VISUAL PHYSICS

SHORT NOTES

CHAPTER

Electric Current

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ELECTRIC CURRENT

Amount of charge passing perpendicular to the area in unit time is known as current

scalar quantity $\boxed{I = \frac{dQ}{dt}}$

unit = Ampere (A)

[Current has direction but do not follow vector addition ≠ vector]

→ Current flows opposite to the direction of electrons motion.

OHM'S LAW:

$I \propto V$ — current is directly proportional to potential difference across conductor.

$\Rightarrow I = \frac{V}{R}$

$\boxed{V = IR}$

V → potential difference

I → current

R → Resistance

$\boxed{R = \rho \frac{l}{A}}$

ρ → resistivity

l → length of Conductor

A → Area

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

σ → conductivity

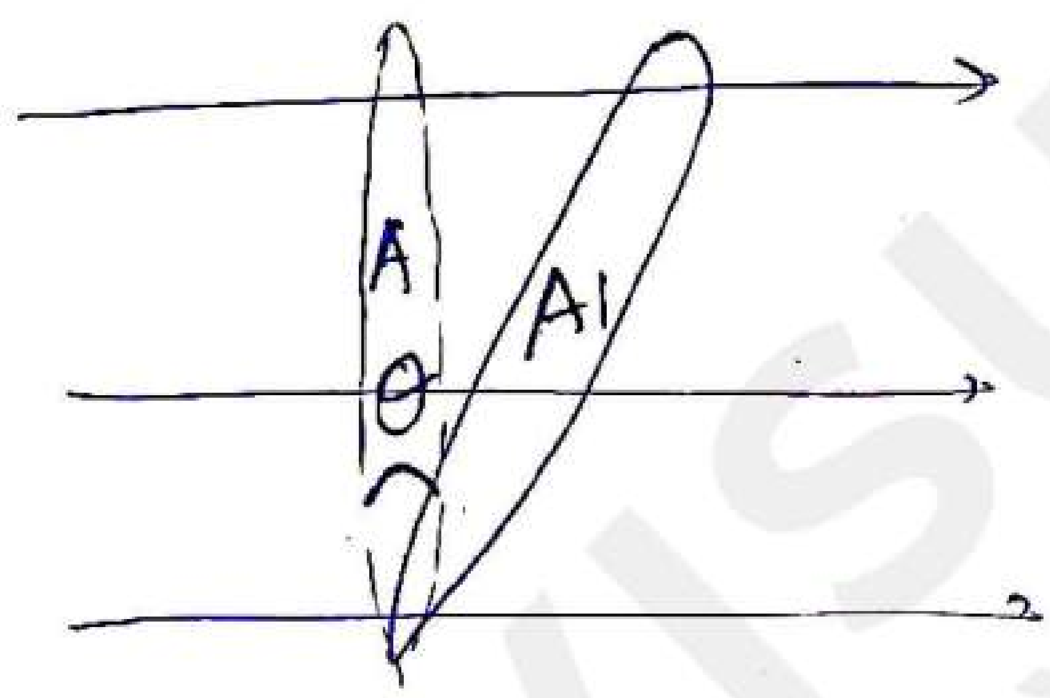
R → unit = ohm	= Ω
ρ → (ohm) m	= Ωm

Current density (J)

↳ Current per unit perpendicular Area

⇒ $\boxed{J = \frac{I}{A}}$ $[A/m^2]$

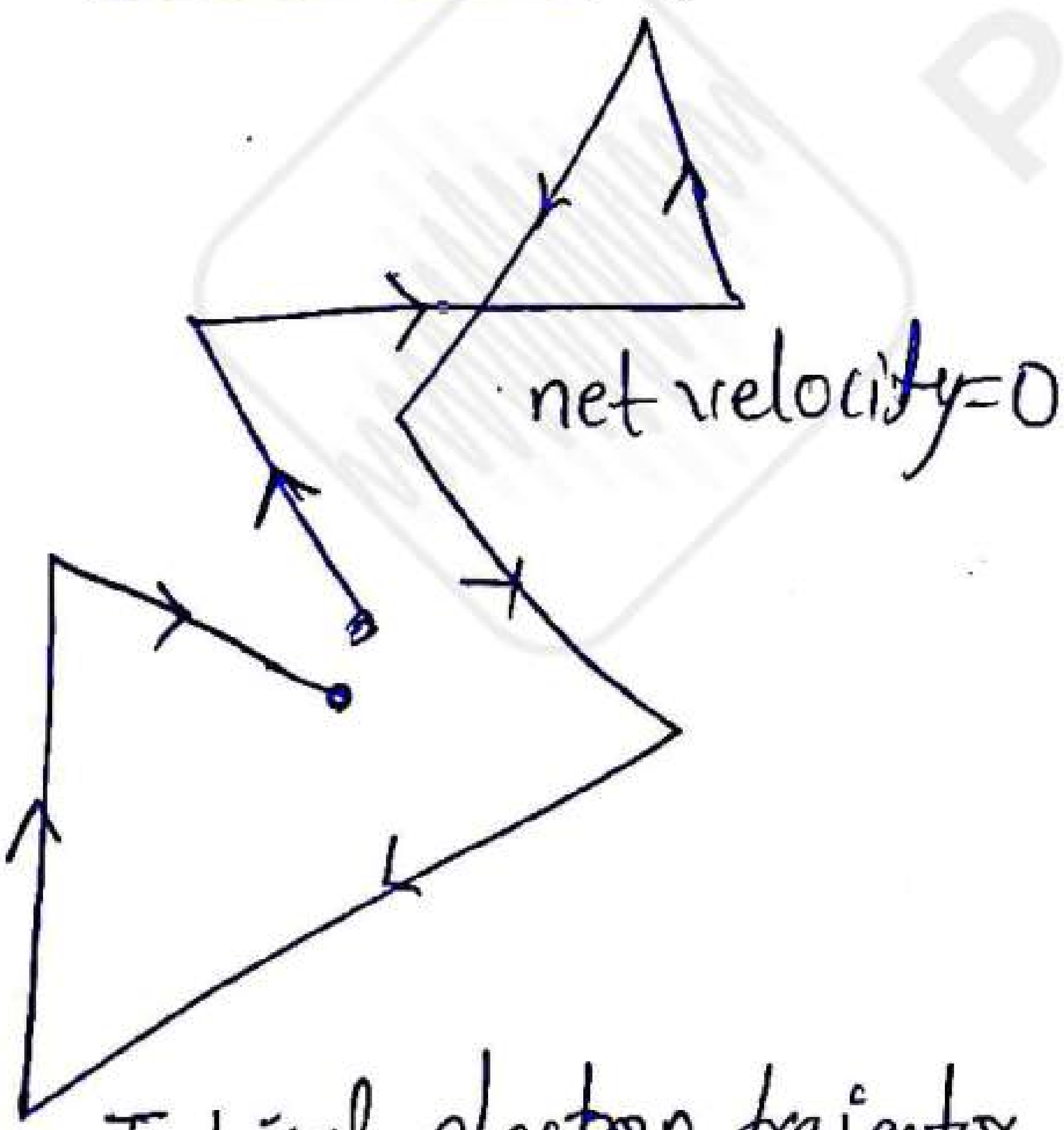
↳ perpendicular Area



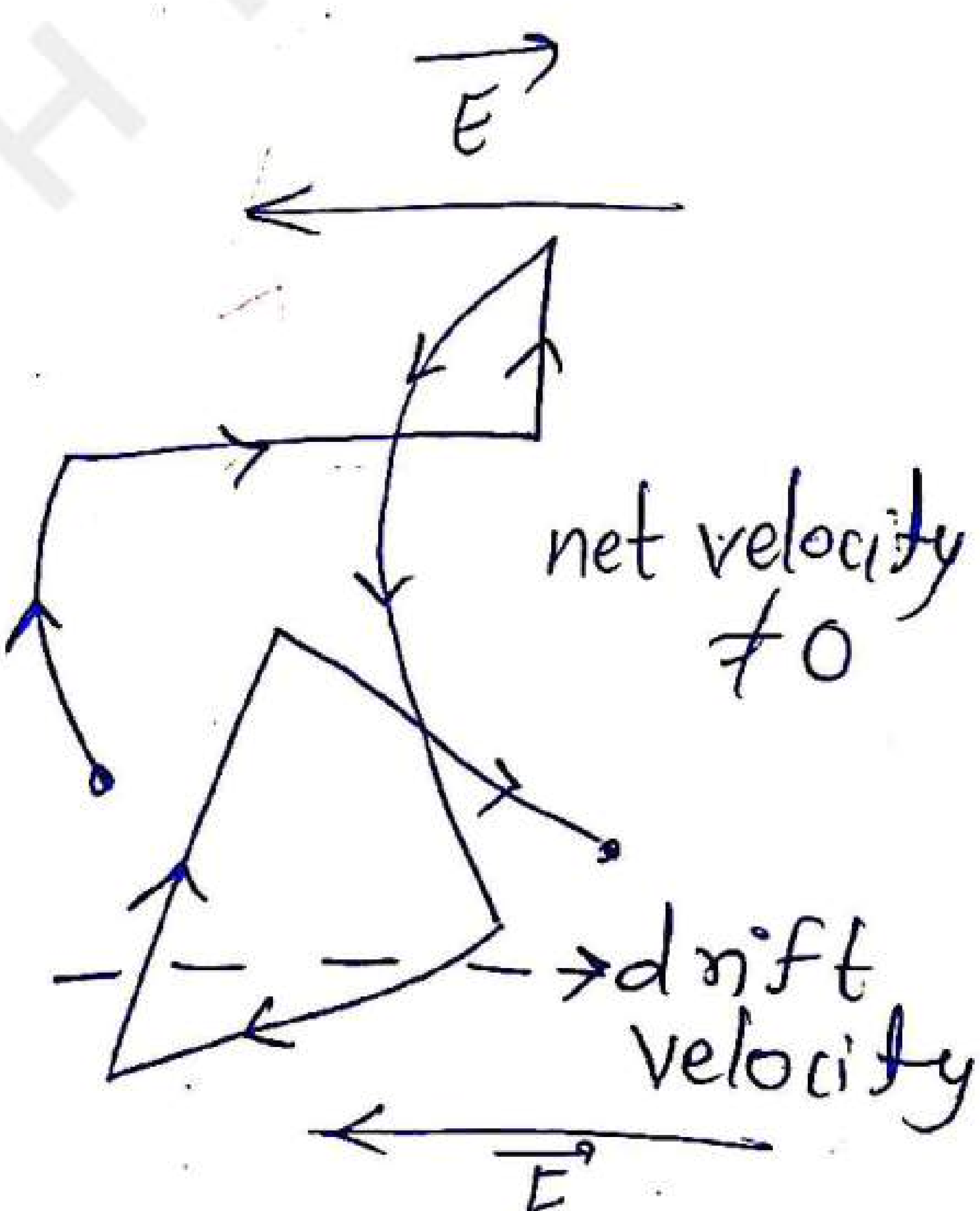
$A = A_1 \cos\theta$

so, $J = \frac{I}{A_1 \cos\theta}$

Drift velocity:

