



**VISUAL**  
PHYSICS

# SHORT NOTES

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C H A P T E R

## 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 does not follow vector addition  $\neq$  vector

→ Current flows opposite to the direction of electrons motion.

OHM'S LAW:

$$I \propto V$$

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

Current is directly proportional to potential difference across conductor.

$\boxed{V = IR}$  → Resistance

potential difference →  $V$

current →  $I$

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

length of conductor →  $l$

Area →  $A$

resistivity →  $\rho$

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

conductivity →  $\sigma$

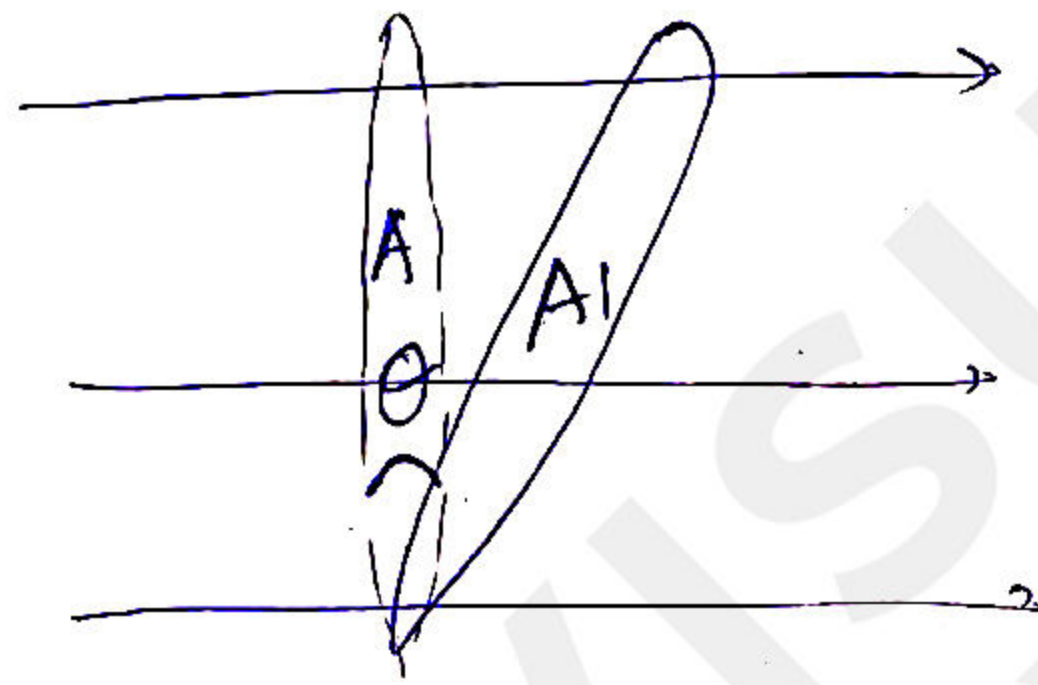
|                            |              |
|----------------------------|--------------|
| $R \rightarrow$ unit = ohm | = $\Omega$   |
| $\rho \rightarrow$ (ohm) m | = $\Omega m$ |

Current density ( $J$ )

↳ current per unit perpendicular area

$$\Rightarrow J = \frac{I}{A} \quad [A/m^2]$$

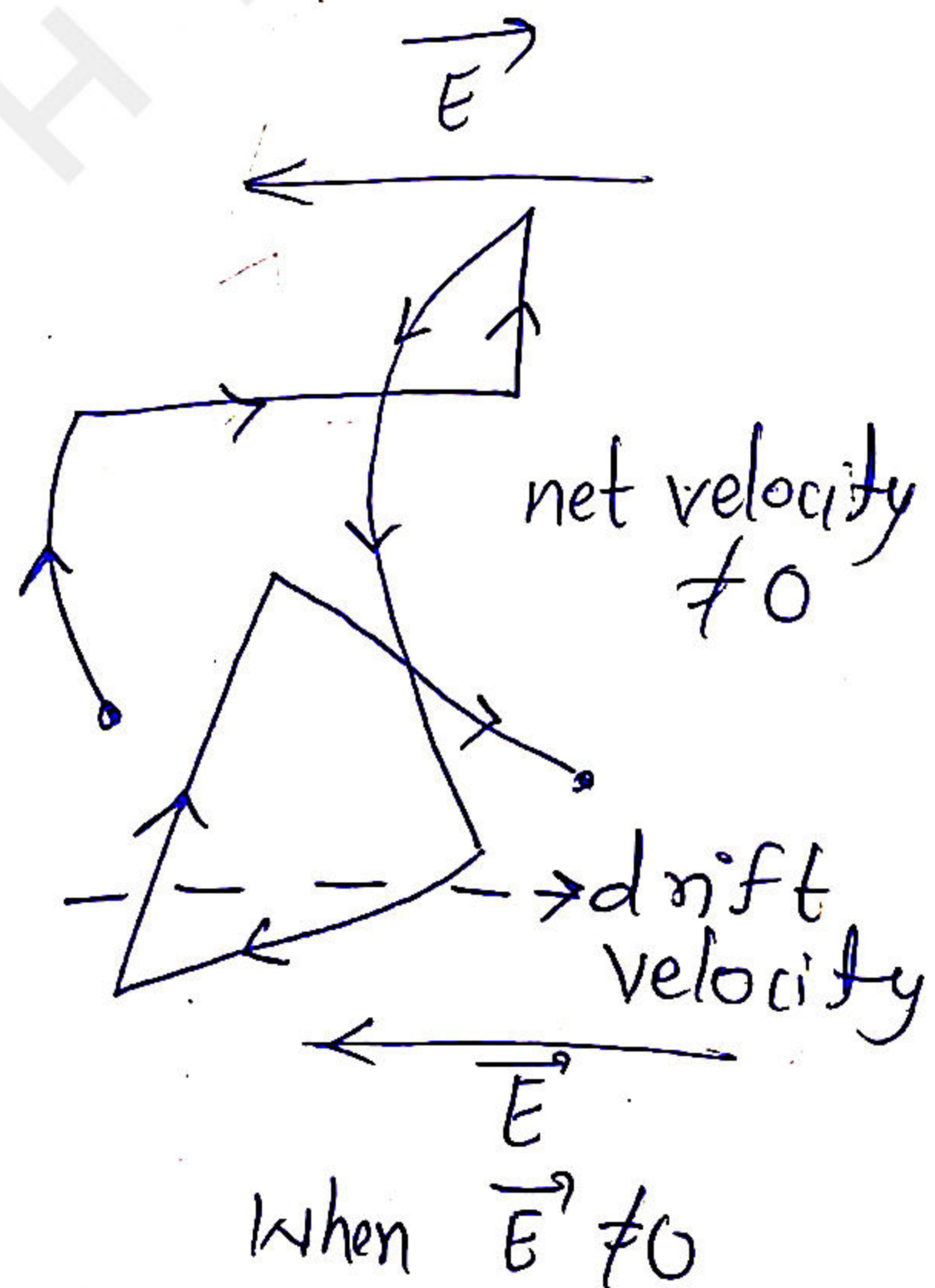
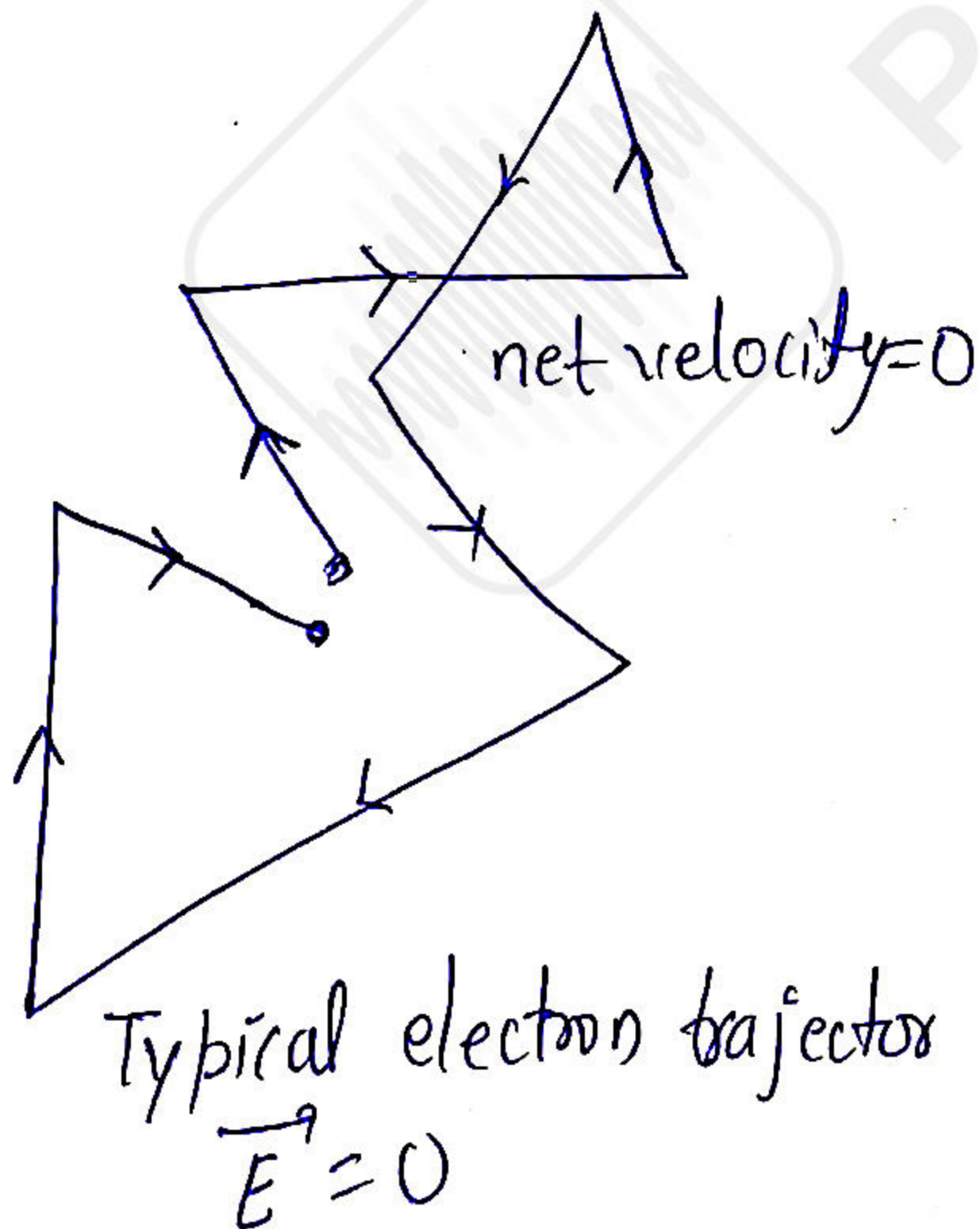
perpendicular Area



