity & Mobility — avg. velocity with which e^- drift towards the positive terminal of battery.

- Let there be battery of voltage V is applied across conductor of length 'L'.



- all e^- experience force

$$\vec{F} = -e\vec{E}$$

$$a = -e\vec{E}/m$$

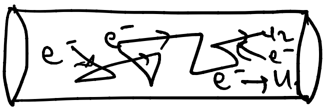
— due to force all e^- experiences collision with atoms & drift towards ⊕ terminal of battery.

$$V_{drift} = \vec{V}_{avg} = \frac{\vec{V_1} + \vec{V_2} + \vec{V_3} + \cdots \vec{V_n}}{n}$$

$$= \frac{u_1 + u_2 + \cdots u_n}{n} \to 0 \; - \frac{e\vec{E}}{m} \frac{(t_1 + t_2 + t_3 + \cdots)}{n}$$

$$V_{drift} = \vec{V}_{avg} = \frac{-e\vec{E}}{m}\tau$$

τ = avg. time for collision = relaxation time



— e^- are in random motion
— there is no net flow of charge

let e^- have initial velocity $\vec{u_1}, \vec{u_2}, \vec{u_3} \cdots \vec{u_n}$

$$\vec{u}_{avg} = \frac{\vec{u_1} + \vec{u_2} + \vec{u_3} + \cdots \vec{u_n}}{n} = 0$$

velocity of all e^- at time 't'.

$$\vec{V_1} = \vec{u_1} - \frac{e\vec{E}}{m} t_1$$

$$\vec{V_2} = \vec{u_2} - \frac{e\vec{E}}{m} t_2$$

$$\vec{V_n} = \vec{u_n} - \frac{e\vec{E}}{m} t_n.$$

$\boxed{\text{Mobility} -}$ drift velocity attained per unit EF.

$$\mu = \frac{V_d}{E} = \frac{eE\tau}{mE} = \frac{e\tau}{m}$$

$m \downarrow \quad \mu \uparrow$

$\mu_e > \mu_p$

$\mu_e > \mu_n$.

$\boxed{\text{Current density}}$

⊕ flow dirⁿ → I (conventional)
⊖ flow dirⁿ → opp. to dirⁿ of I.

$\vec{J}$ = current density = amount of current passing per unit area.

$\vec{J} = \frac{I}{A}$ unit $= \frac{A}{m^2}$ Dim $= [AL^{-2}]$

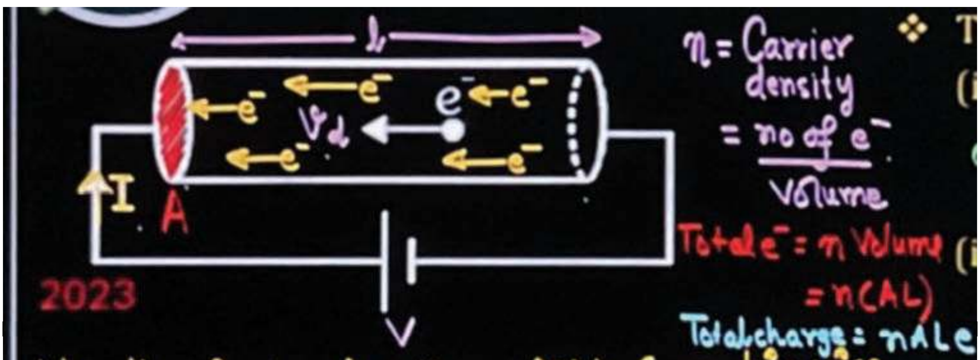
$\vec{J}$ is a vector quantity (dirⁿ is same as that of current)