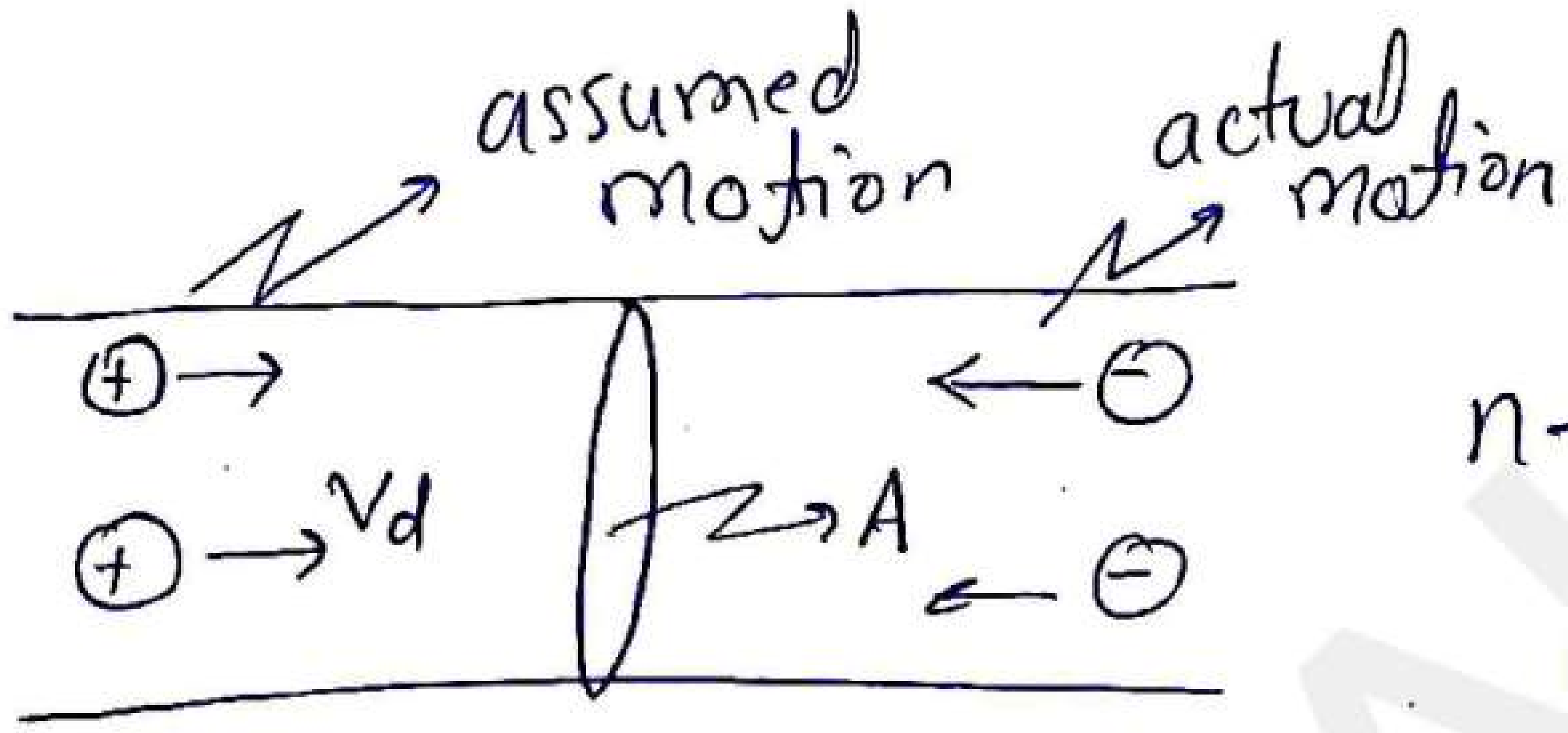


Typical electron trajector
$\vec{E} = 0$



When $\vec{E} \neq 0$

current flows oppositly to electron motion,
→ the speed is V_d = drift velocity.
→ Area of cross section = A (perpendicular to charge motion)



n → number of electrons per unit volume.

so net charge passing through 'A' in unit time 't'.

$$= (A n V_d)\, q \longrightarrow \text{charge of electron}$$

↓ Volume per second passing through 'A'.

now charge per second = Current

so, $\boxed{\text{Current} = (I) = A n q V_d}$

& $\boxed{\vec{J} = \dfrac{I}{A} = -ne\,\vec{V_d}}$

now actual charge $= -e = q$

As $\vec{F}_{net} = m_e\vec{a}$ → acceleration

m_e → mass of electron

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

$$\Rightarrow \boxed{\vec{a} = \frac{-e\vec{E}}{m_e}}$$

now $\vec{V} = \vec{V_0} + \vec{a}t = \vec{V_0} - \frac{e\vec{E}}{m_e}t$

$\vec{V_0}$ → initial velocity of electron

on taking average

$$\vec{V}_d = (\vec{V_0}_{avg}) - \frac{e\vec{E}}{m_e}(t_{avg})$$

$(\vec{V_0}_{avg})$ → zero

$t_{avg} = \tau$ → average relaxation time

time between two collisions

$$\Rightarrow \boxed{\vec{V}_d = \frac{-e\vec{E}}{m_e}\tau}$$

So, $\boxed{I = Anev_d = \frac{ne^2E}{m_e}\tau A}$

$$I = \frac{V}{R}$$ → potential difference

$$I = \frac{VA}{\rho l}$$

As $V = El$

E → electric field applied

l → length of conductor

$$\boxed{I = \frac{EA}{\rho}}$$

on comparing

$$\boxed{\rho = \frac{m_e}{ne^2\tau}}$$

$$\boxed{\mu = \frac{V_d}{E}}$$

μ → mobility → drift velocity gained per unit $\vec{E}$ field applied.

Normally

when Temperature $\uparrow \rightarrow \tau \downarrow$

means average time interval between two collision decrease

as, $\rho \propto \frac{1}{\tau}$

$\Rightarrow \boxed{T\uparrow \rightarrow \rho\uparrow}$

$\boxed{\text{as } \rho\uparrow \rightarrow R\uparrow}$

$$R = R_0[1+\alpha[T-T_0]]$$

$R \rightarrow$ resistance at Temp T (k)

$R_0 \rightarrow$ resistance at Temp T_0 (k)

