JEE MAIN

# CURRENT ELECTRICITY FORMULAE

*Now that's how you REVISE*

-Mohit Goenka, IIT Kharagpur

# List of Content on Eduniti YouTube Channel:

1. PYQs Video Solution Topic Wise:
   (a) JEE Main 2018/2020/2021 Feb & March
2. Rank Booster Problems for JEE Main
3. Part Test Series for JEE Main
4. JEE Advanced Problem Solving Series
5. Short Concept Videos
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7. JEE Advanced PYQs

........and many more to come

## 1. CHARGE FLOW

$$q_{flown} = \int_{t_1}^{t_2} i(t)\,dt$$

Ex: $i(t) = 2\sin 50\pi t$

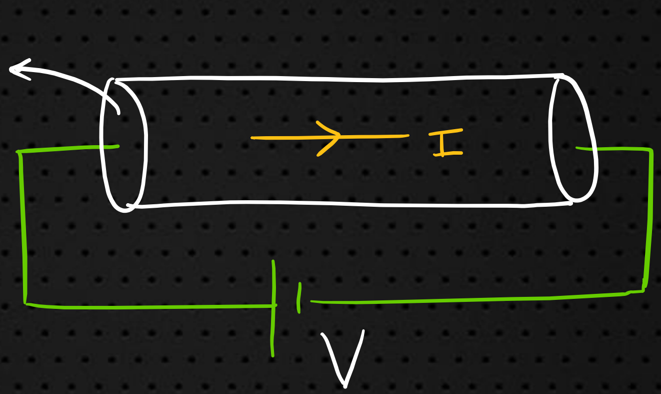
$i(t) = 3t^2$

## 2. IMPORTANT CURRENT PARAMETERS

→ DRIFT VELOCITY, $V_d = \dfrac{eE\tau}{m}$

"$\tau$" Relaxation time (avg time elapsed between two collisions)

→ $I = neAV_d$




$n$: no of free $e^-$ per unit volume

→ MOBILITY, $\mu = \dfrac{V_d}{E} = \dfrac{eE\tau/m}{E} = \dfrac{e\tau}{m}$

$(m^2/Vs)$


→ CURRENT DENSITY, $J = I/A \Rightarrow I = \vec{J}\cdot\vec{A}$

$(A/m^2)$

$\boxed{E = \rho J}$ $\rho$: Resistivity

# 3. RESISTANCE $\left(R = \underbrace{\frac{m}{ne^2\tau}}_{\rho}\frac{l}{A}\right)$, ohm ($\Omega$)

$\rho$ : resistivity, $\sigma = \frac{1}{\rho}$ → conductivity

R DEPENDS ON :

- $R \propto l$
- $R \propto 1/A$
- If temperature increases, Resistance also increases. $\left\{\rho = \frac{m}{ne^2\tau}\right.$, If $T\uparrow \Rightarrow \tau\downarrow \Rightarrow \rho\uparrow$
  $\Rightarrow R\uparrow$

  → For SEMICONDUCTORS

  If $T\uparrow \Rightarrow \rho\downarrow$
  $\Rightarrow R\downarrow$

  (on $\uparrow T$, $n\uparrow$ dominating $\downarrow$ in $\tau$)

For small variation in temp°

$R_{T_2} = R_{T_1}(1+\alpha\Delta T)$,

$\rho_{T_2} = \rho_{T_1}(1+\alpha\Delta T)$

Source : NCERT

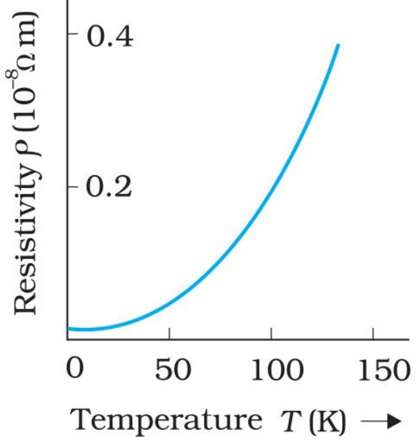



**FIGURE 3.9** Resistivity $\rho_T$ of copper as a function of temperature $T$.

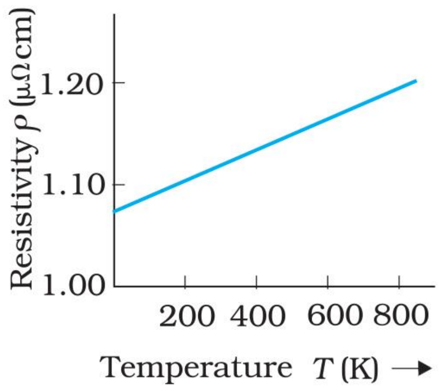



**FIGURE 3.10** Resistivity $\rho_T$ of nichrome as a function of absolute temperature $T$.

→ Manganin and constantan

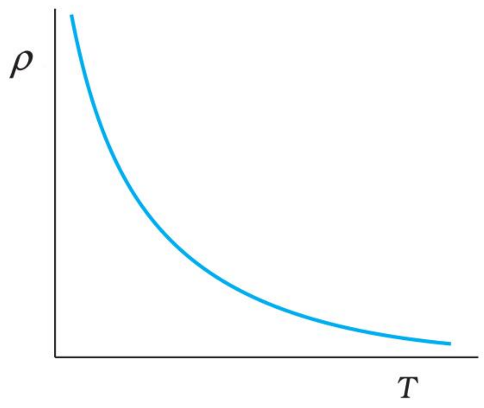
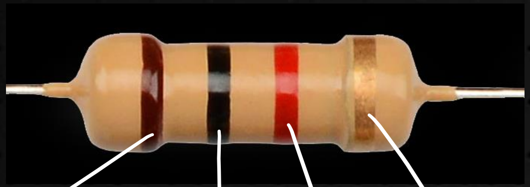