∴ Other form $= \vec{J}.\vec{A} = I$ $\boxed{I = JA\cos\theta}$

example – $\vec{J} = (2 \times 10^4 \hat{j})\ Am^{-2}$
find the current through area $\vec{S} = (2\hat{i} + 3\hat{j})\ cm^2$

solⁿ – $\vec{J} = (2 \times 10^4)\hat{j}\ Am^{-2}$
$\vec{A} = (2\hat{i} + 3\hat{j})(10^{-2})^2\ m^2$
$I = \vec{J}.\vec{A}$
$(2 \times 10^{-4}) \times 0 + 3 \times 10^{-4} \times 2 \times 10^4$
$\boxed{I = 6A.}$

Relation between current and drift velocity



when there is V_d of e⁻ there will be current in wire

$I = \frac{\text{charge}}{\text{time}} = \frac{nALe}{t}$ $\quad \boxed{I = neAV_d}$

I — current; n — carrier density; e — e^- charge; A — area of cross-section; V_d — drift velocity.

speed $= \frac{d}{t}$

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

carrier density $= \frac{\text{no. of } e^-}{\text{volume}}$ → depends on nature of cond.

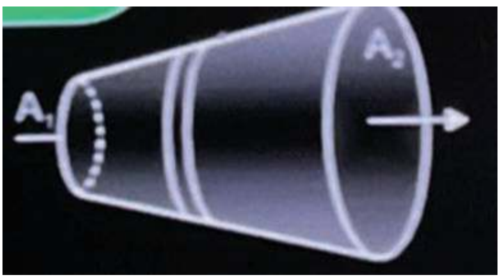
* The conductor remains uncharged.

i) It is same along the wire

$$I_1 = I_2$$

$$I = neAV_d$$

ii) Current density, electric field strength, drift velocity are inversely proportional to area. Here $I_1 = I_2$ but $A_1 < A_2$, so $J_1 > J_2$, $E_1 > E_2$, $V_{d_1} > V_{d_2}$.



conductor of random shape

$AV_d =$ const. $\quad J = \frac{I}{A}$ (same)

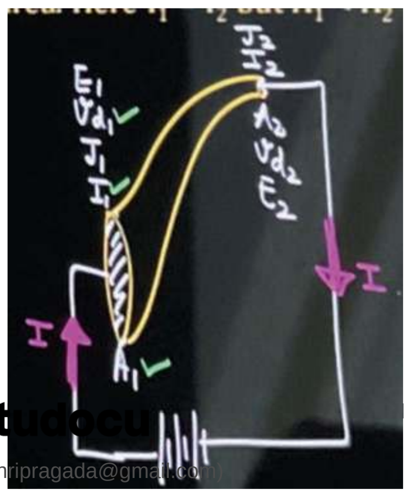
$$\vec{J} = \sigma \vec{E}$$

$A_1 > A_2$

$V_{d_1} < V_{d_2}$

$J_1 < J_2$

$E_1 < E_2$.



Ohm's law, Resistance, Resistivity

↳ when we apply battery of voltage V across a conductor, relation between V & I.

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

$I = neAV_d$

$$I = neA\frac{eE\tau}{m}$$

$$I = \frac{ne^2\tau AE}{m}$$

$$I = I\left(\frac{ml}{ne^2\tau A}\right)$$

Resistance, $R = \dfrac{ml}{ne^2\tau A}$

length of conductor → $R \propto l$

area of cross section − $R \propto \frac{1}{A}$

nature of Mat. → $R \propto \frac{1}{n}$

Temp. → $R \propto \frac{1}{\tau}$

ohm's law −

at low & const. temp. $V_{app} \propto I_{\text{through cond}}$.

resistivity − depends on temperature

− temp ↑ − collision rate ↑ − time b/w collision

− τ = avg. time of collision ↓ ⇒ R ↑.

$\boxed{R = R_0(1 + \alpha \Delta T)}$

↳ R at 0°C

↳ change in temp.