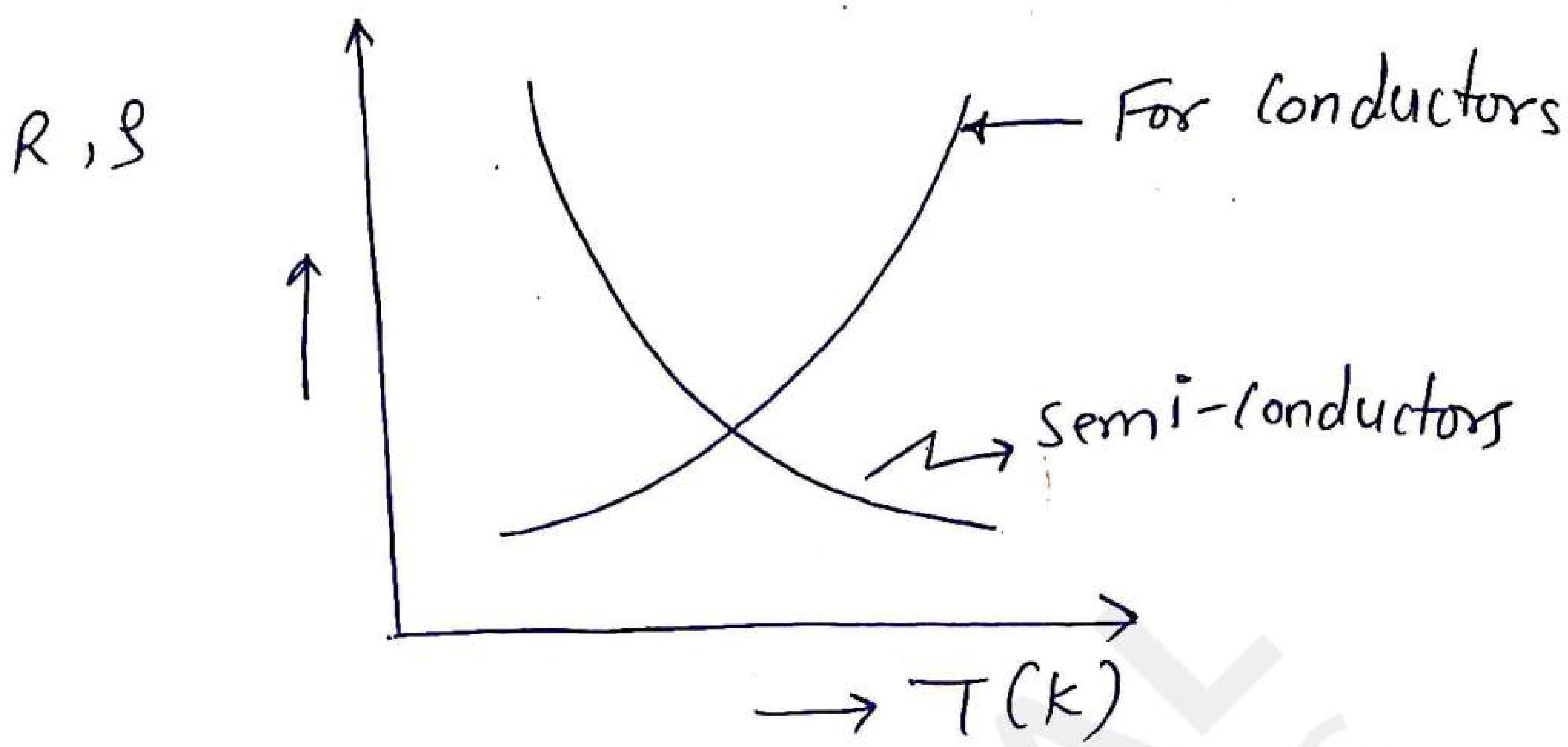
reference Temperature

$\alpha \rightarrow$ constant

↳ different for different Metal

$$\rho = \rho_0[1+\alpha(T-T_0)]$$

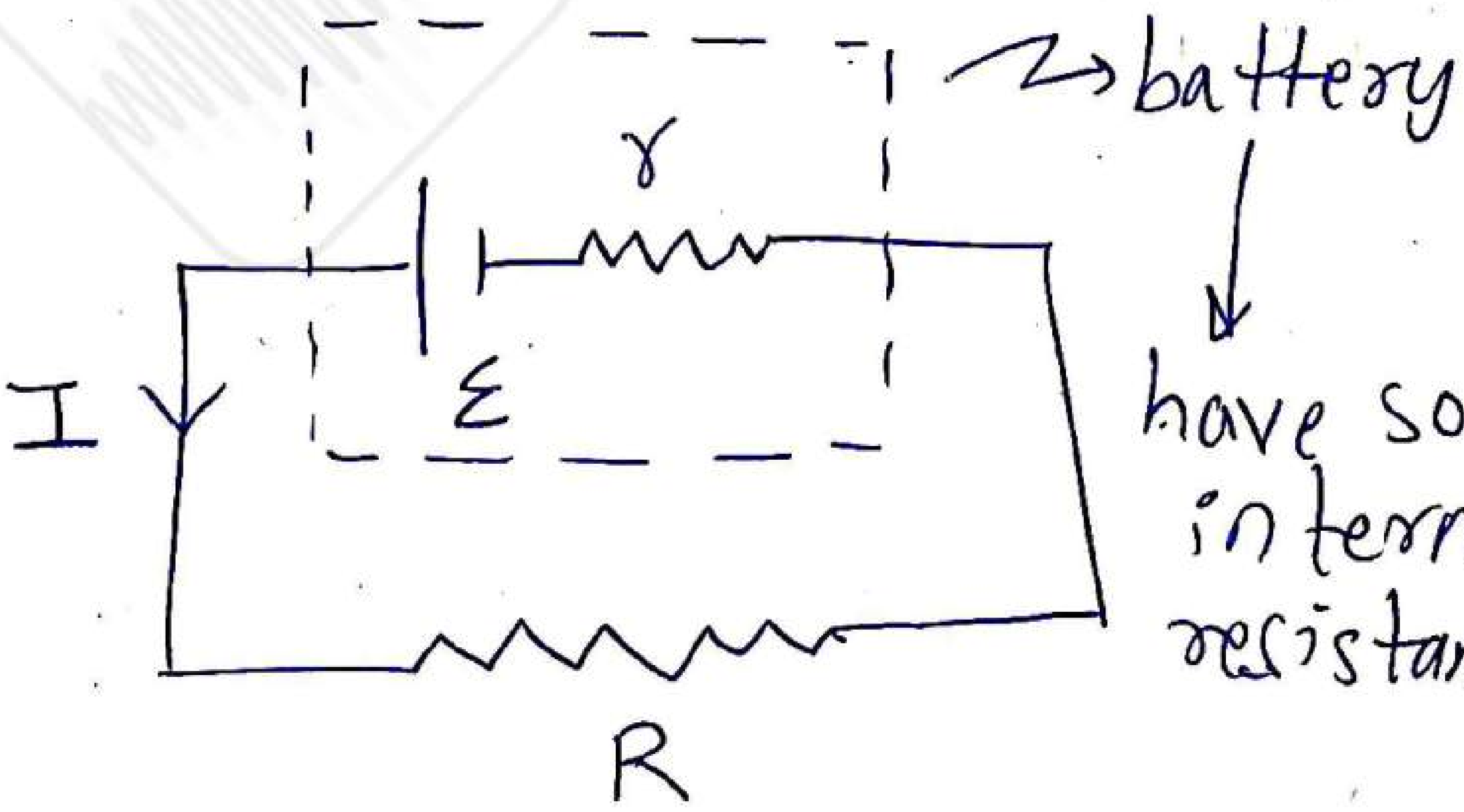
$$\Rightarrow \boxed{\alpha = \frac{1}{\rho_0}\frac{d\rho}{dT}}$$



→ ohm's law ≠ universal law

↳ metal follows ohm's law upto normal working Temperature.

At very high current/voltage ohm's law is not valid



have some internal resistance (r)

$V \rightarrow$ terminal voltage

Potential difference between terminals.

$$\Rightarrow \boxed{V = E - Ir}$$

Ir → potential loss inside battery

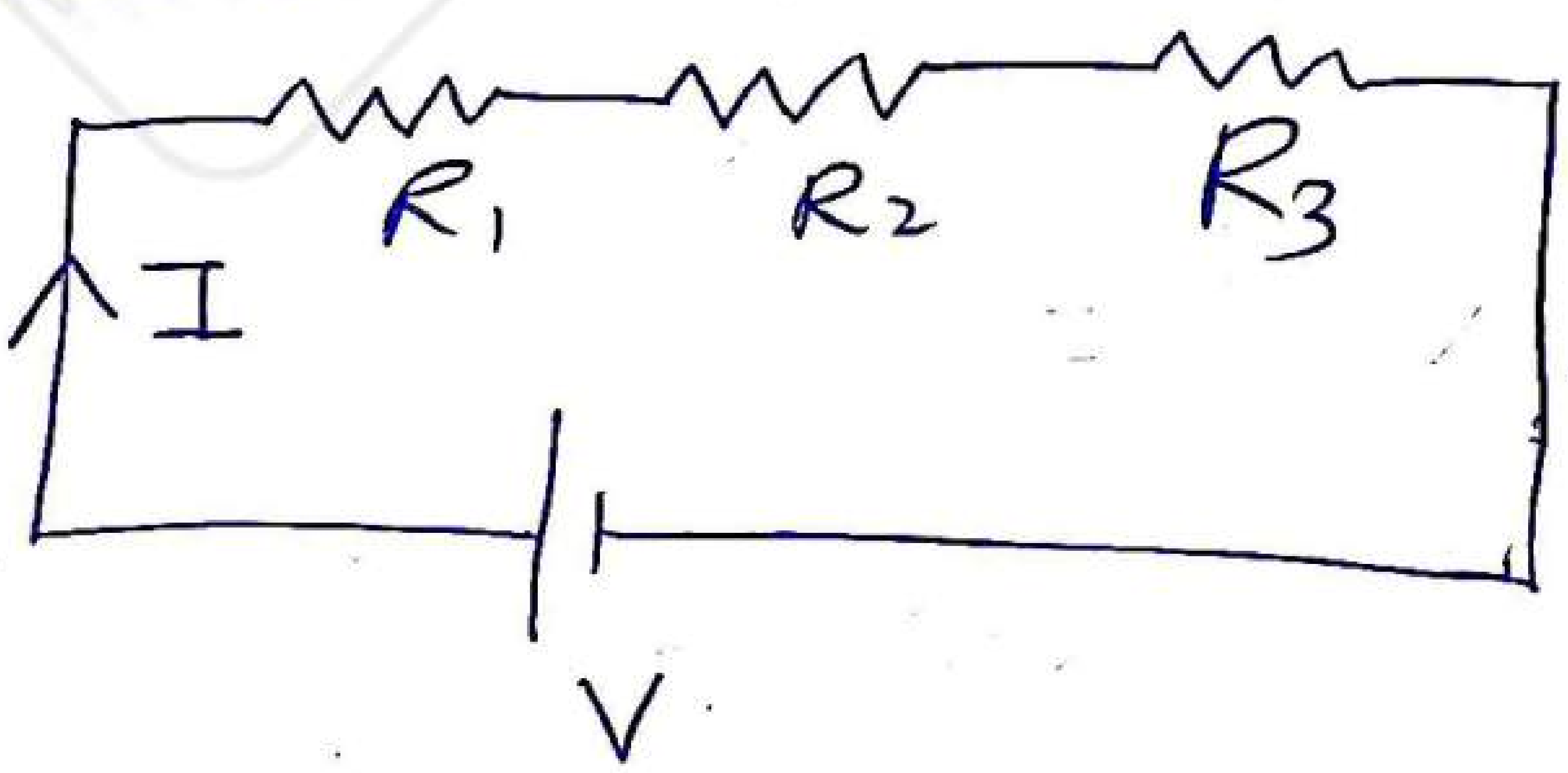
E → emf of battery → (Potential difference, when $I = 0$)

$V < E$ as some internal Energy loss in battery during discharging

$$\boxed{I = \frac{E}{(R+r)}}$$

<u>Resistances Combination</u>

→ <u>SERIES</u>: (current same)