$$A = A_1 \cos \theta$$

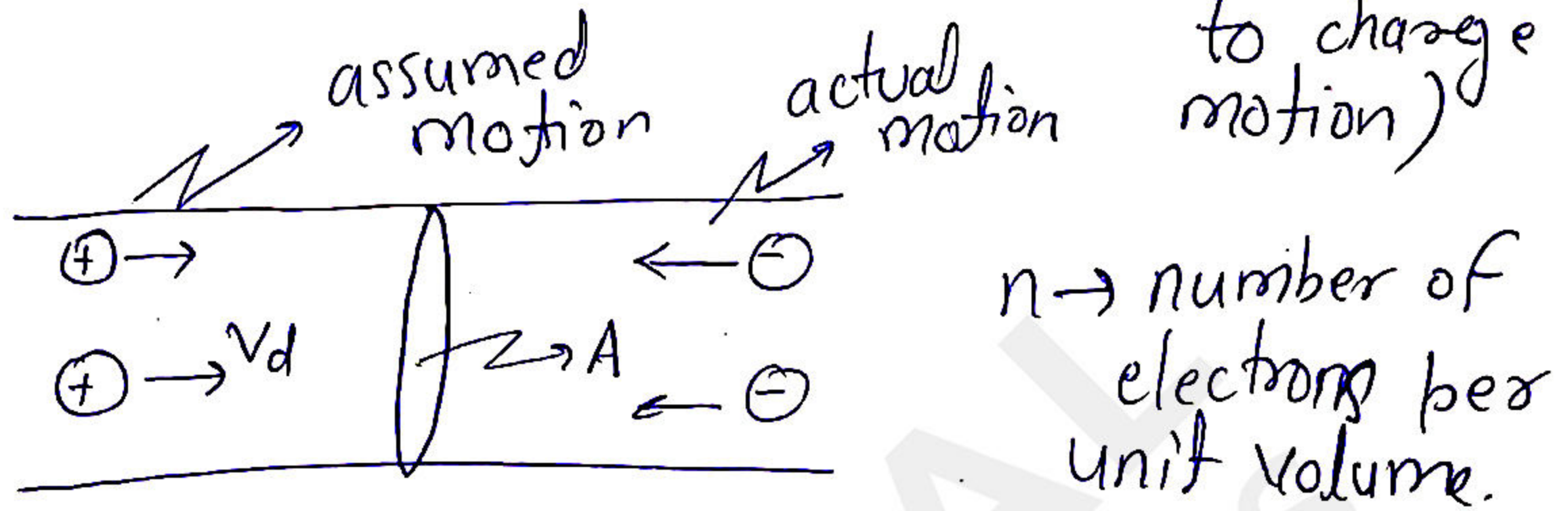
$$\text{So, } J = \frac{I}{A_1 \cos \theta}$$

Drift velocity:



current flows opposite to electron motion,  
 → the speed is  $V_d$  = drift velocity.

→ Area of cross section =  $A$  (perpendicular to charge motion)



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

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

Volume per second passing through 'A'.

now charge per second = Current

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

$$\& \quad \boxed{\vec{J} = \frac{I}{A} = -n e \vec{V}_d}$$

now actual charge =  $-e = q$

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

↓  
mass of electron

$$\vec{F}_{\text{ref}} = -e \vec{E}$$

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

now  $\vec{V} = \vec{V}_0 + \vec{a}t = \vec{V}_0 - \frac{eE}{m_e}t$

on taking average

$$\vec{V}_d = (\vec{V}_0 \text{ avg}) - \frac{c\vec{E}}{m_e} (t \text{ avg})$$

time between two collisions

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

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

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

$$I = \frac{V}{R} \quad \rightarrow \text{potential difference}$$

$$I = \frac{V A}{\rho l}$$

$$\text{As } V = E l$$

$\swarrow \quad \rightarrow$  length of conductor  
electric field applied

$$I = \frac{E A}{\rho}$$

on comparing

$$\rho = \frac{m_e}{n e^2 \tau}$$

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

$\swarrow$   
mobility

$\rightarrow$  drift velocity gained per unit  $\vec{E}$  field applied.