↳ temp. coeff. of resistance

$$\boxed{R = \rho\frac{l}{A}, \quad \rho = \rho_0(1 + \alpha \Delta T)}$$

Microscopic ohm's law vector form law from relation −1 $\dfrac{I}{A} = \dfrac{ne^2\tau E}{m}$, $\vec{J} = \dfrac{\vec{E}}{\rho} \Rightarrow \vec{J} = \sigma\vec{E}$

$\sigma = \dfrac{1}{\rho}$ = conductivity.

(property of cond by which it opposes flow of current through it) unit = Ω ohm

$R = \dfrac{V}{I} = [ML^2T^{-3}A^{-2}]$

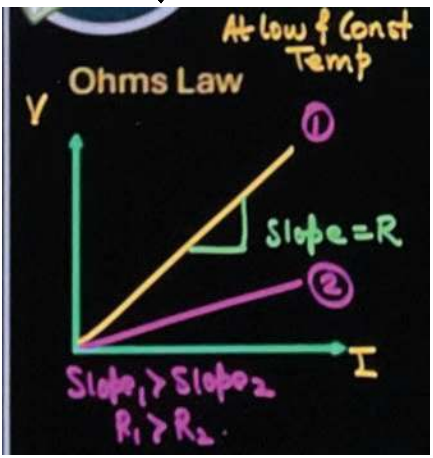
$\boxed{V \propto I} \Rightarrow \boxed{V = IR}$ $\boxed{R = \frac{V}{I}}$

conductance $\Rightarrow$ $G = \frac{1}{R}$

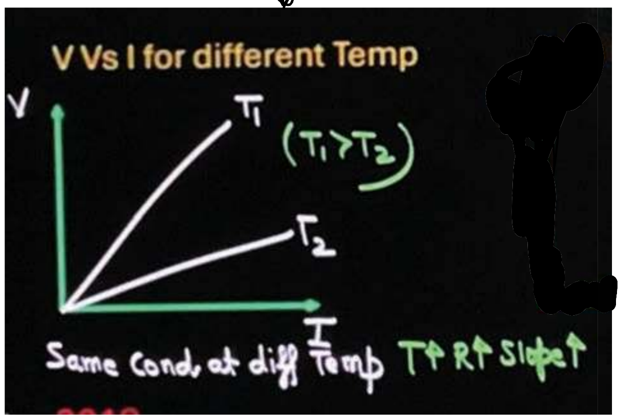
unit $= \Omega^{-1}$, mho, siemen, S.

Important graphs

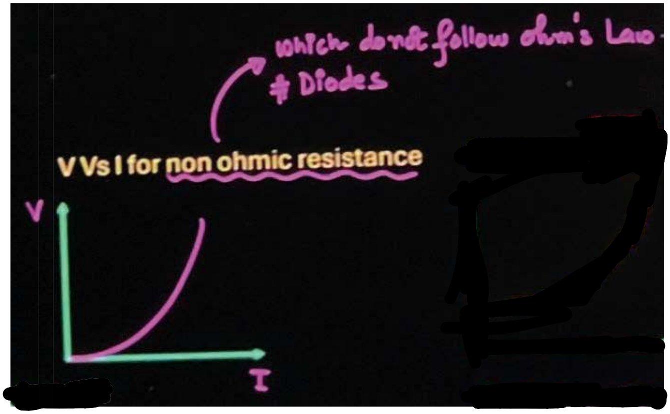
ohm's law



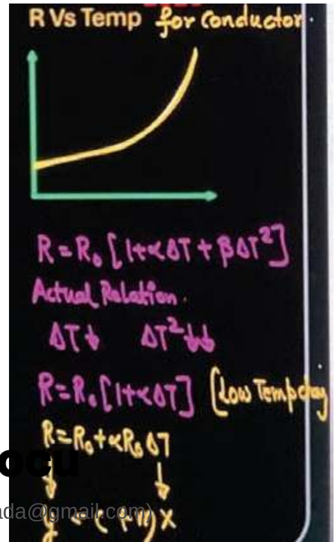
V vs I for diff. temp.