**FIGURE 3.11** Temperature dependence of resistivity for a typical semiconductor.

# 4. COLOUR CODE



BROWN 1

BLACK 0

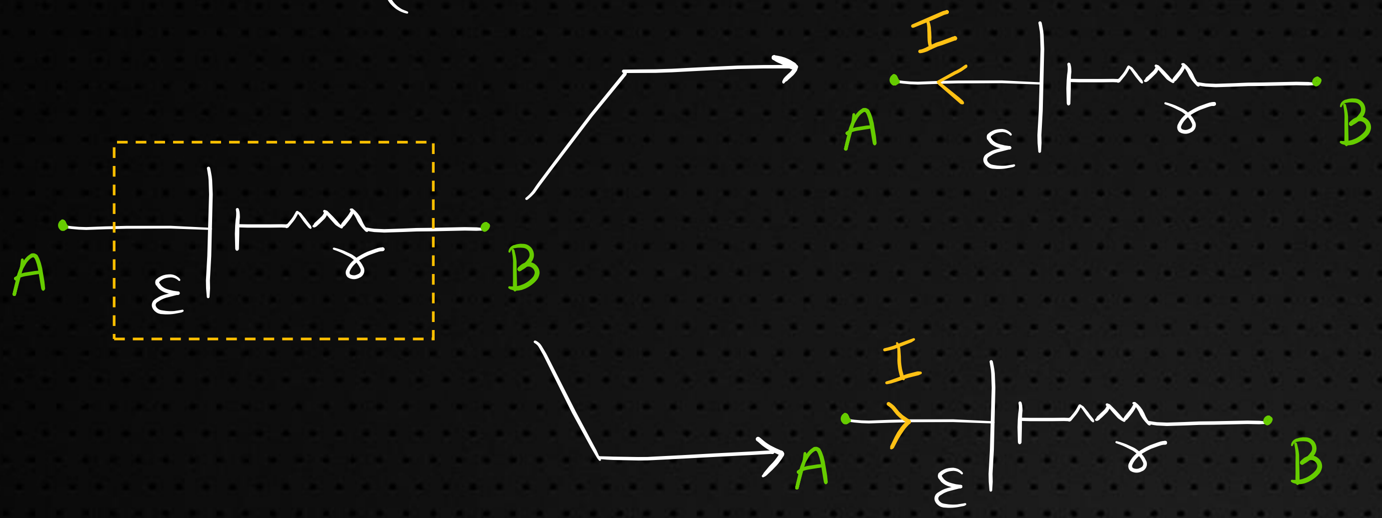
RED 2

GOLDEN $\pm 5\%$

$$R = 10 \times 10^{2} \pm 5\%$$

| Resistor colour codes | | | |
|---|---|---|---|
| **Colour** | **Number** | **Multiplier** | **Tolerance (%)** |
| Black | 0 | $10^0$ | |
| Brown | 1 | $10^1$ | |
| Red | 2 | $10^2$ | |
| Orange | 3 | $10^3$ | |
| Yellow | 4 | $10^4$ | |
| Green | 5 | $10^5$ | |
| Blue | 6 | $10^6$ | |
| Violet | 7 | $10^7$ | |
| Gray | 8 | $10^8$ | |
| White | 9 | $10^9$ | |
| Gold | | $10^{-1}$ | 5 |
| Silver | | $10^{-2}$ | 10 |
| No colour | | | 20 |

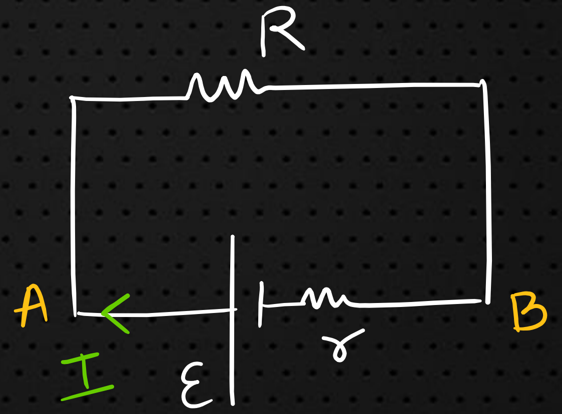
## 5. CELL (Emf, Internal Resistance)




$V_{AB} = \varepsilon - Ir$, Work done by battery

$V_{AB} = \varepsilon + Ir$, Work done on the battery (charging)

\# Alternative:

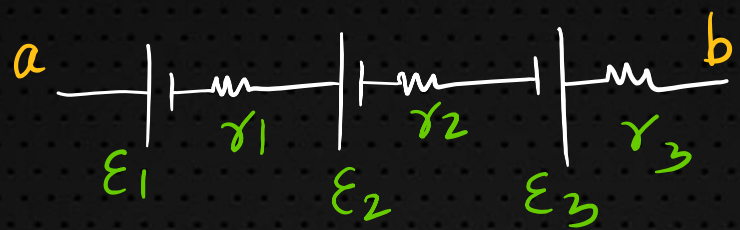



$V_{AB} = IR$

$$\boxed{V_{AB} = \frac{\varepsilon R}{r+R}}$$

# 6. COMBINATION OF CELL

SERIES

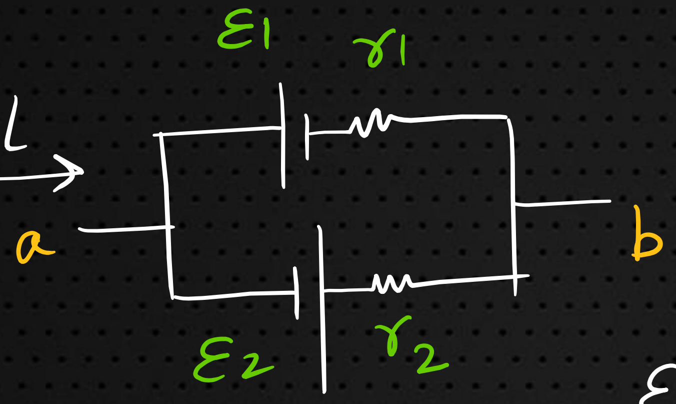



$\Rightarrow$


$$\varepsilon_{eq} = \varepsilon_1 + \varepsilon_2 - \varepsilon_3$$

$$r_{eq} = r_1 + r_2 + r_3$$

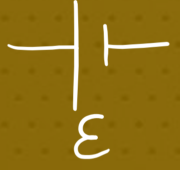
PARALLEL




$\Rightarrow$


$$\varepsilon_{eq} = \frac{\frac{\varepsilon_1}{r_1} - \frac{\varepsilon_2}{r_2}}{\frac{1}{r_1} + \frac{1}{r_2}} \quad , \quad \frac{1}{r_{eq}} = \frac{1}{r_1} + \frac{1}{r_2}$$