Normally

When Temperature  $\uparrow \rightarrow \tau \downarrow$

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

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

means average  
time interval  
between two collision  
decrease

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

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

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

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

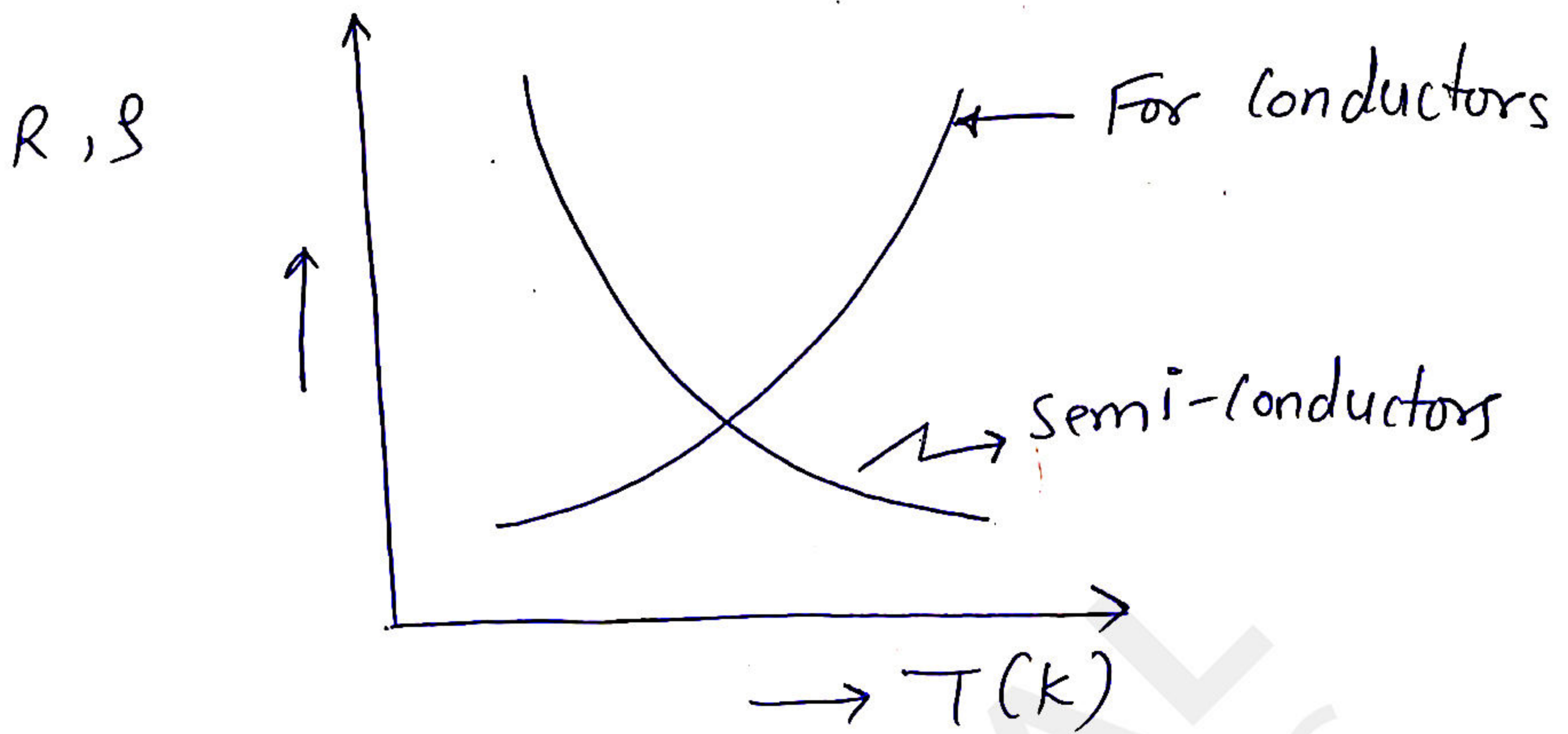
$\alpha \rightarrow$  constant

$\hookrightarrow$  different for different  
Metal

reference  
temperature

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

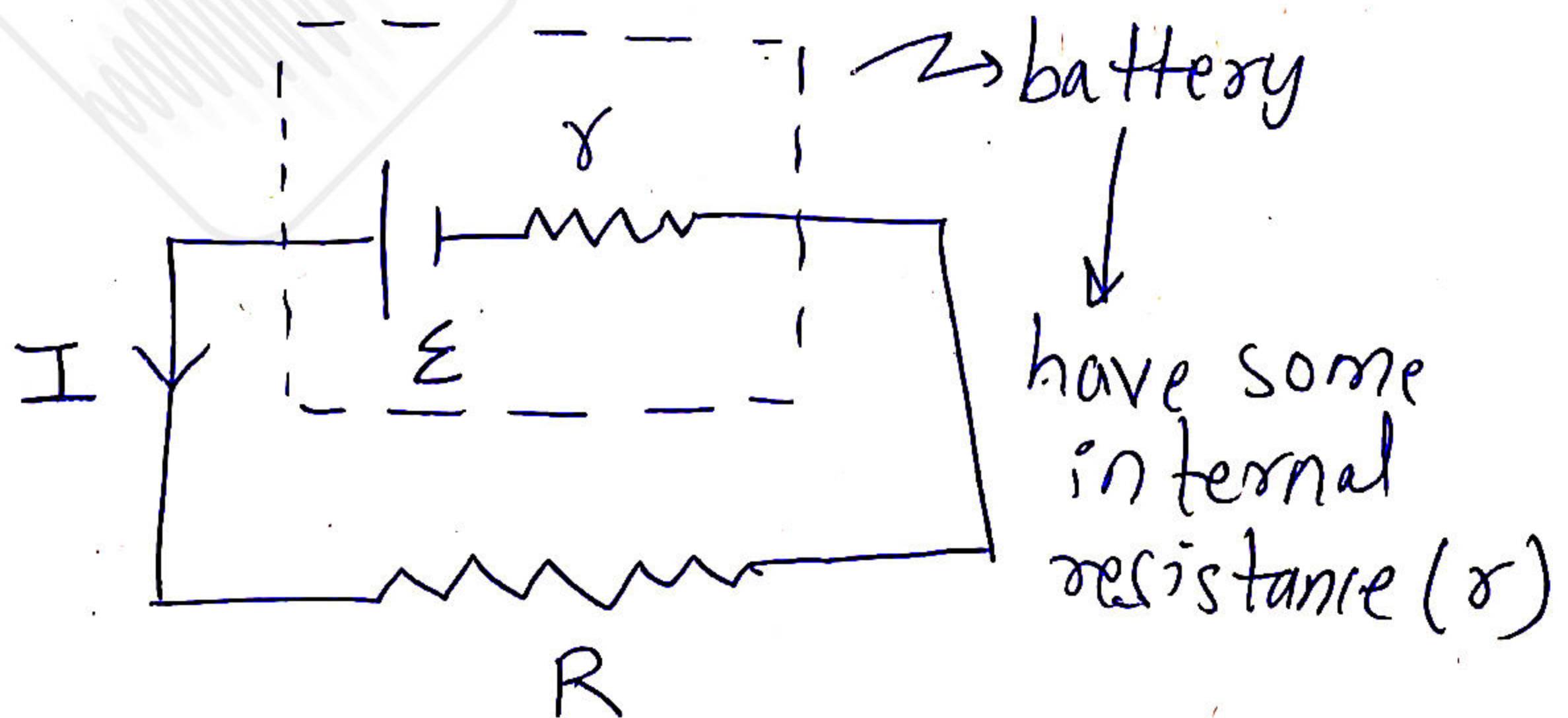
$$\Rightarrow \boxed{\alpha = \frac{1}{\rho_0} \frac{d\rho}{dT}}$$



→ ohm's law  $\neq$  universal law

↳ metal follows ohm's law upto normal working temperature

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



$V \rightarrow$  terminal voltage

Potential difference between terminals.

$\Rightarrow$   $V = E - I\gamma$

potential loss inside battery

(Potential difference, when  $I = 0$ )

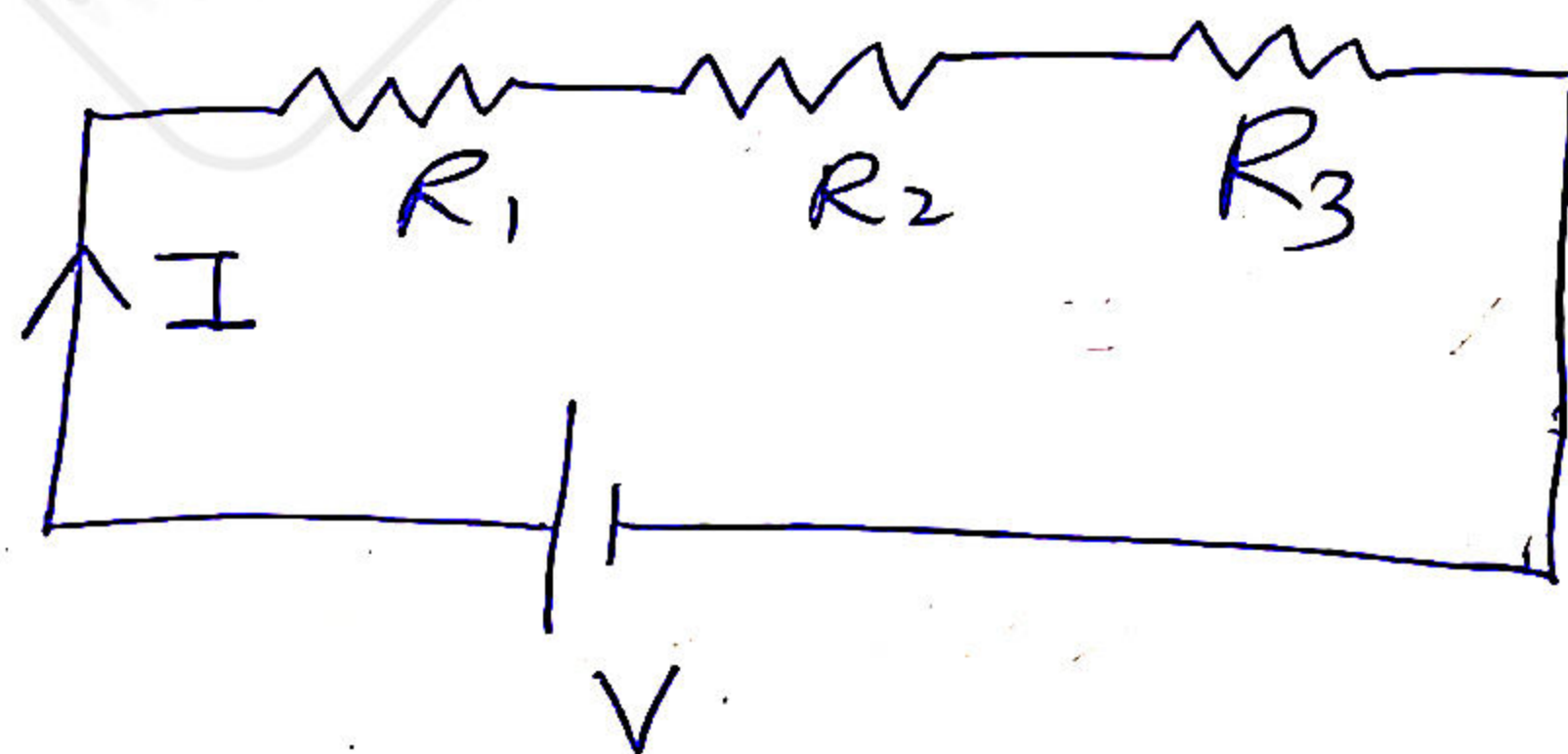
emf of battery

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

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

Resistances combination

SERIES: (current same)