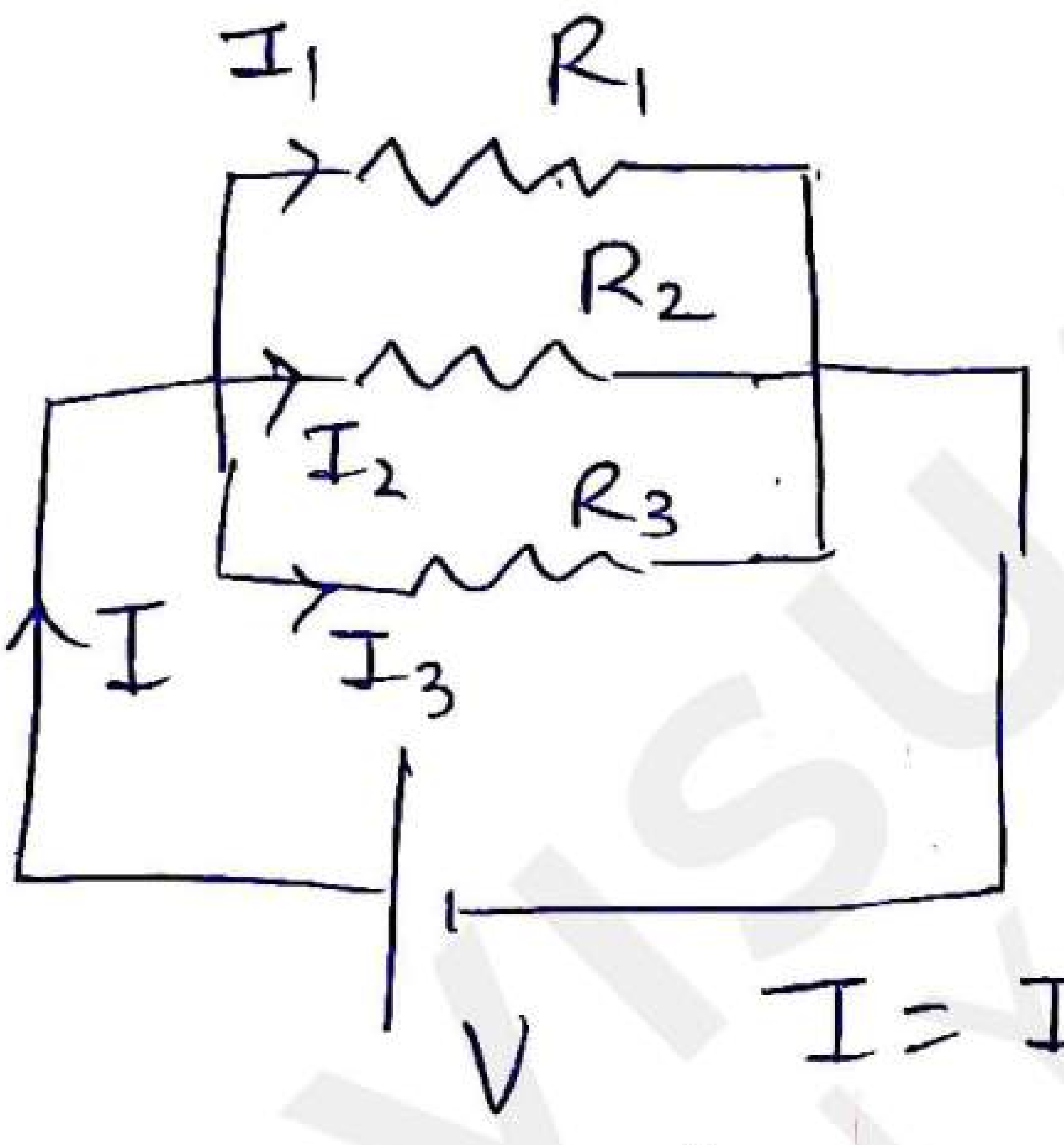
$V_1 = IR_1$, $V_2 = IR_2$, $V_3 = IR_3$

$$\Rightarrow V = V_1 + V_2 + V_3$$

$$\Rightarrow I R_{net} = I(R_1 + R_2 + R_3)$$

$$\Rightarrow \boxed{R_{net} = R_1 + R_2 + R_3}$$

Resistances in parallel: (potential difference same)



$$I_1 = \frac{V}{R_1}$$

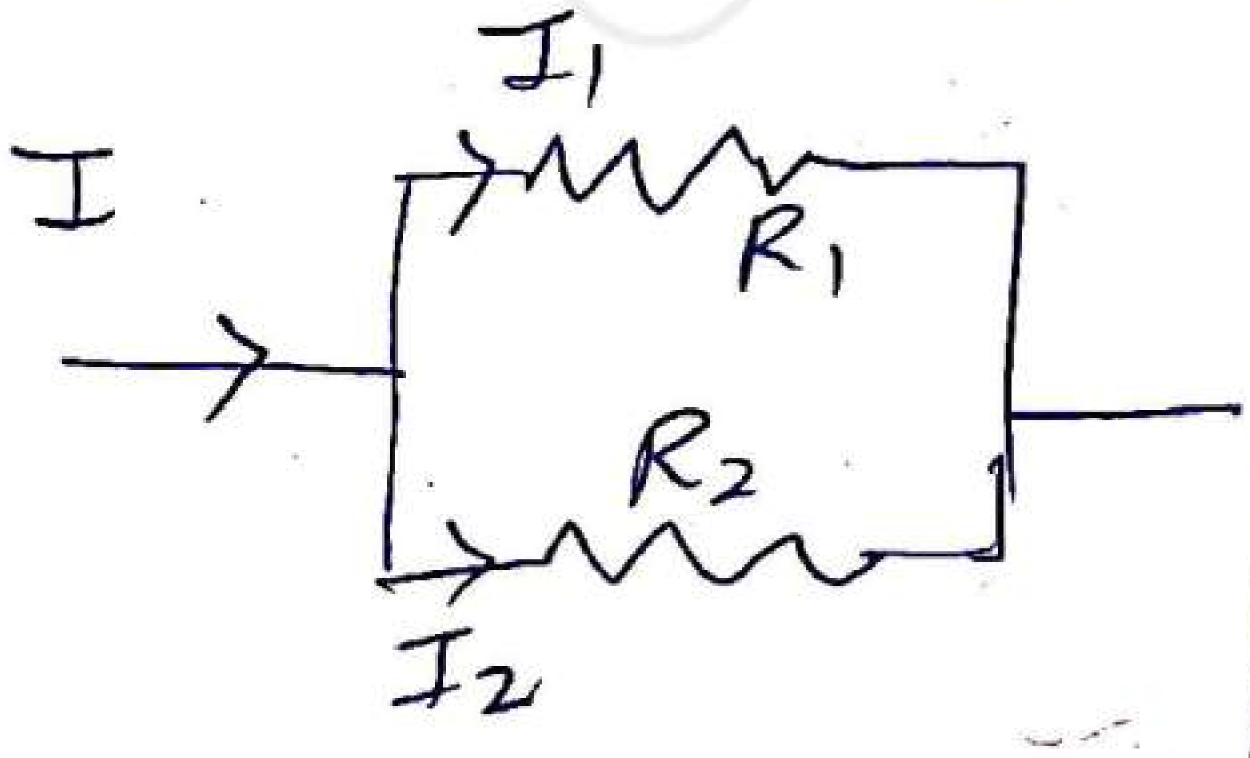
$$I_2 = \frac{V}{R_2}$$

$$I_3 = \cancel{R}\frac{V}{R_3}$$

$$I = I_1 + I_2 + I_3$$

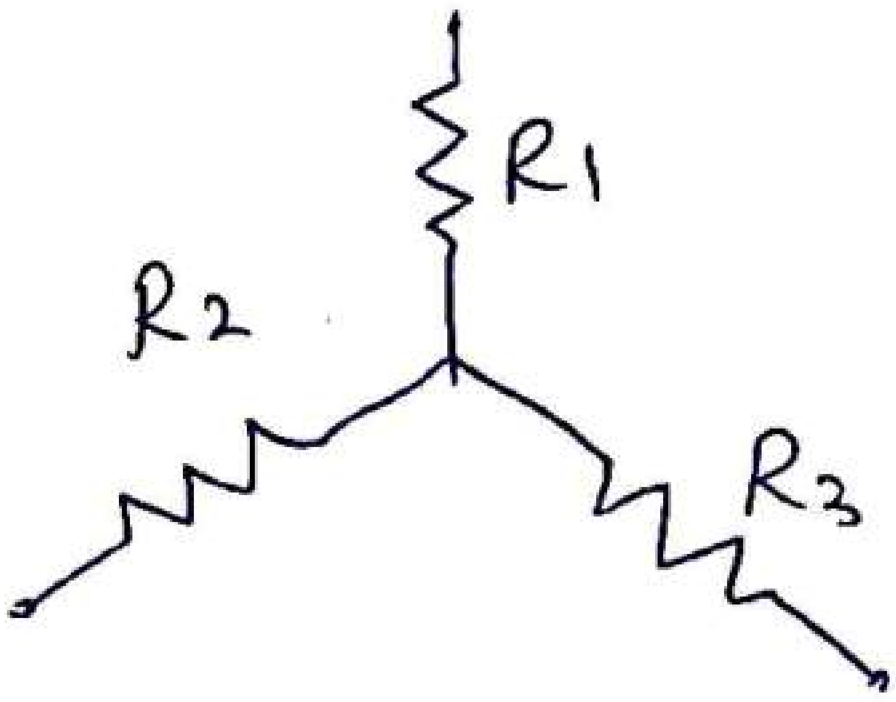
$$\frac{V}{R_{net}} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