Here we took



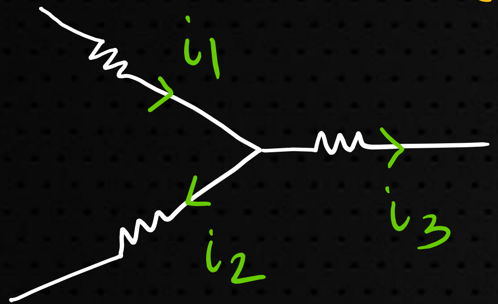

as $+\varepsilon$

# 7. KIRCHHOFF's LAW (KVL and KCL)

KVL → LOOP RULE

KCL → JUNCTION RULE

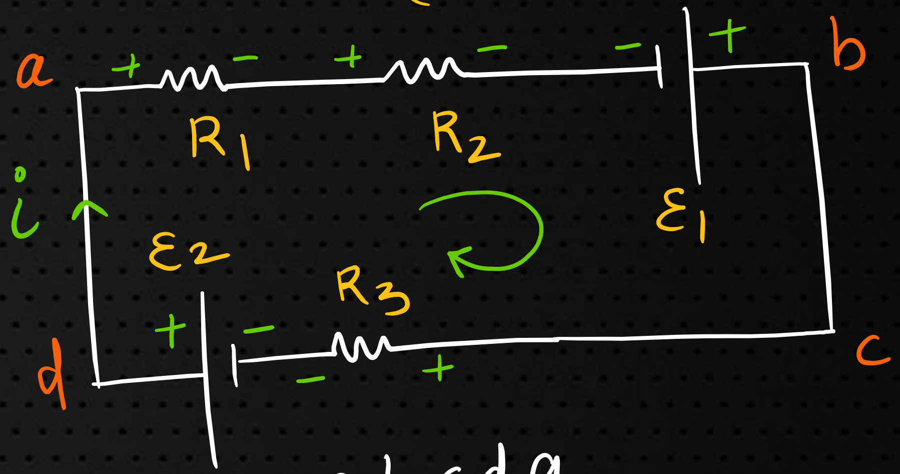
## KCL ($\Sigma i_n = 0$)




$i_1 - i_2 - i_3 = 0$

(i towards Junction is taken +VE)