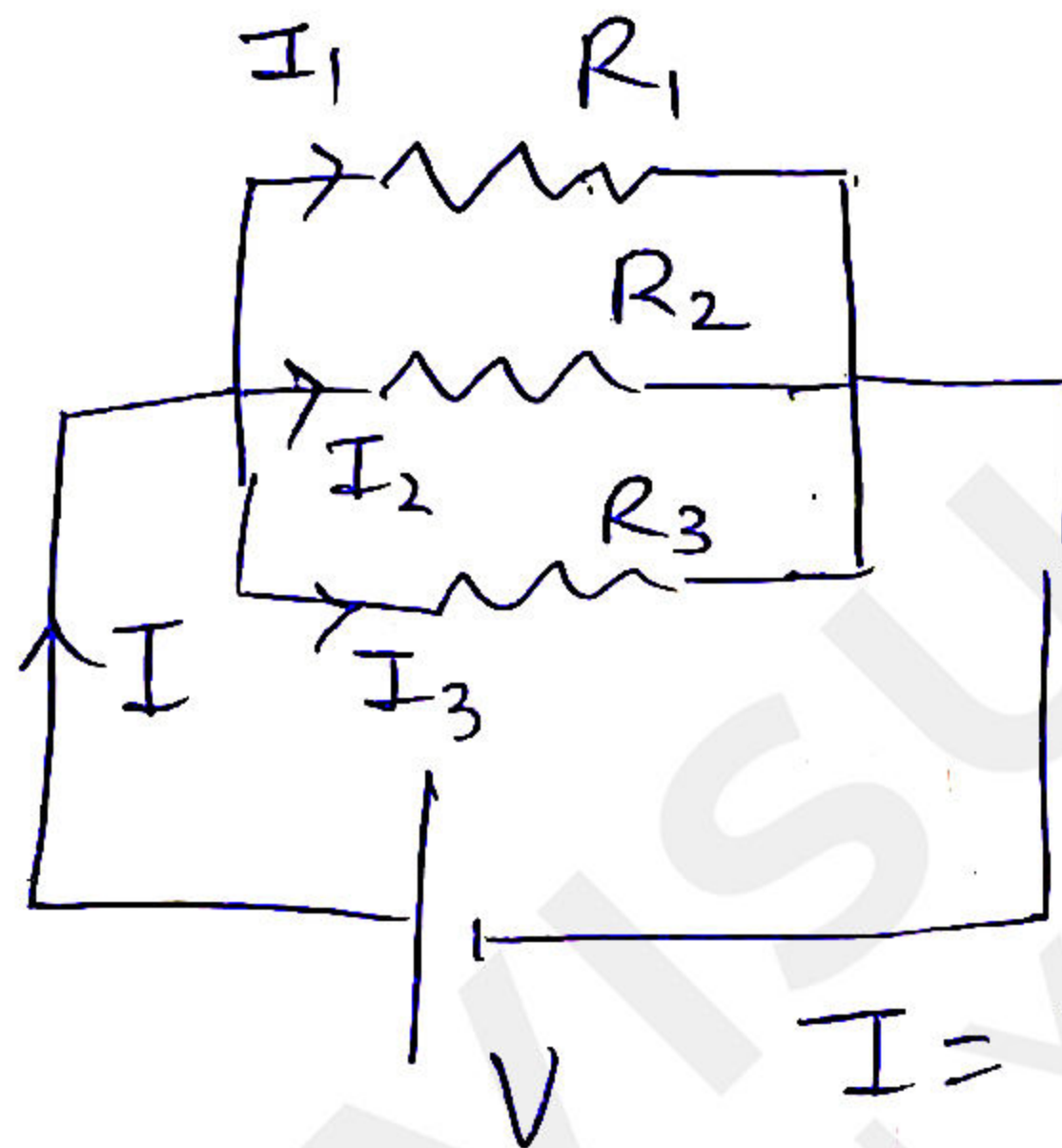
$$V_1 = IR_1, \quad V_2 = IR_2, \quad V_3 = IR_3$$

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

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

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

Resistances in parallel: (potential difference same)