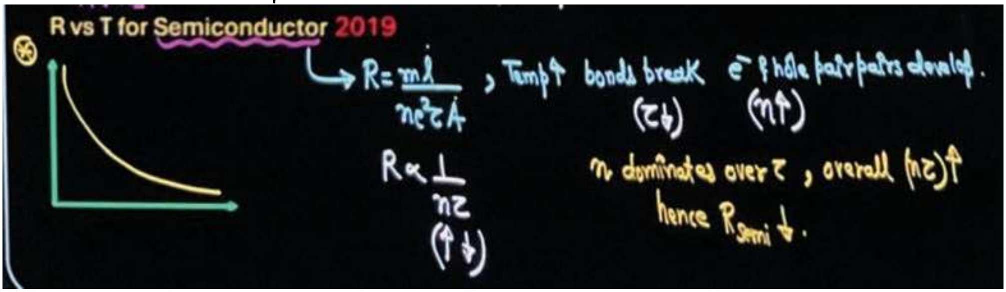
V vs I for non-ohmic resistance



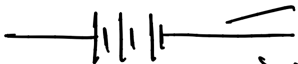
R Vs temp for conductor



R Vs T for semiconductor



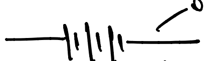
Combination of Cells



open PD = E

close PD = E

Ideal $r_i = 0$



E, r

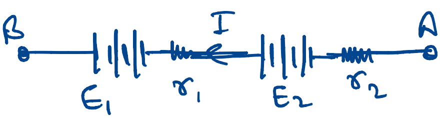
open ckt P.D = E

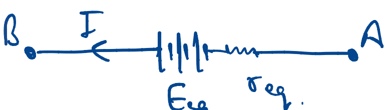
while discharging, close ckt PD = E − Ir

when battery is charge

PD = E + Ir

a) Series combination





$$V_A - Ir_2 + E_2 - Ir_1 + E_1 = V_B$$

$$\boxed{E_2 + E_1 - I(r_1 + r_2) = V_B - V_A} \rightarrow (1)$$

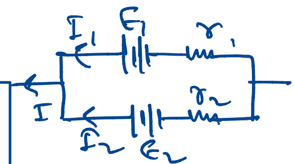
$$V_A - Ir_{eq} + E = V_B$$

$$\boxed{E_{eq} - Ir_{eq} = V_B - V_A} - (2)$$

b) Parallel combination

$$I = I_1 + I_2$$

$$\boxed{\frac{E_{eq}}{r_{eq}} = \frac{E_1}{r_1} + \frac{E_2}{r_2}}$$



If there are n batteries

$$\frac{E_{eq}}{r_{eq}} = \frac{E_1}{r_1} + \frac{E_2}{r_2} + \frac{E_3}{r_3} + \cdots$$

on comparing 1 & 2

$E_{eq} = E_1 + E_2 \qquad r_{eq} = r_1 + r_2$

If n batteries tnt

$E_{eq} = E_1 + E_2 + E_3 + \dots E_n$

$r_{eq} = r_1 + r_2 + r_3 + \dots r_n$

In n equal battery

$E_{eq} = nE \qquad r_{eq} = nr$

n identical batteries in parallel.

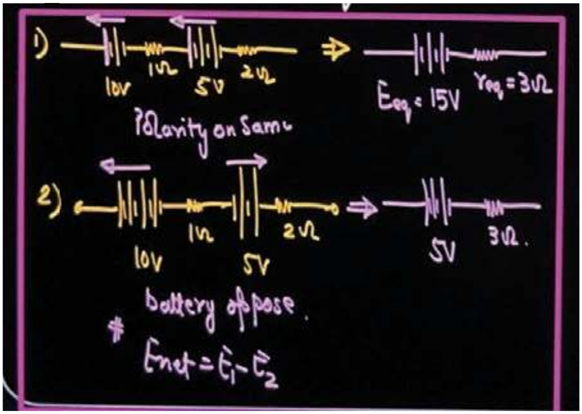
$\frac{1}{r_{eq}} = \frac{1}{r} + \frac{1}{r} + \frac{1}{r} + \dots$