## KVL ($\Sigma V_n = 0$) In a Loop

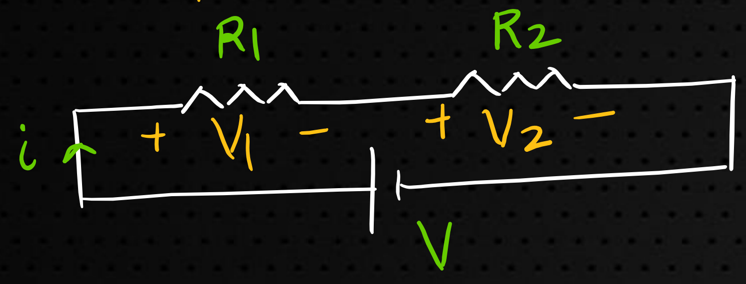



In Loop abcda

$$iR_1 + iR_2 - \varepsilon_1 + iR_3 - \varepsilon_2 = 0$$

# 8. CIRCUIT ANALYSIS MORE TECHNIQUES

## P.d. distribution



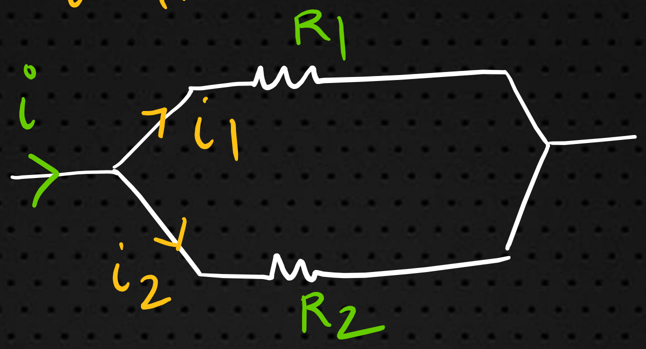

$\because$ $i$ is same

$\Rightarrow V \propto R$

$$V_1 = \frac{VR_1}{R_1+R_2},$$

$$V_2 = \frac{VR_2}{R_1+R_2}$$

## i distribution



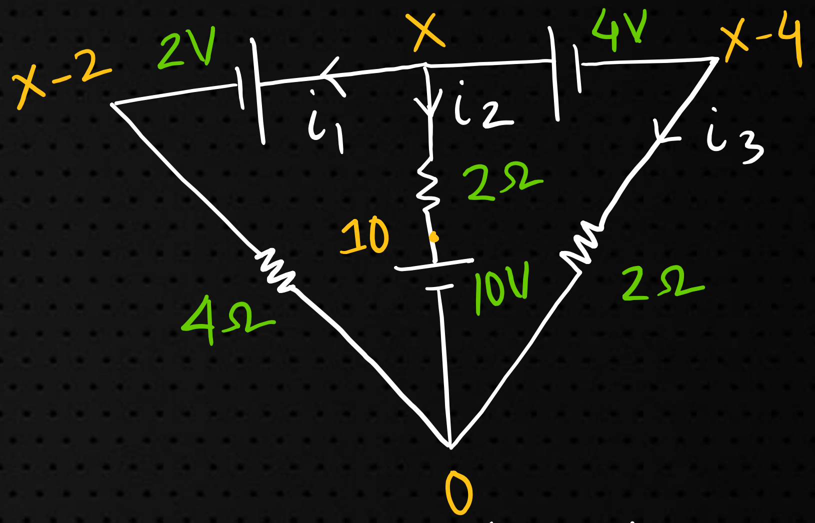

$\because$ V is same

$\Rightarrow i \propto 1/R$

$$i_1 = \frac{iR_2}{R_1+R_2}$$

$$i_2 = \frac{iR_1}{R_1+R_2}$$

## Point Potential Method




$$i_1 + i_2 + i_3 = 0$$

$$\Rightarrow \frac{x-2}{4} + \frac{x-10}{2} + \frac{x-4}{2} = 0$$

$$x = 6V$$

# 9. COMBINATION OF RESISTORS

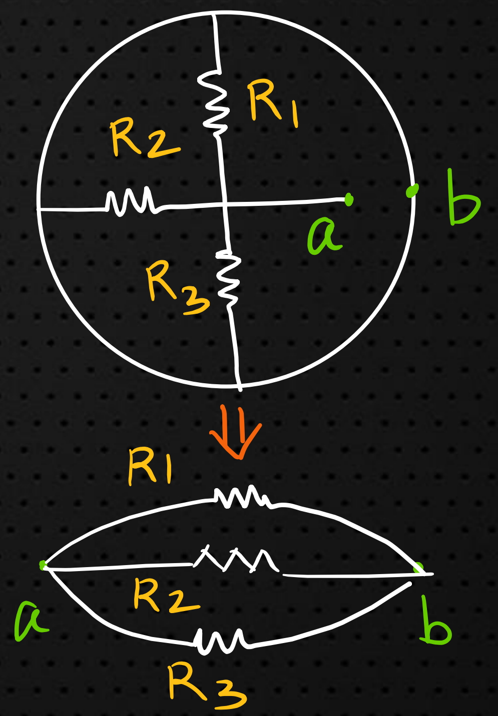
## SERIES

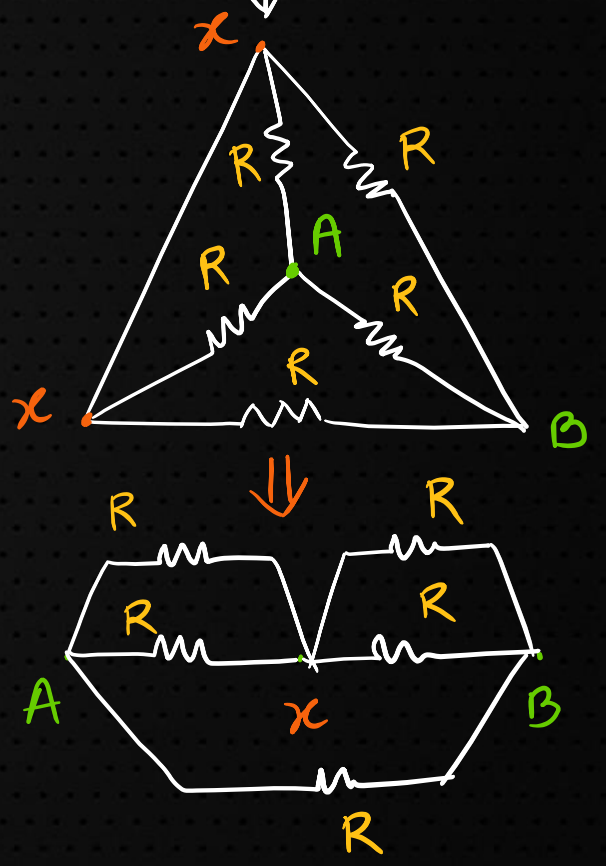

$$R_{eq} = R_1 + R_2$$

## PARALLEL

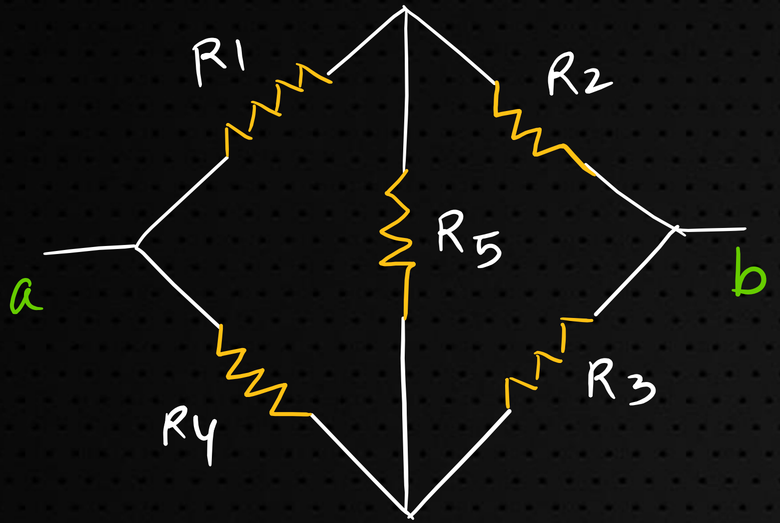

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\Rightarrow R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$$