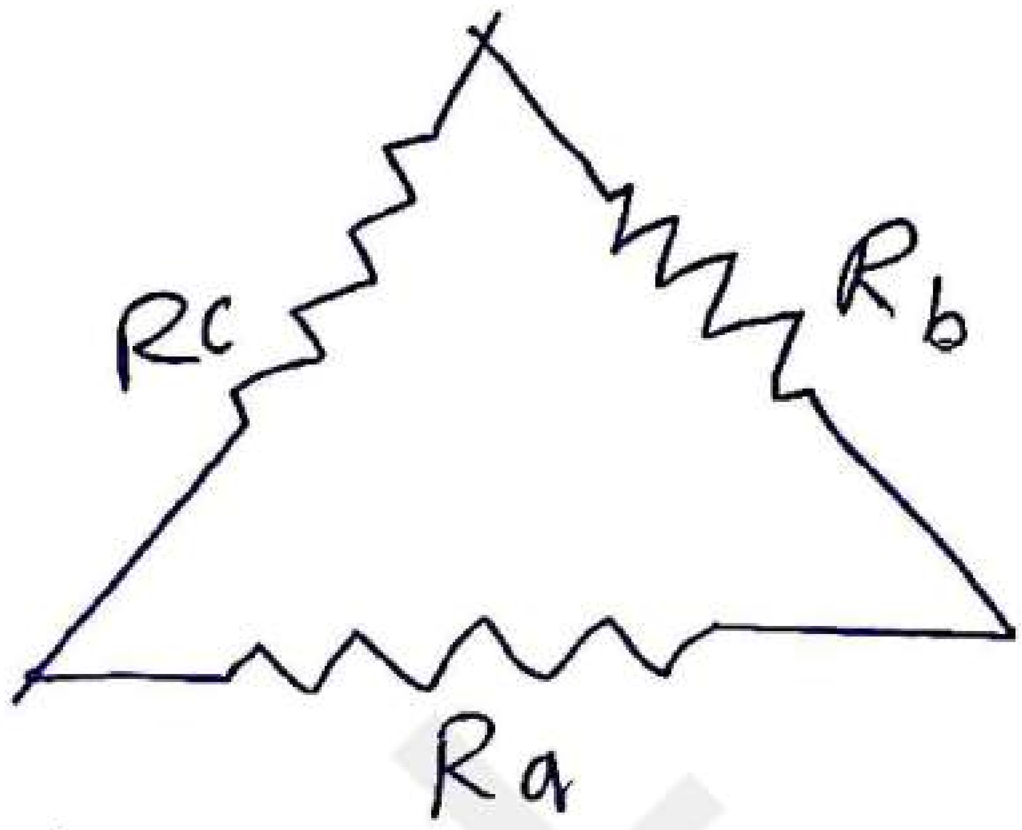
$$\Rightarrow \boxed{\frac{1}{R_{net}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$



$$\boxed{\begin{aligned} I_1 &= \left(\frac{R_2}{R_1 + R_2}\right) I \\ I_2 &= \left(\frac{R_1}{R_1 + R_2}\right) I \end{aligned}}$$

Star-Delta Conversion

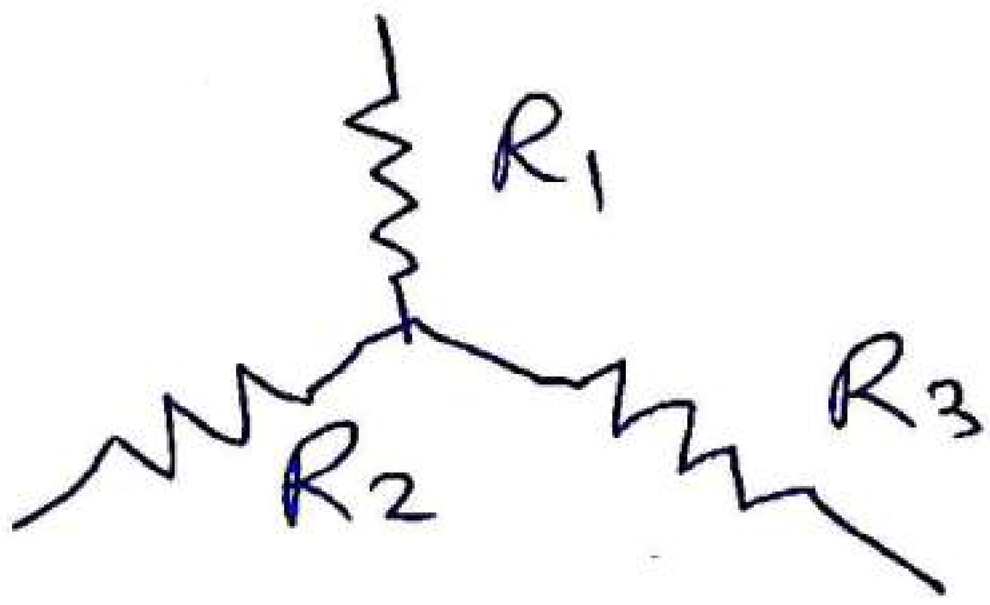




$$R_a = \frac{R_1R_2 + R_1R_3 + R_2R_3}{R_1}$$

$$R_b = \frac{R_1R_2 + R_1R_3 + R_2R_3}{R_2}$$

$$R_c = \frac{R_1R_2 + R_1R_3 + R_2R_3}{R_3}$$



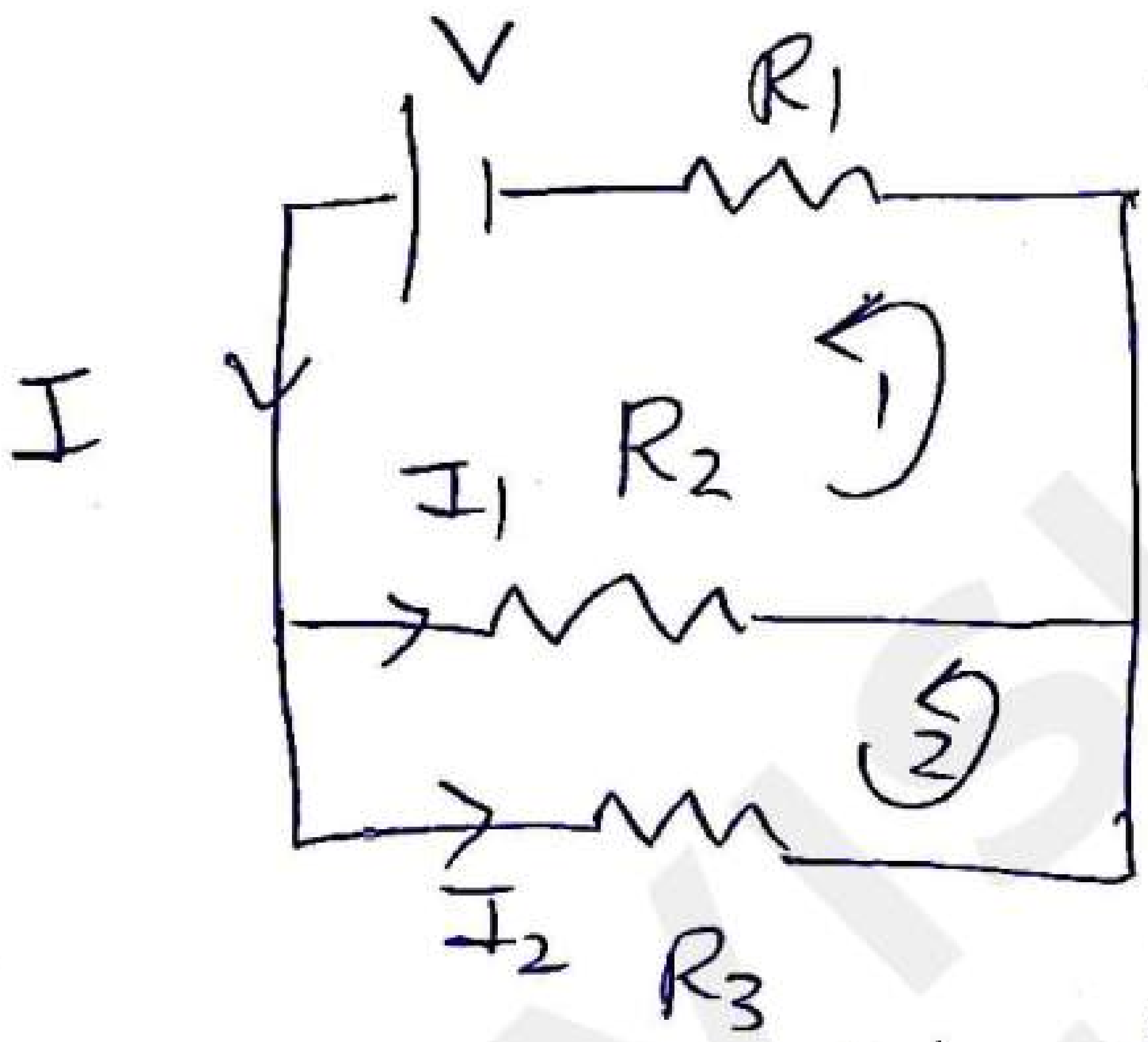
$$\boxed{R_3 = \frac{R_aR_b}{R_a+R_b+R_c}}$$

$$\boxed{R_1 = \frac{R_bR_c}{R_a+R_b+R_c} \qquad R_2 = \frac{R_aR_c}{R_a+R_b+R_c}}$$

Kirchhoff's laws :

voltage law

→ Sum of potential difference across each component in a circular loop is Zero



In loop ①

$$V - I_1R_2 - IR_1 = 0$$

$$-I_2R_3 + I_1R_2 = 0$$

in loop ②

Sign → going from low potential to high potential side on battery = +ve

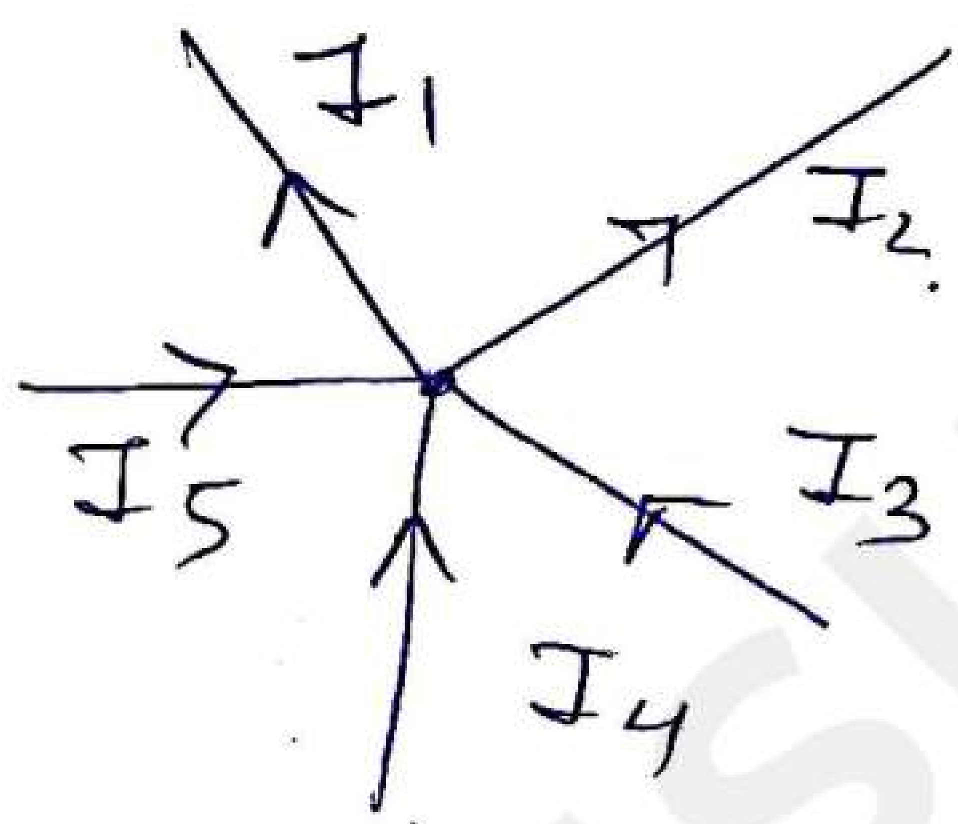
→ −ve (when going positive to negative side)