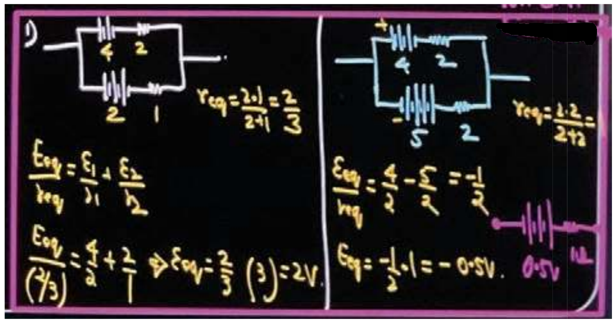
$\frac{1}{r_{eq}} = \frac{n}{r} \Rightarrow \boxed{r_{eq} = \frac{r}{n}}$

$\frac{E_{eq}}{r_{eq}} = \frac{E}{r} + \frac{E}{r} + \dots n \text{ times}$

$\frac{E_{eq}}{r_{eq}} = \frac{nE}{r} \cdot r_{eq} = E \cdot \frac{n}{r}\left(\frac{r}{n}\right)$

$= E$

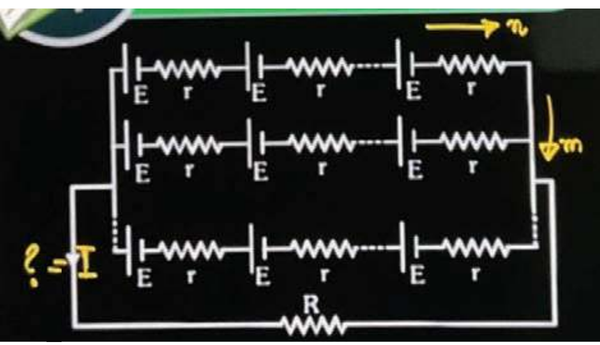


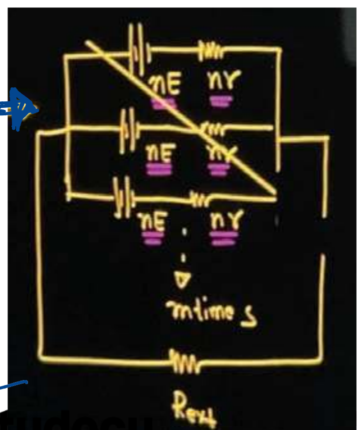


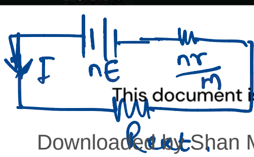
$\boxed{\text{Battery griding}}$

n identical batteries in series & m rows

– find current in Rext.







$$\boxed{I = \frac{V_T}{R_T} = \frac{nE}{R_e + \frac{nr}{m}}}$$

What is the condⁿ for I to be maxᵐ –

$$I = \frac{mnE}{mR + nr}$$

$I = \max^m$

deno. → minᵐ

$$mR + nr = (\sqrt{mR})^2 + (\sqrt{nr})^2$$

$$\min^n = (\sqrt{mR})^2 + (\sqrt{nr})^2 + 2\sqrt{mnRr} - 2\sqrt{mnRr}$$

$$= \underbrace{(\sqrt{mR} - \sqrt{nr})^2}_{=0} + 2\sqrt{mnRr}$$

condⁿ, $\sqrt{mR} = \sqrt{nr}$

$$mR = nr$$

$$R = \frac{nr}{m}$$

when Rext of ckt is equal net internal resistance of batteries

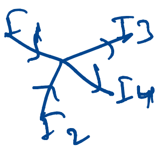
$I \rightarrow \max^m$.