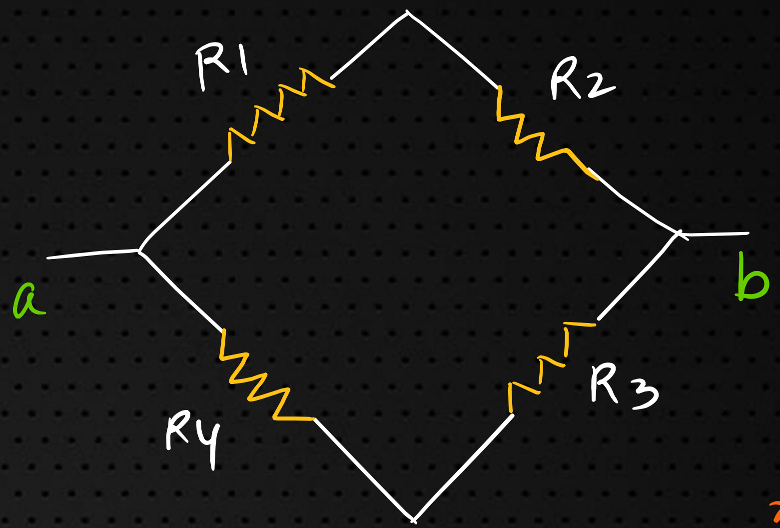


## 10. WHEATSTONE BRIDGE (BALANCED)

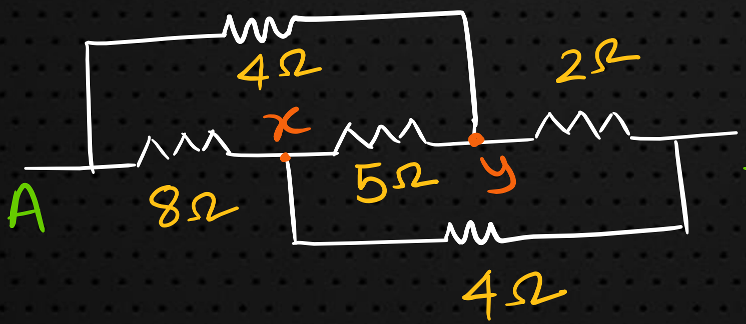



If
$R_1 R_3 = R_2 R_4$
$\longrightarrow$

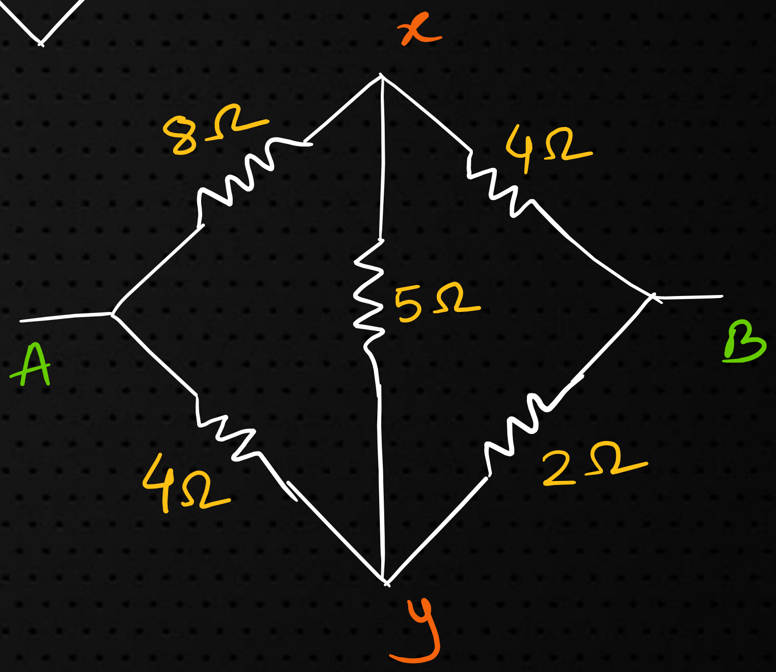



$$\left\{ \frac{R_1}{R_2} = \frac{R_4}{R_3} \right\}$$

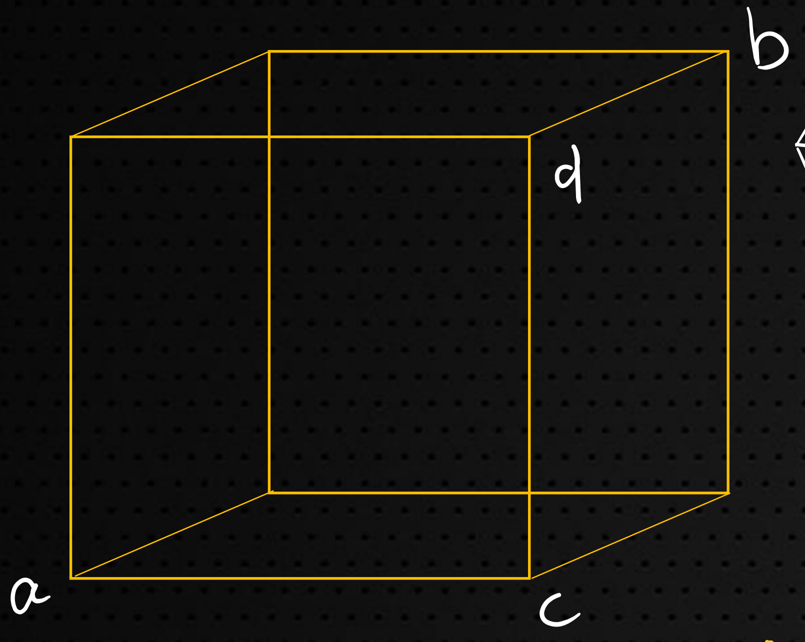
\# Alternative fig.