Sign → +IR (when move opposite to current)

−IR (when going along the current)

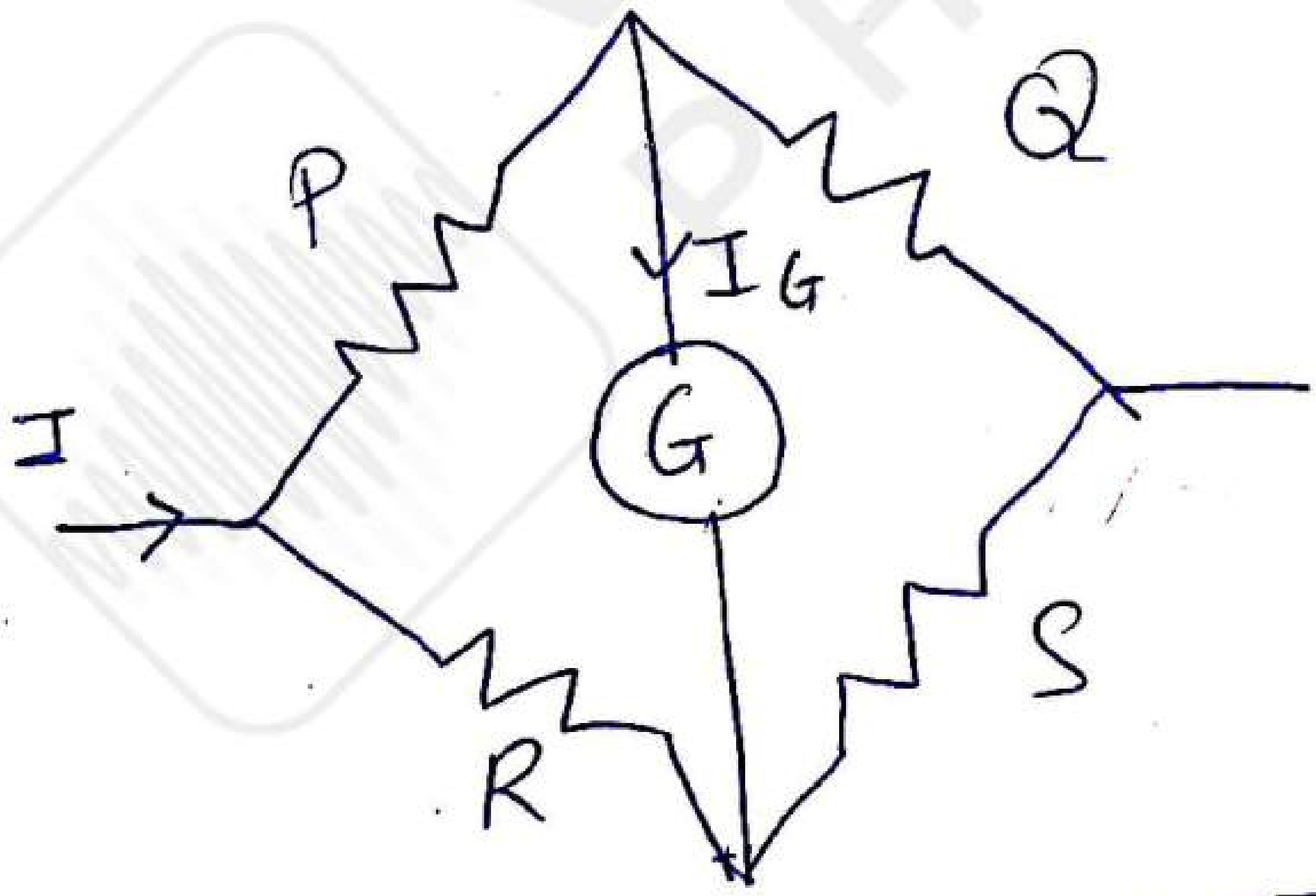
Junction law :

Current coming to junction
= current going away from Junction.



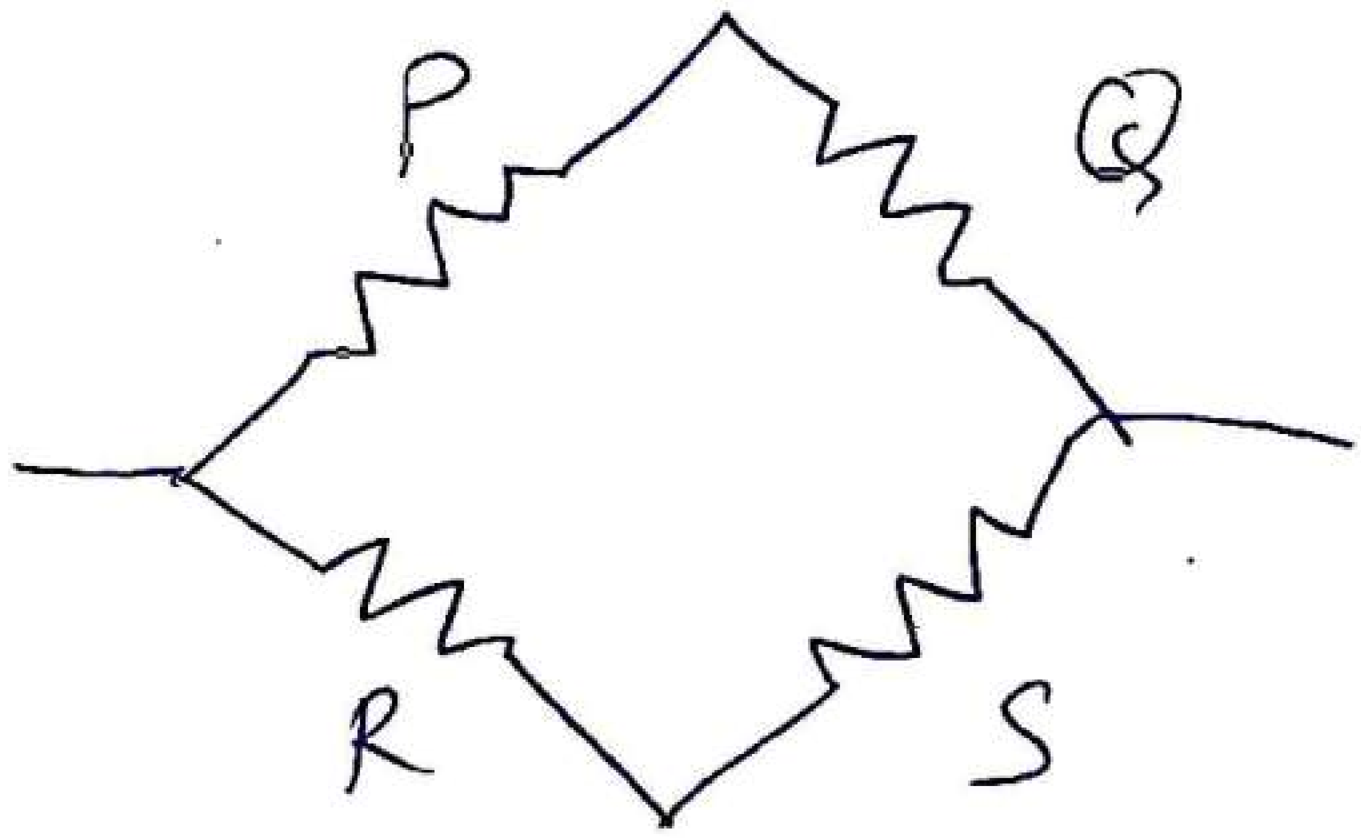
$$\boxed{I_1 + I_2 = I_3 + I_4 + I_5}$$

WHEATSTONE BRIDGE :