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

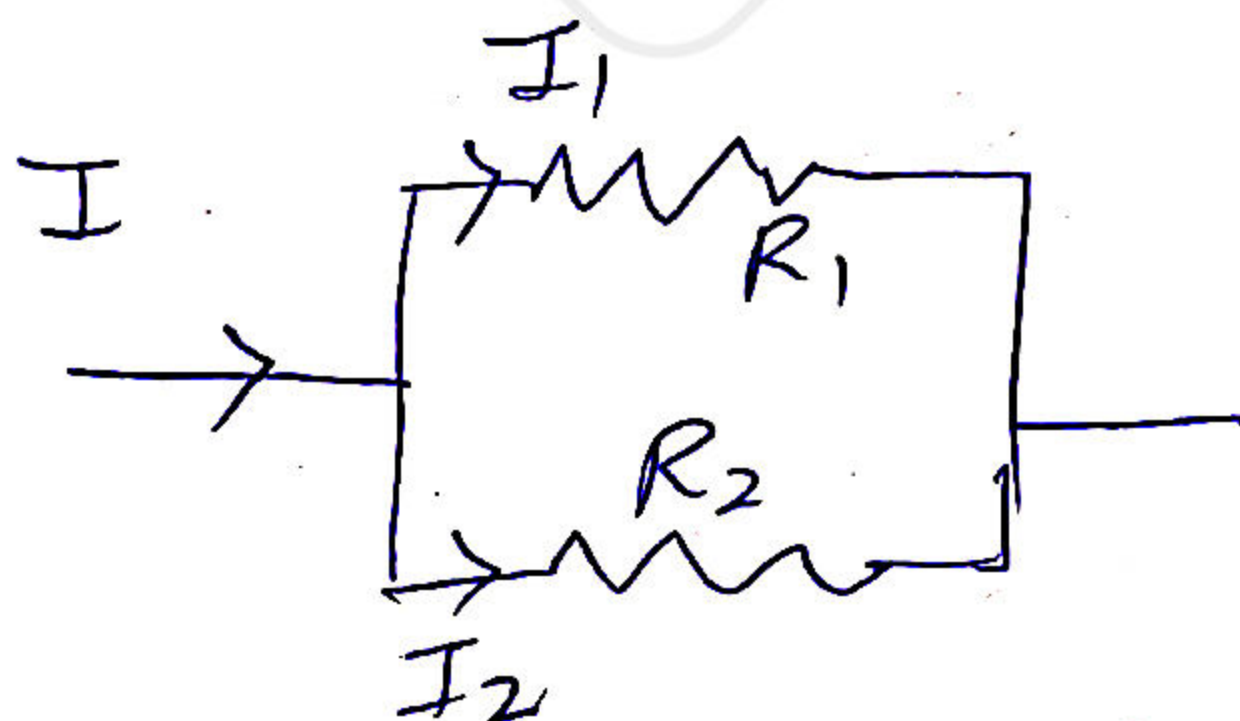
$$I_2 = \frac{V}{R_2}$$

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

$$I = I_1 + I_2 + I_3$$

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

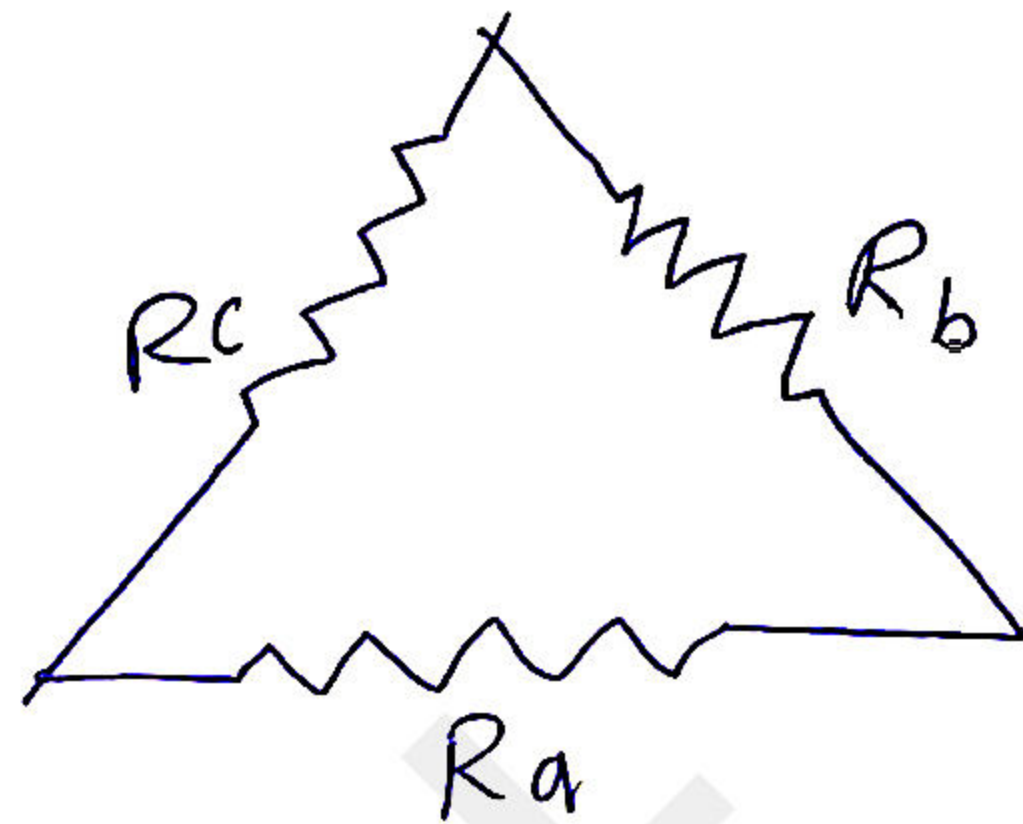
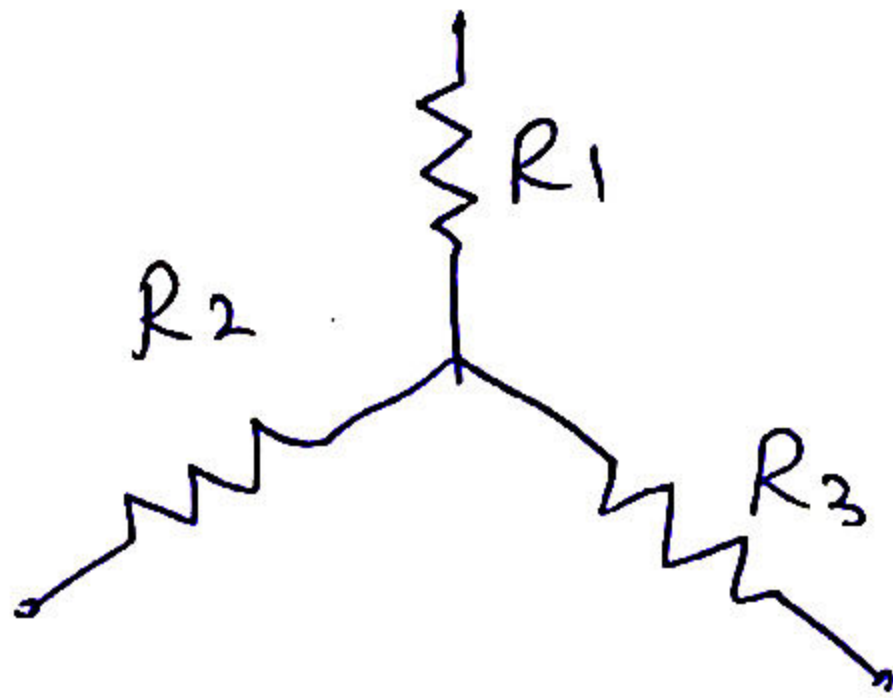
$$\Rightarrow \boxed{\frac{1}{R_{\text{net}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$