$\Rightarrow$



## 11. CUBE RESISTORS

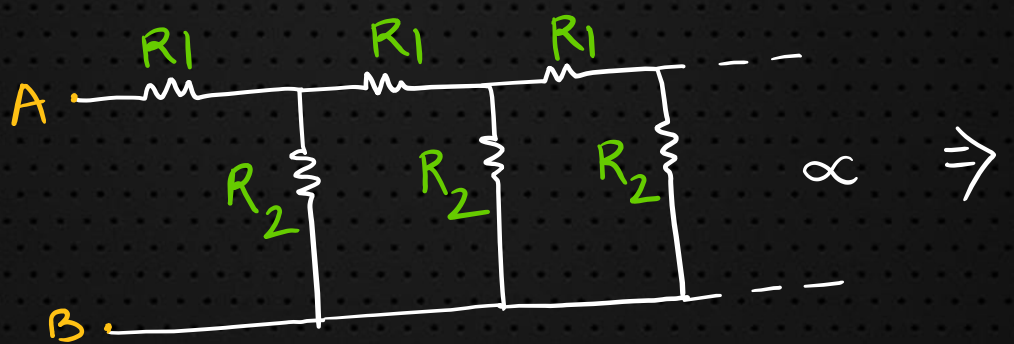



$R_{eq,ab} = 5R/6$ (body diagonal)

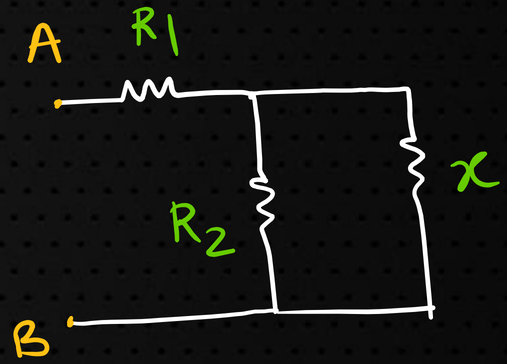
$R_{eq,ac} = 7R/12$ (edge)

$R_{eq,ad} = 3R/4$ (face diagonal)

## 12. INFINITE LADDER




$\Rightarrow$

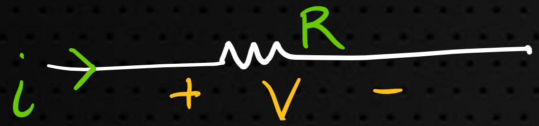



$$R_{AB} = R_1 + \frac{xR_2}{x+R_2}$$

$x$

# 13. THERMAL EFFECT OF CURRENT (JOULES HEATING EFFECT)

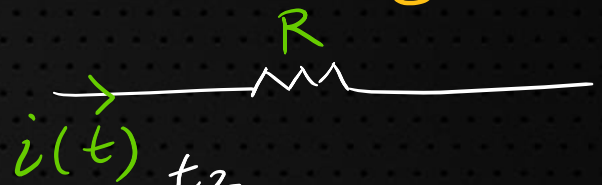
## CONSTANT CURRENT




$$P = i^2 R = \frac{V^2}{R} = Vi \text{ (Watt)}$$

$$H = i^2 R t = \frac{V^2}{R} t = Vit \text{ (Joules)}$$

## Time Varying Current

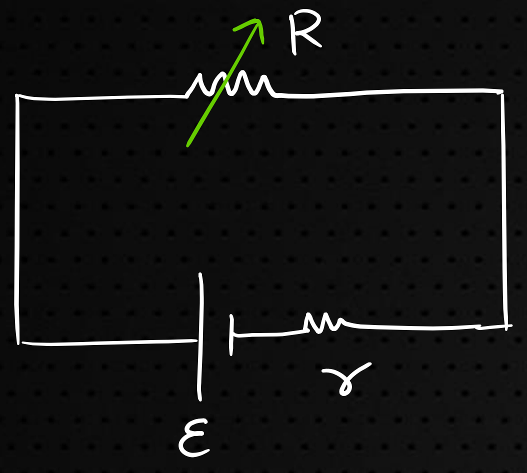



$$H = \int_{t_1}^{t_2} i^2 R \, dt$$

$$P_{av} = \frac{\int i^2 R \, dt}{\int dt}$$

Ex: $i(t) = i_0 \sin \omega t$

## 14. MAX POWER TRANSFER THEOREM




CONDITION :

$$\boxed{R = r}$$

↳ for maximum power transfer, External resistance must be equall to internal resistance.

## 15. CONCEPT OF POWER RATING

BULB

specifications

220V , 50 W

220V → Rated Voltage

50 W → Rated Power

NOTE:

(i) Means bulb will Consume 50 W if 220V is across it.

(ii) $R_{bulb} = \frac{V^2}{P} = \frac{220^2}{50} = 968\,\Omega$

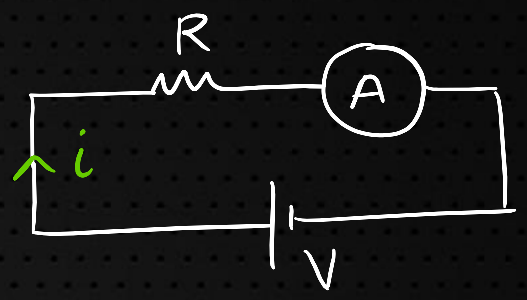
(iii) If $V > 220V$ is across bulb, it will fuse

(iv) More power ⇒ More Bright

# 16. GALVANOMETER TO AMMETER AND VOLTMETER

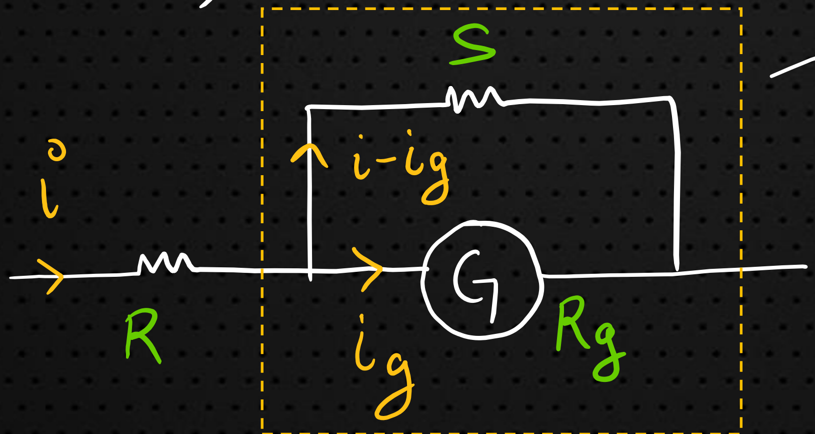
## (a) AMMETER

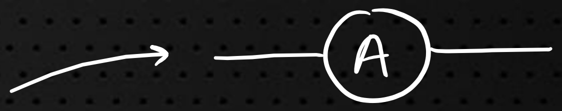
→ connected in series




→ IDEAL AMMETER has zero resistance
(Practically it has very low resistance)