$\boxed{\text{Kirchoff's Laws}}$

first law or junction law (Kirchoff's current law) (KCL)

The total current entering a junⁿ or a node is equal to charge leaving the node as no charge is lost

Based on charge conservation.

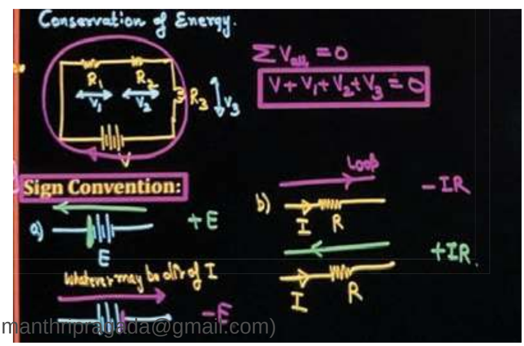


- net current at any juncⁿ = zero
- sign $I_{incoming} = -ve$
  $I_{outgoing} = +ve$

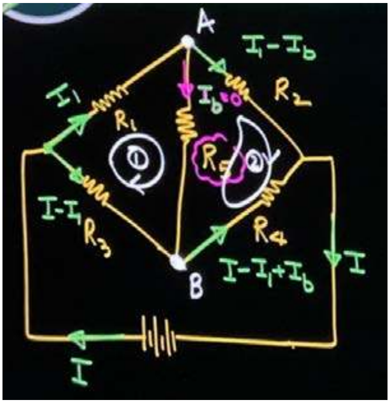
$$-I_1 - I_2 + I_3 + I_4 = 0$$

Second law or Juncⁿ law (Kirchoff's Voltage law) (KVL)

The voltage around a loop equals the sum of every voltage drop in the same loop for any closed network and equals zero



Wheatstone Bridge



Combination of 5 Resistance as shown in which if there is no current in bridging Resistance

→ $V_A = V_B$ → $I_b = 0$

→ $\frac{R_1}{R_2} = \frac{R_3}{R_4}$

→ this condⁿ is c/a balanced WSB

KVL for loop 1 $+R_3(I - I_1) - I_1 R_1 - I_b R_5 = 0$

KVL for loop 2 $+I_b R_5 - (I_1 - I_b) R_2 + (I - I_1 + I_b) R_4 = 0$

In balanced condⁿ $I_b = 0$

$R_3 (I - I_1) = I_1 R_1$

$R_4 (I - I_1) = I_1 R_2$

Ratio ⇒ $\boxed{\frac{R_1}{R_2} = \frac{R_3}{R_4}}$

Meter Bridge

— working principle = balanced condⁿ of WSB.

applicⁿ of WSB = to find value of unknown resistance

⇒ It has a wire of length '1m'

when there is no deflection in Jockey ($I_g = 0$) WSB is balanced.

$$\frac{R_K}{R_u} = \frac{\rho L}{A} \Big/ \frac{\rho(100 - l)}{A}$$

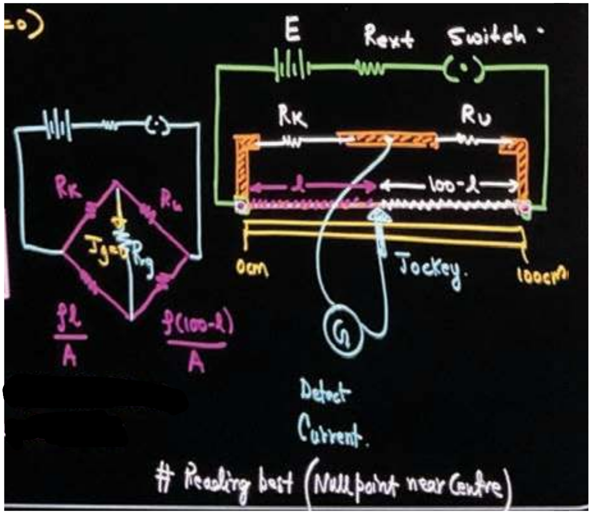
$$\frac{R_K}{R_u} = \frac{l}{100-l} \Rightarrow R_u = R_K \frac{(100-l)}{l}$$