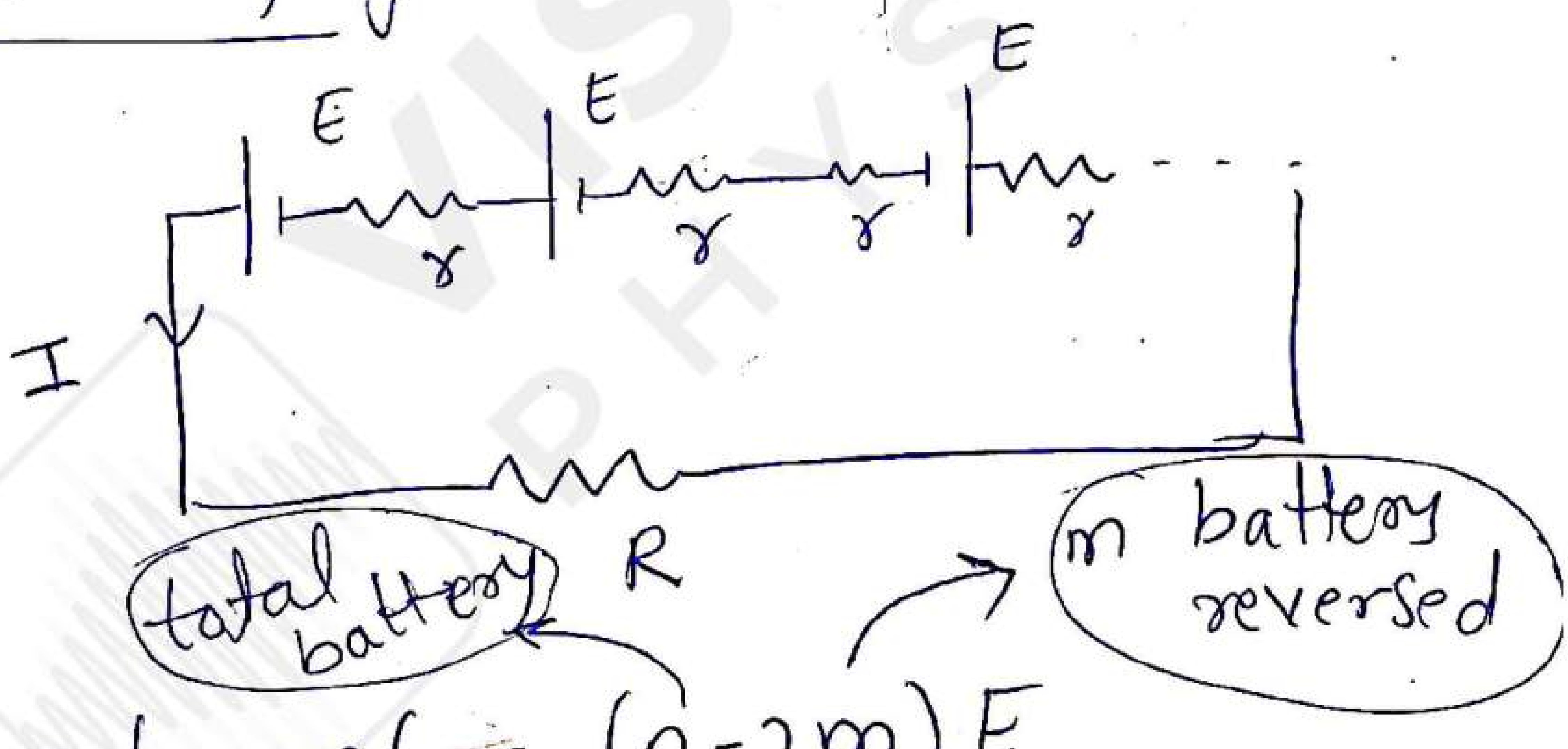
when, $\boxed{\frac{P}{R} = \frac{Q}{S}}$ $\boxed{I_G = 0}$

so,



Combination of Cells:

Series - Grouping:

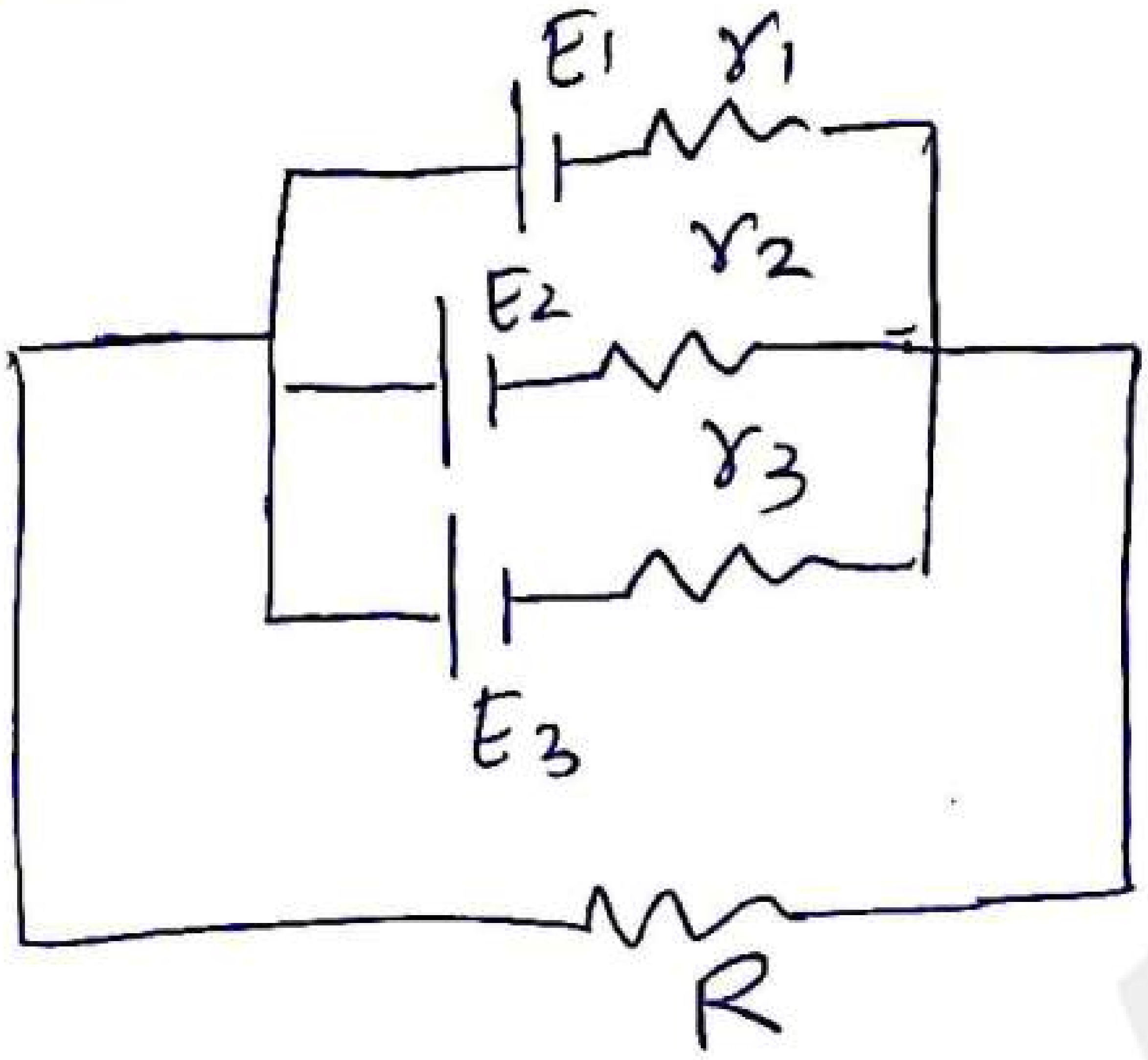


net emf = $(n-2m)E$

net resistance = $nr+R$

$$\boxed{i = \frac{(n-2m)E}{nr+R}}$$

parallel - Grouping :



$$\boxed{E_{eq} = \frac{\sum\left(\frac{E}{r}\right)}{\sum\left(\frac{1}{r}\right)} = \frac{\frac{E_1}{r_1} + \frac{E_2}{r_2} + \dots}{\frac{1}{r_1} + \frac{1}{r_2} + \dots}}$$

$$R_{eq} = R + \frac{1}{\sum\left(\frac{1}{r}\right)}$$

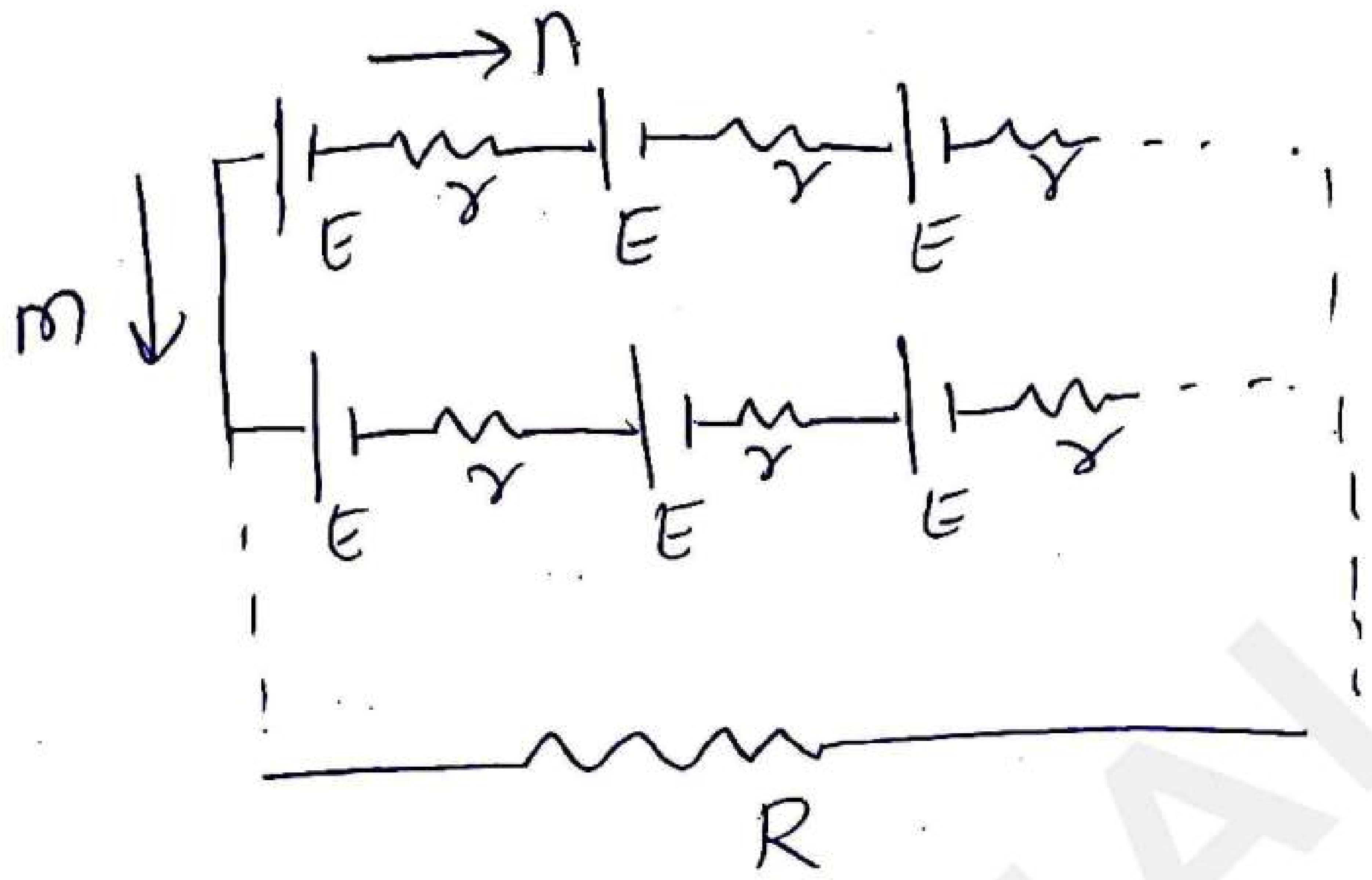
$$\boxed{R_{eq} = R + \frac{1}{\frac{1}{r_1} + \frac{1}{r_2} + \dots}}$$

$$I = \frac{E_{eq}}{R_{eq}}$$

if all are Same

$$\boxed{I = \frac{E}{R + \frac{r}{n}}}$$

Mixed Grouping : (E & r same)