→ CONVERSION:




(i) $i_g$ is max current that can pass through G for full deflection

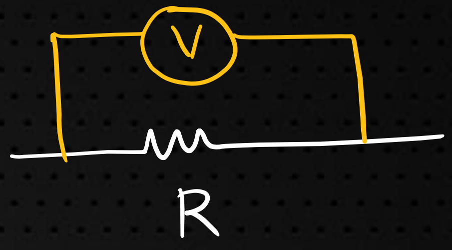
(ii) $S << R_g$ (S: shunt)

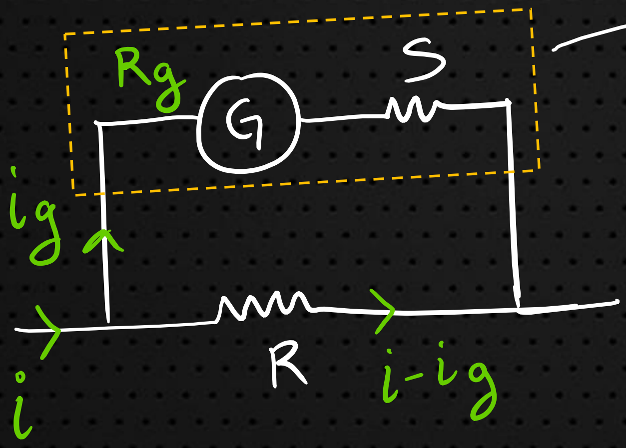
(iii) $(i-i_g)S = i_g R_g \Rightarrow i = i_g\left(1+\frac{R_g}{S}\right)$

# 17. GALVANOMETER TO AMMETER AND VOLTMETER

## (b) Voltmeter

- Connected in parallel
- IDEAL VOLTMETER has infinite Resistance (Practically it has very resistance)





so max p.d. measured by voltmeter is,

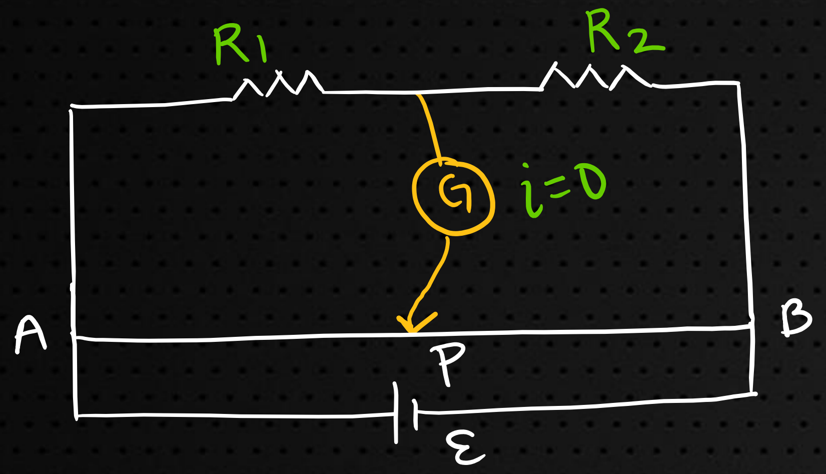
$$V = i_g(R_g + S)$$

↳ $i_g$ : galvanometer current for full deflection

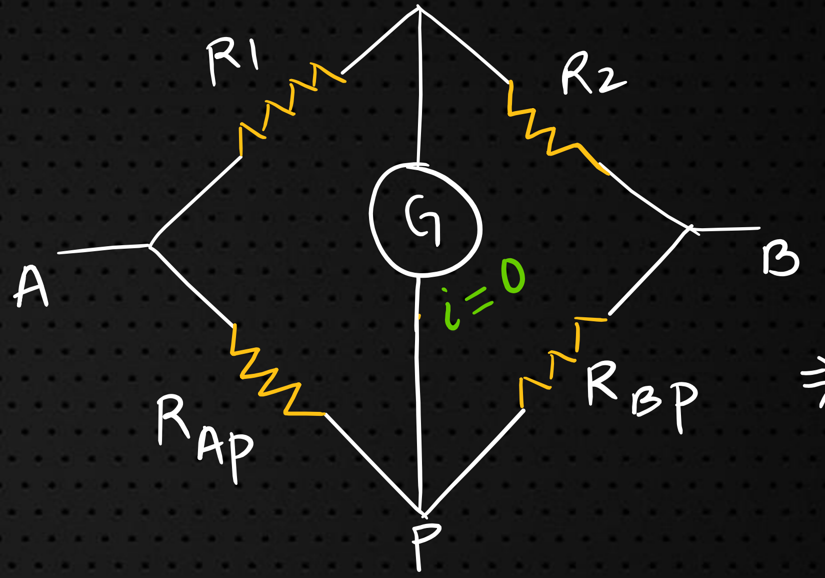
# 18. METER BRIDGE

→ AIM : to find resistance of unknown resistor ($R_2$)

→ Based on Balanced WHEATSTONE BRIDGE




⇒




$AP = l_1$

$BP = l_2$

P is "Null-Deflection" point.