$$I_1 = \left( \frac{R_2}{R_1 + R_2} \right) I$$

$$I_2 = \left( \frac{R_1}{R_1 + R_2} \right) I$$

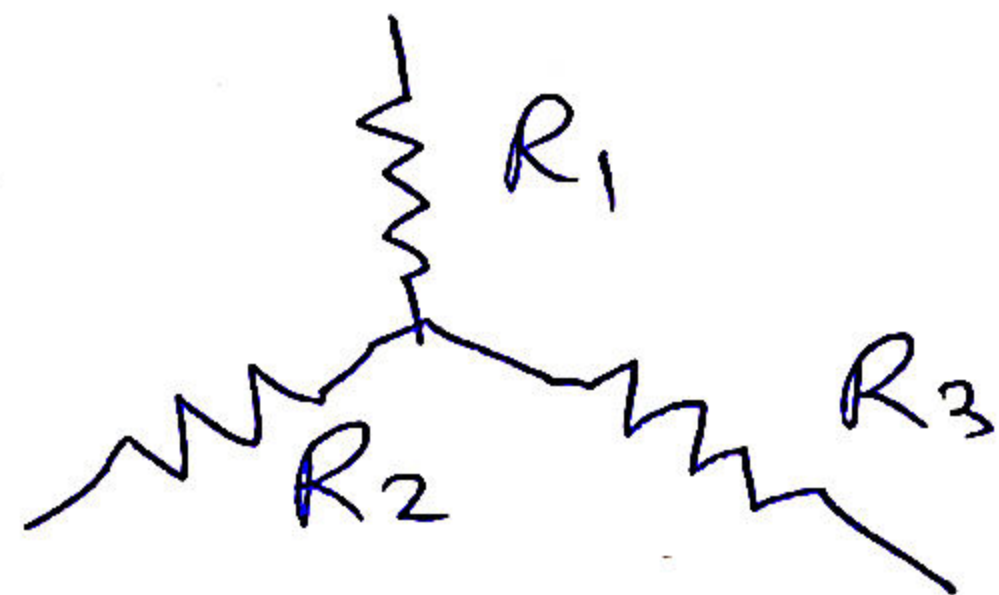
## Star-Delta Conversion



$$R_a = \frac{R_1 R_2 + R_1 R_3 + R_2 R_3}{R_1}$$

$$R_b = \frac{R_1 R_2 + R_1 R_3 + R_2 R_3}{R_2}$$

$$R_c = \frac{R_1 R_2 + R_1 R_3 + R_2 R_3}{R_3}$$

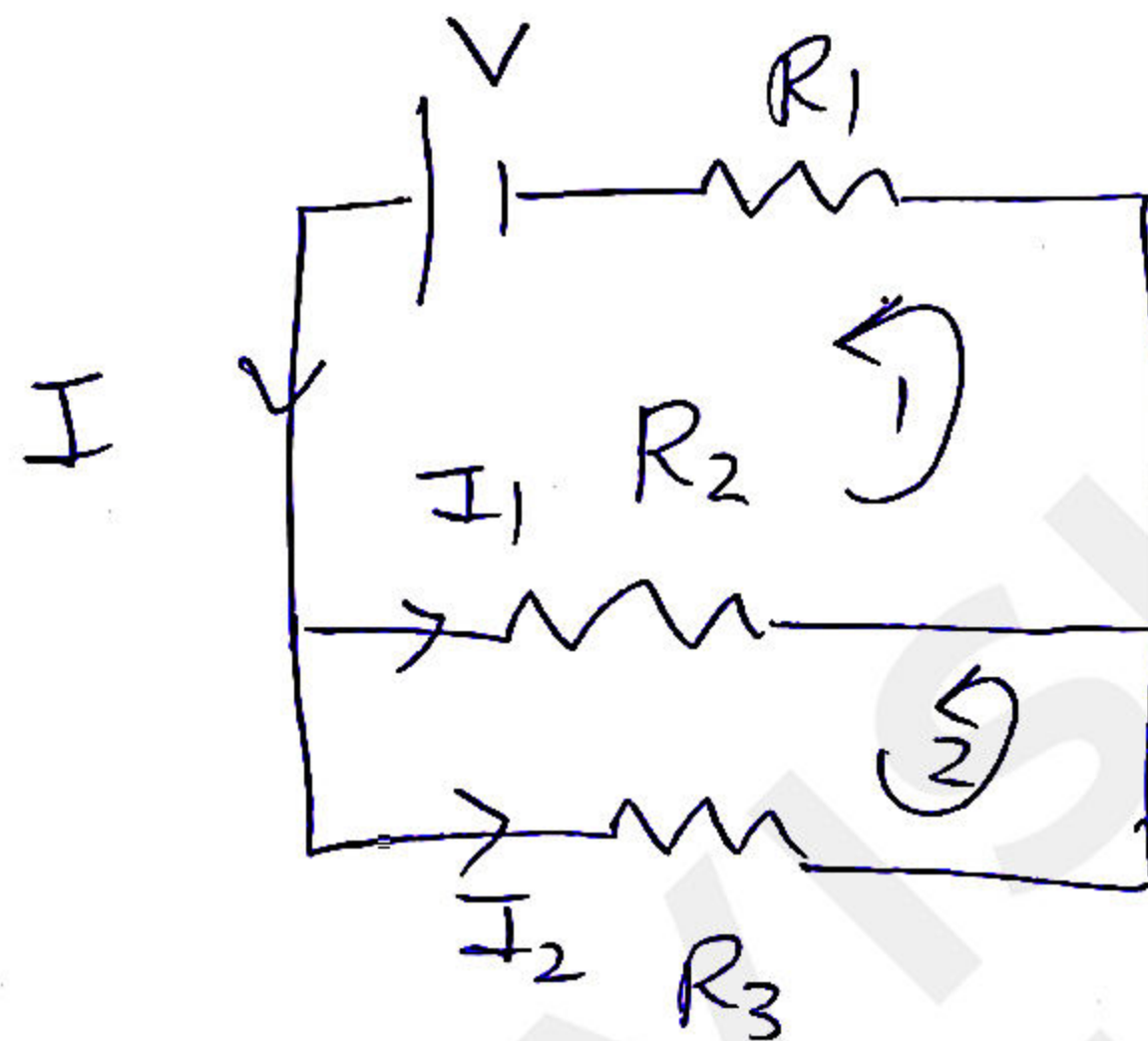


|                                         |                                         |
|-----------------------------------------|-----------------------------------------|
| $R_3 = \frac{R_a R_b}{R_a + R_b + R_c}$ | $R_1 = \frac{R_b R_c}{R_a + R_b + R_c}$ |
|                                         | $R_2 = \frac{R_a R_c}{R_a + R_b + R_c}$ |

Kirchhoff's laws:

Voltage law

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



In loop ①

$$V - I_1 R_2 - I R_1 = 0$$

$$-I_2 R_3 + I_1 R_2 = 0$$

In loop ②

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

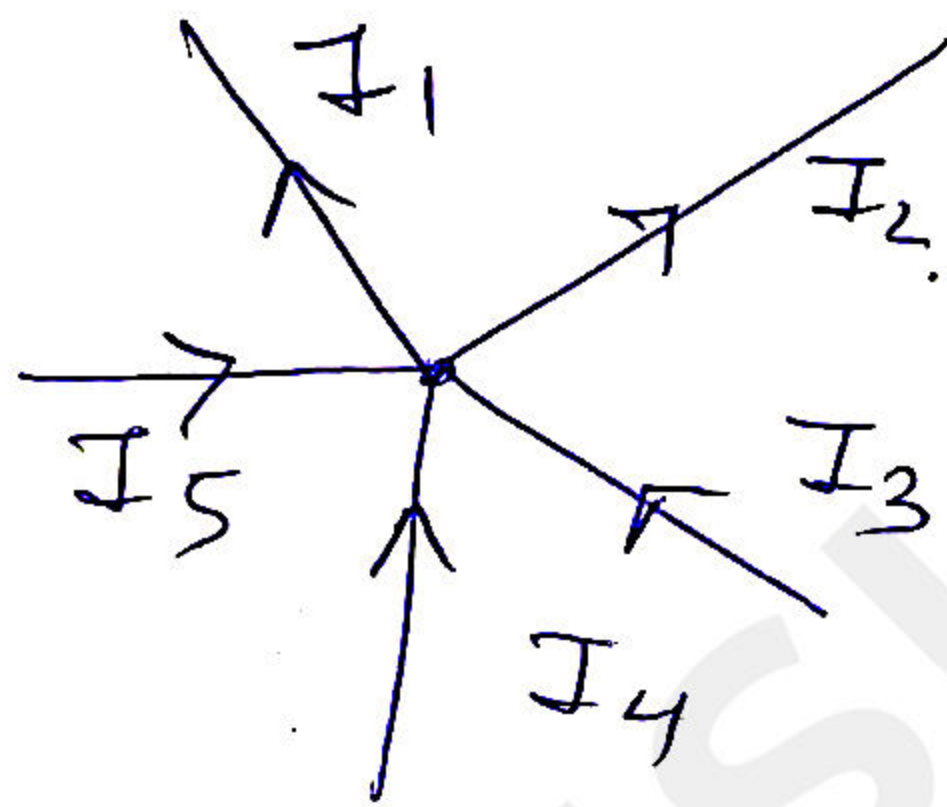
→ -ve (When going positive to negative side)

Sign → +IR (when move opposite to current)

-IR (when going along the current)

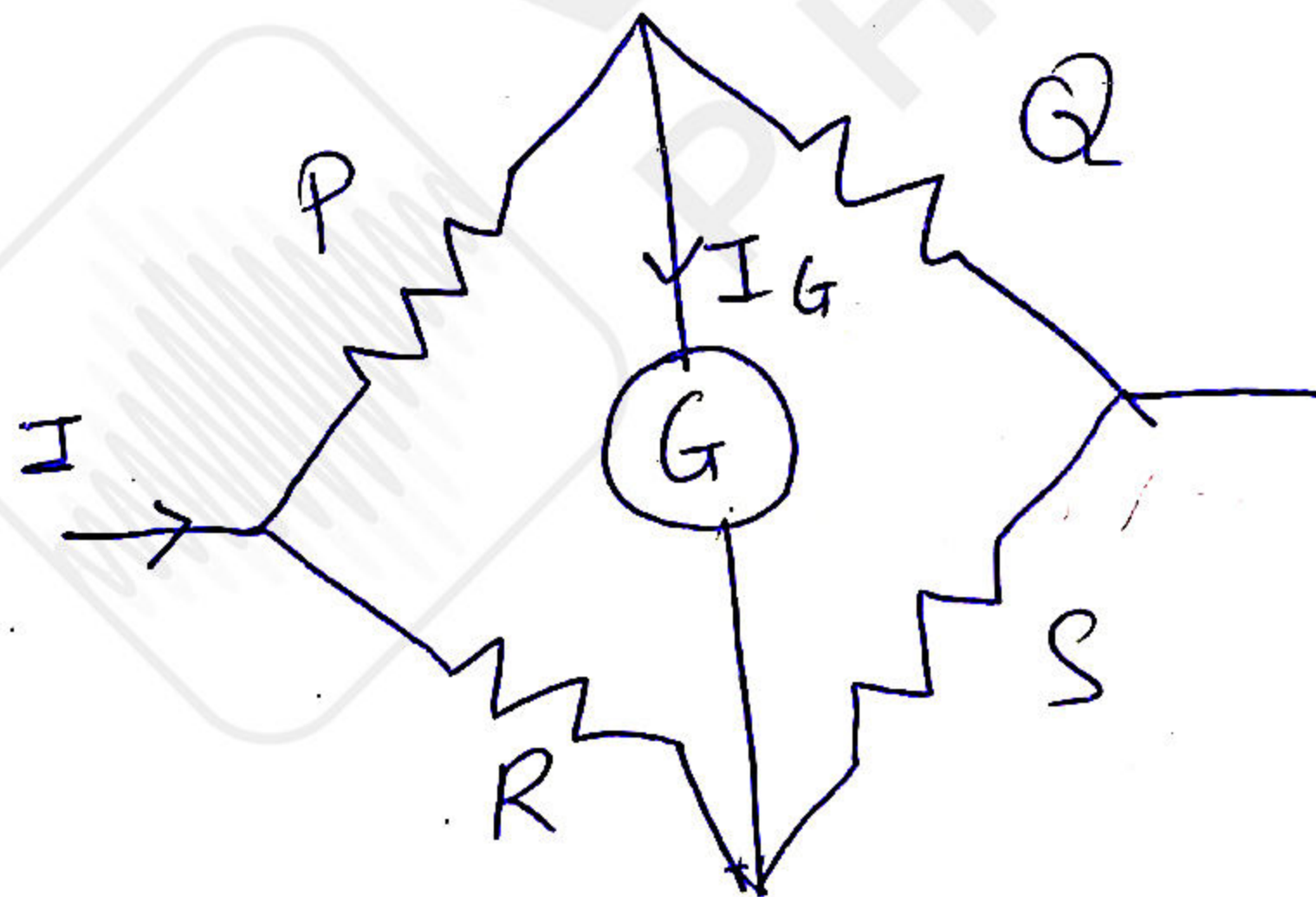
## Junction law :