$n \rightarrow$ cells in each row of m rows

Net emf of one row $= nE$

and internal resistance of one row $= nr$

so, $\boxed{i = \dfrac{nE}{R + \dfrac{nr}{m}}}$

$$\boxed{i = \frac{mnE}{(\sqrt{mR} - \sqrt{nr})^2 + 2\sqrt{mnrR}}}$$

$i \rightarrow i_{max}$ $\sqrt{mR} = \sqrt{nr}$

$\Rightarrow \boxed{R = \dfrac{nr}{m}}$

Ammeter: used to find current

→ ideally resistance = 0

Connected in series with the current, so to get value

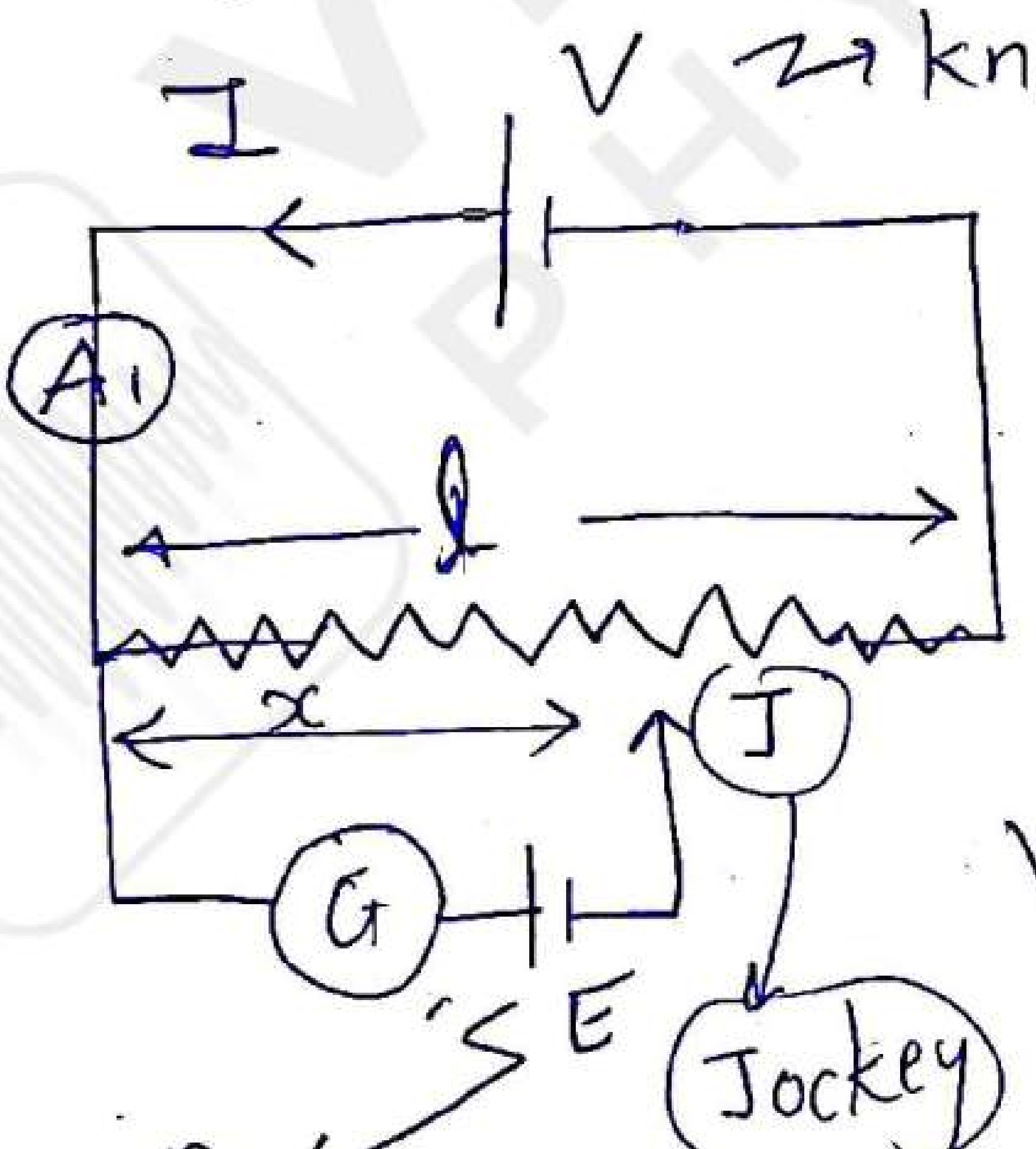
Voltmeter: Use to calculate p.d

→ ideal resistance = ∞

Connected parallel with element to get the result.

G → 0 when Jockey is balanced so to get value of x

V → known voltage (V) of part 'l' length



unknown Emf ($E < V$)

$V = IR$

$V = I\left(\frac{\rho l}{A}\right)$

$V = \left(\frac{I\rho}{A}\right) l$

if I is constant

$\boxed{V = Kl}$

$$\boxed{V \propto l}$$

potential difference directly proportional to length.

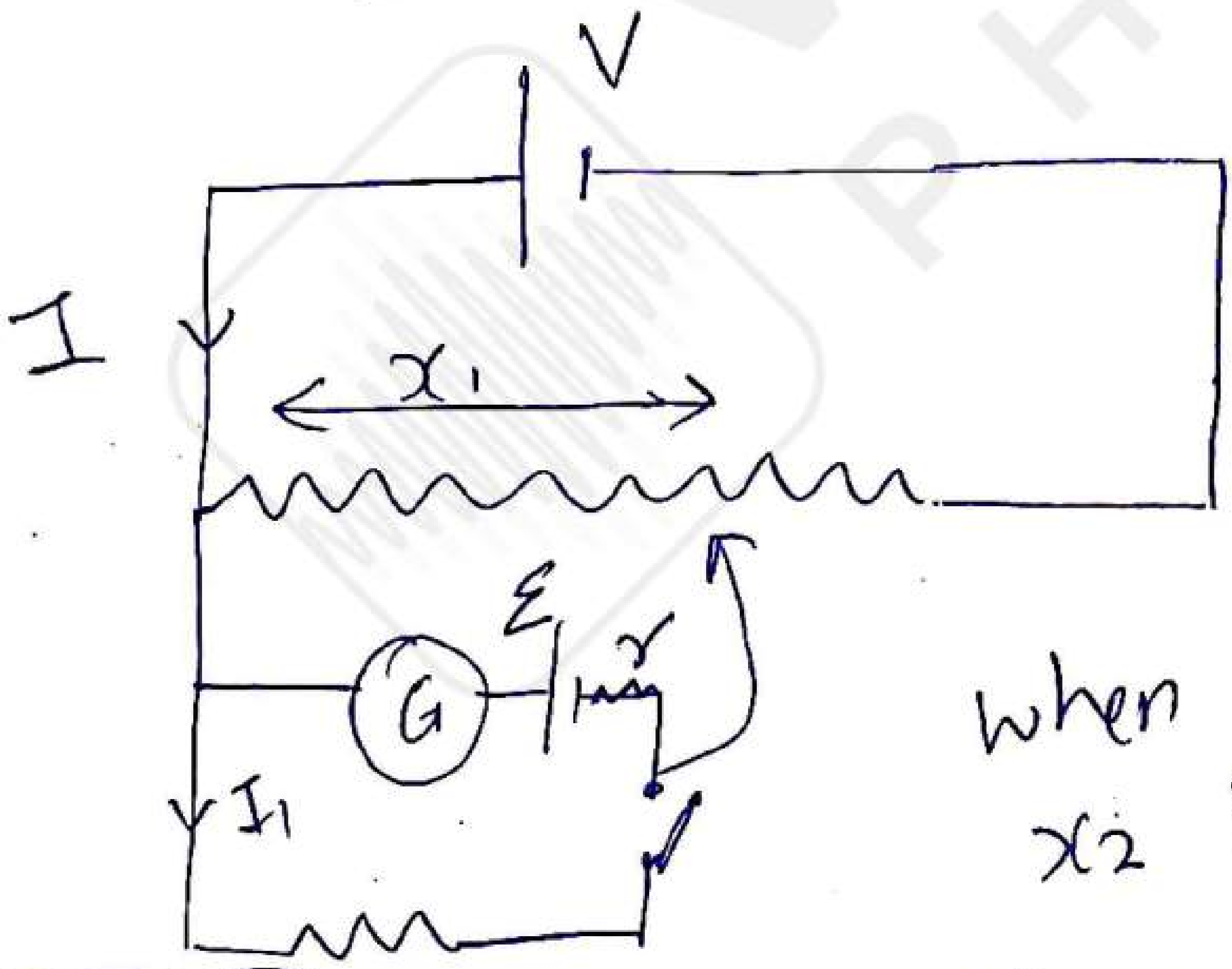
Now

$$E = kx$$

$$\boxed{E = \left(\frac{I\rho}{A}\right) x}$$

so if we have two battery, E_1 & E_2

So, $$\boxed{\frac{E_1}{E_2} = \frac{x_1}{x_2}}$$



when switch close, x_2 is balanced point

$$\frac{V}{E} = \frac{x_2}{x_1}$$

$$\boxed{\frac{E - I_1 r}{E} = \frac{x_2}{x_1}}$$

So, 'r' can be found