$$\frac{R_1}{R_2} = \frac{R_{AP}}{R_{BP}}$$

$$\Rightarrow \boxed{\frac{R_1}{R_2} = \frac{l_1}{l_2}}$$

or

$$R_2 = R_1 \times \frac{l_2}{l_1}$$

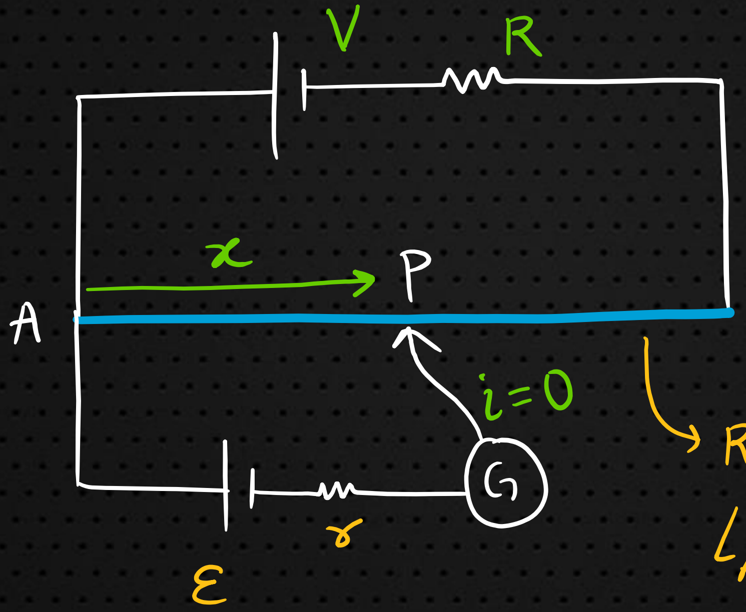
Generally $l_1 + l_2 = 100\,cm$

# 19. POTENTIOMETER

↳ AIM: To find emf of a cell and its internal resistance

↳ Potential gradient (K) : $K = \frac{p.d.}{l}$ V/m (Potential difference per unit length)

## (a) FINDING EMF OF A CELL




$R_{AB} = R_0$

$L_{AB} = l_0$

(i) P is null-deflection pt. or balance pt.

(ii) $k = V_{AB}/l_0$, $V_{AB} = \frac{VR_0}{R_0+R}$

(iii) $\varepsilon = V_{AP}$

$\Rightarrow \boxed{\varepsilon = kx}$

NOTE: Max value of ε that can be measured is "$\varepsilon_{max} = V_{AB}$"

(b) FINDING Internal resistance ($r$)

(i) When key is open :
(Null deflection at Q)

$$\varepsilon = kx_1 \quad \text{---} \ (1)$$

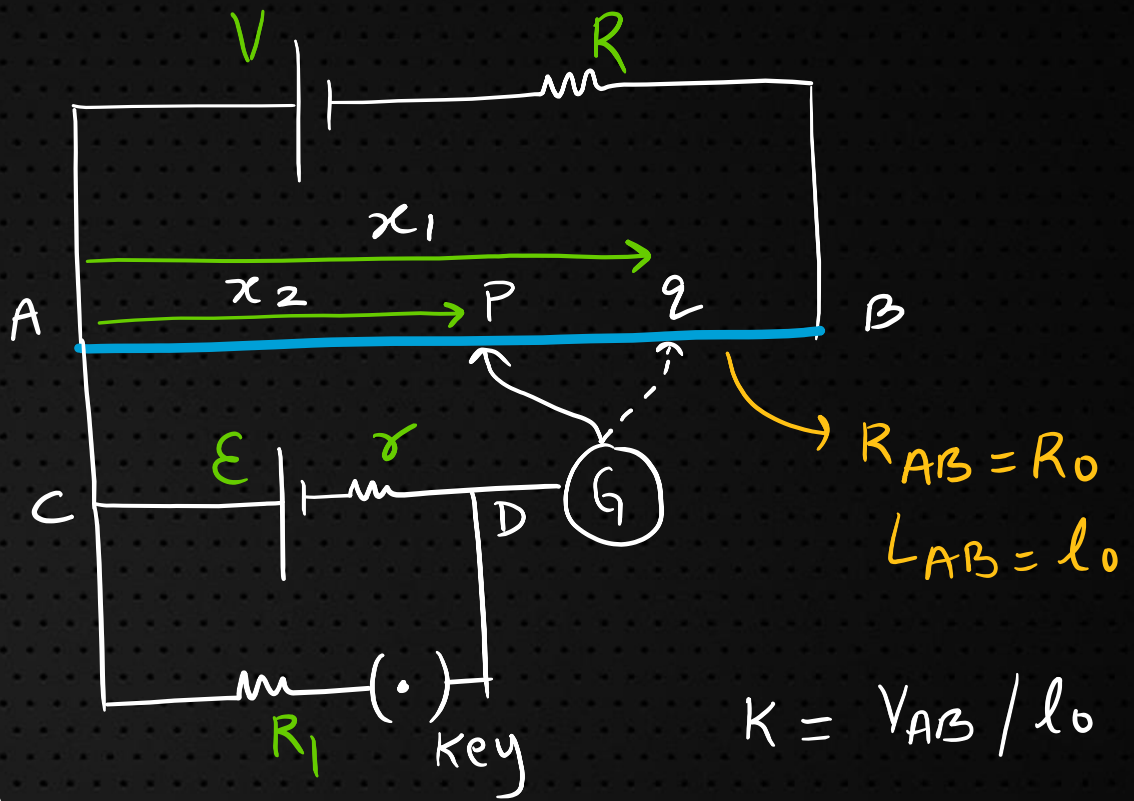
(ii) When key is closed
(Null deflection at P)

$$V_{CD} = kx_2$$

$$\Rightarrow \frac{\varepsilon R_1}{R_1 + r} = kx_2 \quad \text{---} \ (2)$$

$$(1)/(2) : \quad \frac{R_1 + r}{R_1} = \frac{x_1}{x_2}$$

$$\Rightarrow \boxed{r = R\left(\frac{x_1 - x_2}{x_2}\right)}$$




$$K = V_{AB}/l_0$$

$$= \left(\frac{VR_0}{R + R_0}\right)\frac{1}{l_0}$$