R_K = known resistance

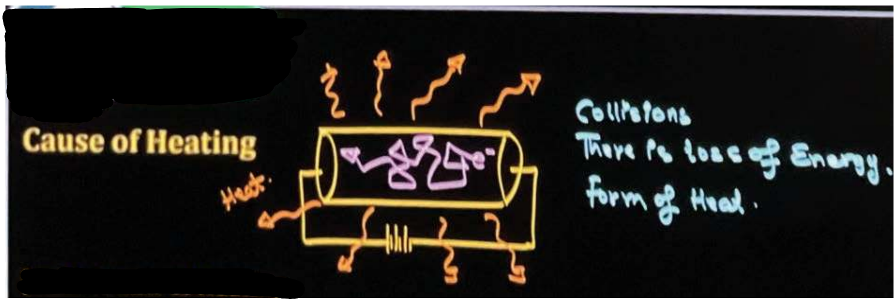
R_u = unknown resistance

end correction

wire endings at screw give additional resistance if we consider that resistance also, it is called end correction.



Heat



Joules law of heating — when a current I is made to flow through a ohmic resistance R for time t, heat Q is produced such that

$$\text{heat} = I^2Rt$$
$$= \frac{V^2}{R}t$$
$$= VIt$$

heat produced in a conductor does not depend upon the direction of current.

SI unit = J

Power through bulbs

[redacted]

Power: Rate of doing work

$P = \frac{Heat}{t}$

$$\boxed{P = VI = \frac{V^2}{R} = I^2R}$$

unit = Watts.

Commercial unit = Kwh.

Bulb: 2020

$P_0 = \frac{V_0^2}{R}$

$$\boxed{R_{bulb} = \frac{V_0^2}{P_0}}$$

→ doesn't vary.

Tungsten filament

① High Melting point.

② Not Easily oxidised

③ R doesn't vary Rapidly Temp.

$\begin{cases} P_0 = \text{Rated Power} \\ V_0 = \text{Rated Voltage.} \end{cases}$

Jo upar likha hai.

Ex:- 100 Watt, 220V.

Jab 220V milega tab 100 Watt power dega.

$\boxed{\text{More is Power in ckt} \Uparrow \text{ More is the Brightness}}$

$P_{ckt} = \frac{V_{apply}^2}{R} = \frac{V^2}{V_0^2} P_0.$

$P_{ckt} = \left(\frac{V}{V_0}\right)^2 P_0$

→ $V < V_0$ Brightness ↓

→ $V = V_0$ $P = P_0$.

→ $V > V_0$ Brightness ↑.

Series Combination I = Same, $(P = I^2R)$ better

Parallel Combination V = Same, $\left(P = \frac{V^2}{R}\right)$ better.

Brightness/Power ⇒ Replace all bulbs by $R = \frac{V_0^2}{P_0}$ & then find Power in ckt, P↑ B↑, P↓ B↓.

(a) Series combinations 2024,2019

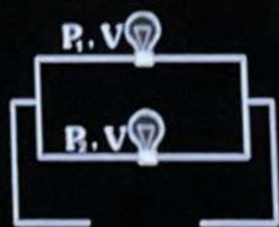
$R_s = R_1 + R_2$

$\frac{V^2}{P_s} = \frac{V^2}{P_1} + \frac{V^2}{P_2}$

$$\boxed{\frac{1}{P_s} = \frac{1}{P_1} + \frac{1}{P_2}}$$

(b) Parallel Combination 2023,2019

Parallel Comb.



$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$

$\frac{P_p}{V^2} = \frac{P_1}{V^2} + \frac{P_2}{V^2}$

$$\boxed{P_p = P_1 + P_2}$$

THANK YOU !!