Current coming to junction  
= Current going away from  
Junction



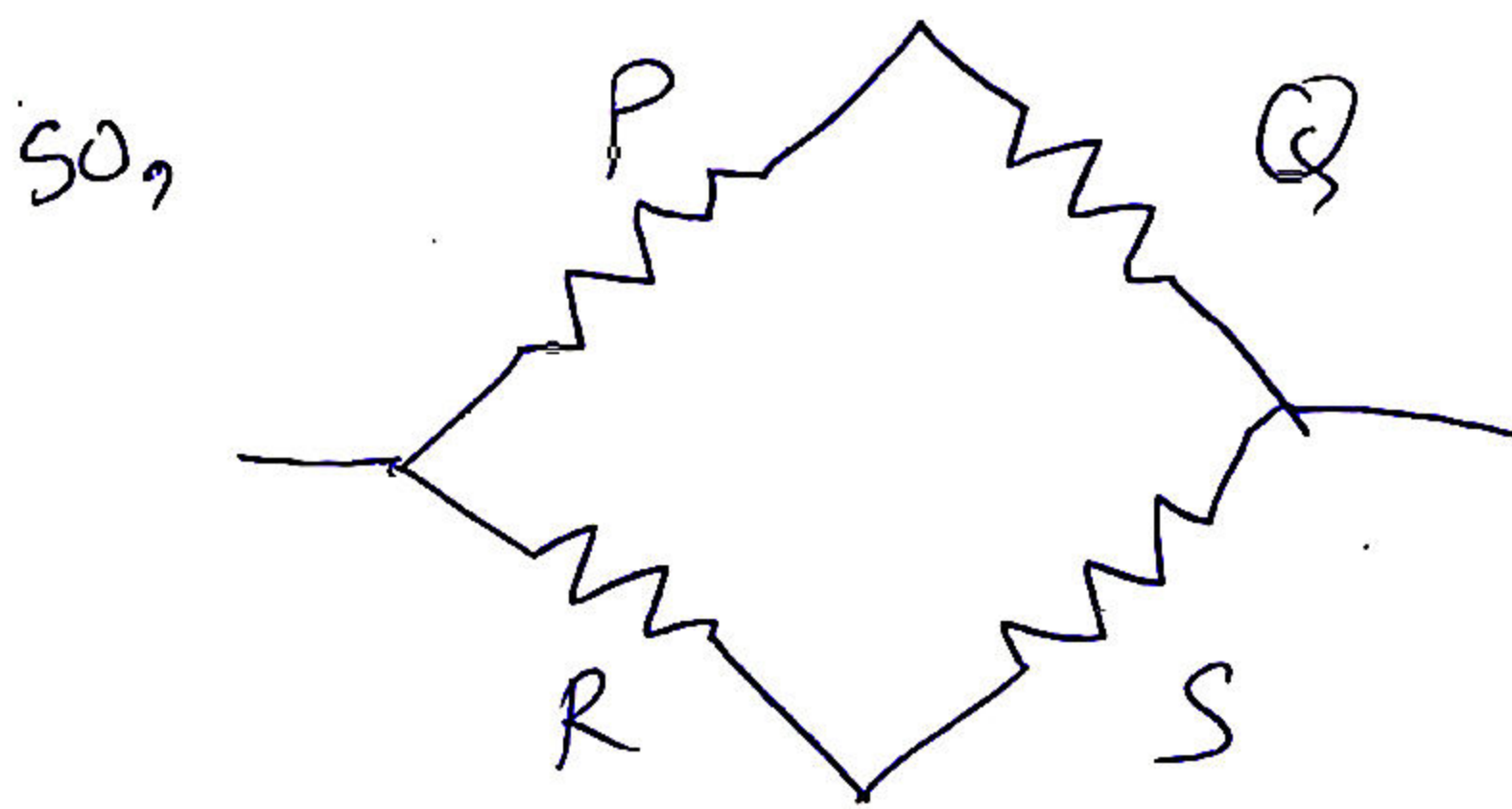
$$I_1 + I_2 = I_3 + I_4 + I_5$$

## WHEATSTONE BRIDGE:



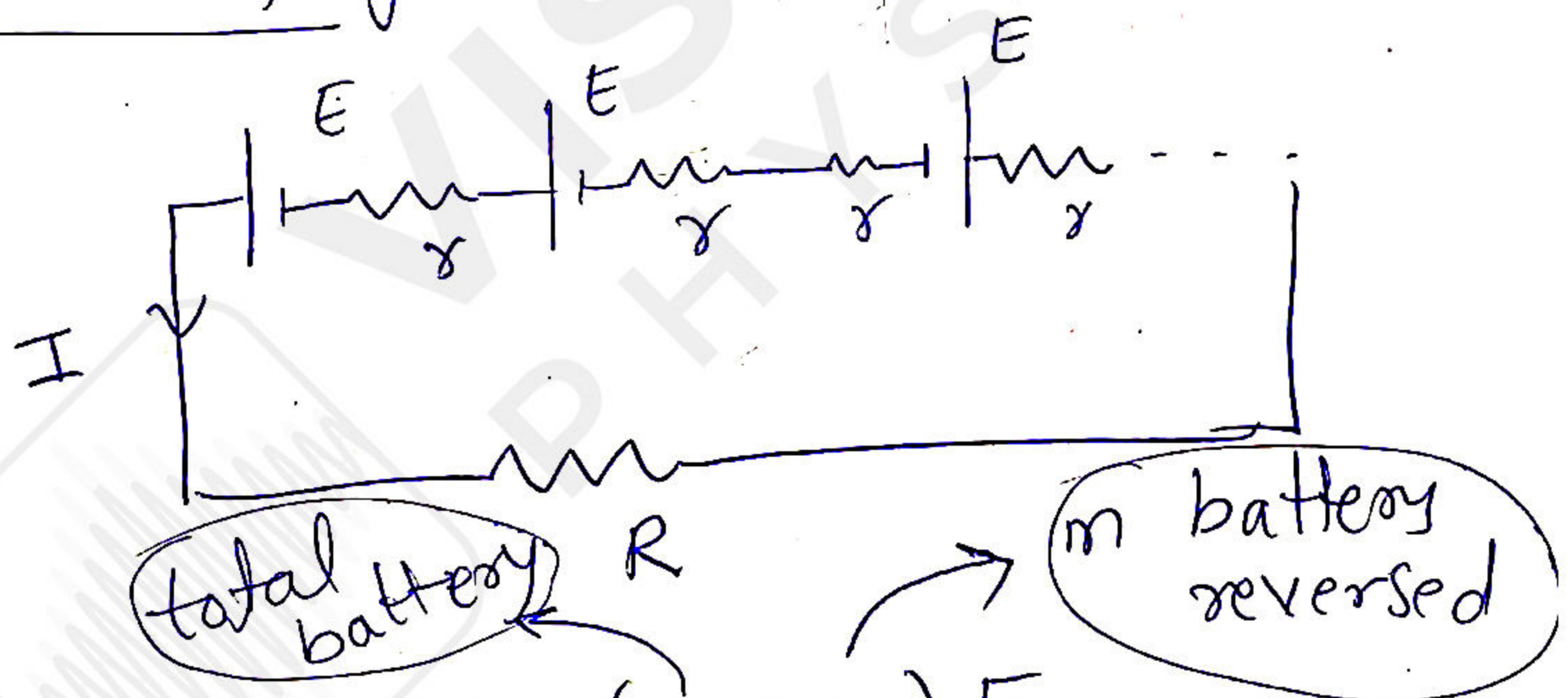
when,  $\boxed{\frac{P}{R} = \frac{Q}{S}}$

$$\boxed{I_G = 0}$$



## Combination of cells:

### Series - Grouping:

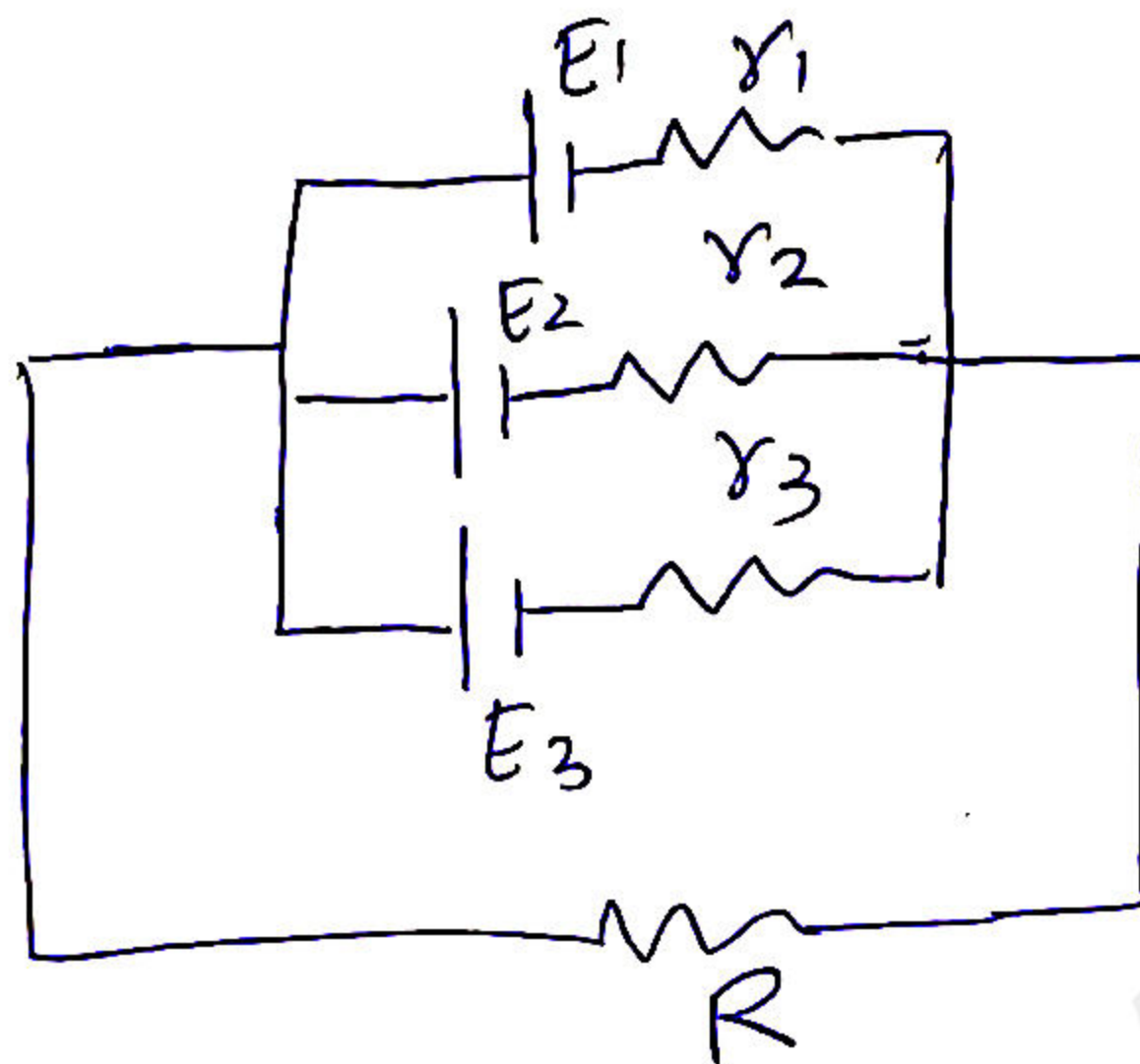


$$\text{net emf} = (n - 2m)E$$

$$\text{net resistance} = nr + R$$

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

## parallel - Grouping :



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

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

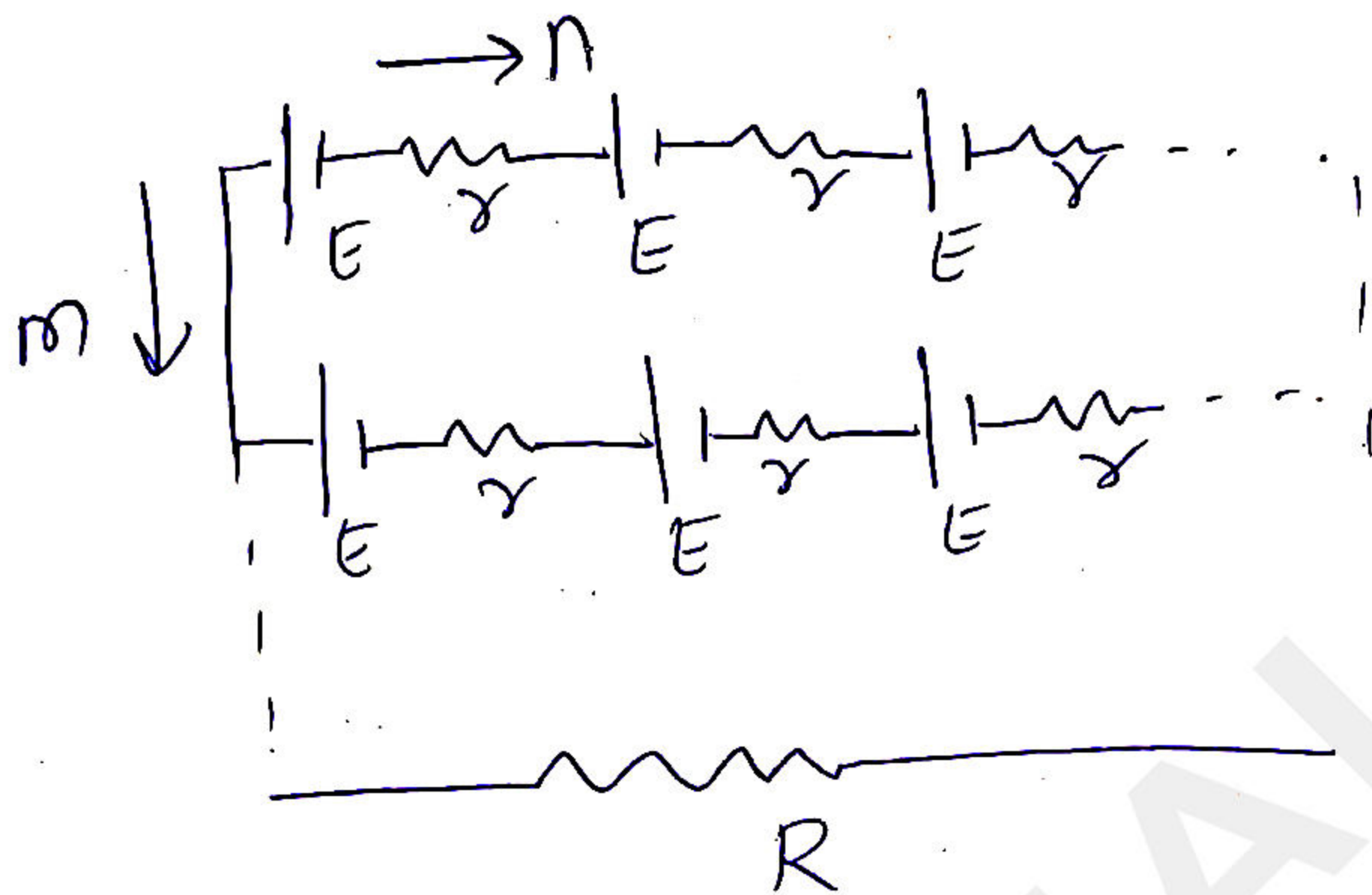
$$R_{eq} = R + \frac{1}{\frac{1}{r_1} + \frac{1}{r_2} + \dots}$$

if all are Same

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

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

Mixed Grouping : ( $E$  &  $r$  same)



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

Net emf of one row =  $nE$

and resistance of one row =  $n r$   
internal

So, 
$$i = \frac{nE}{R + \frac{n r}{m}}$$

$$i = \frac{mnE}{(\sqrt{mR} - \sqrt{nr})^2 + 2\sqrt{mn r R}}$$

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

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

Ammeter: → used to find current

Use to calculate  $\rho$  of

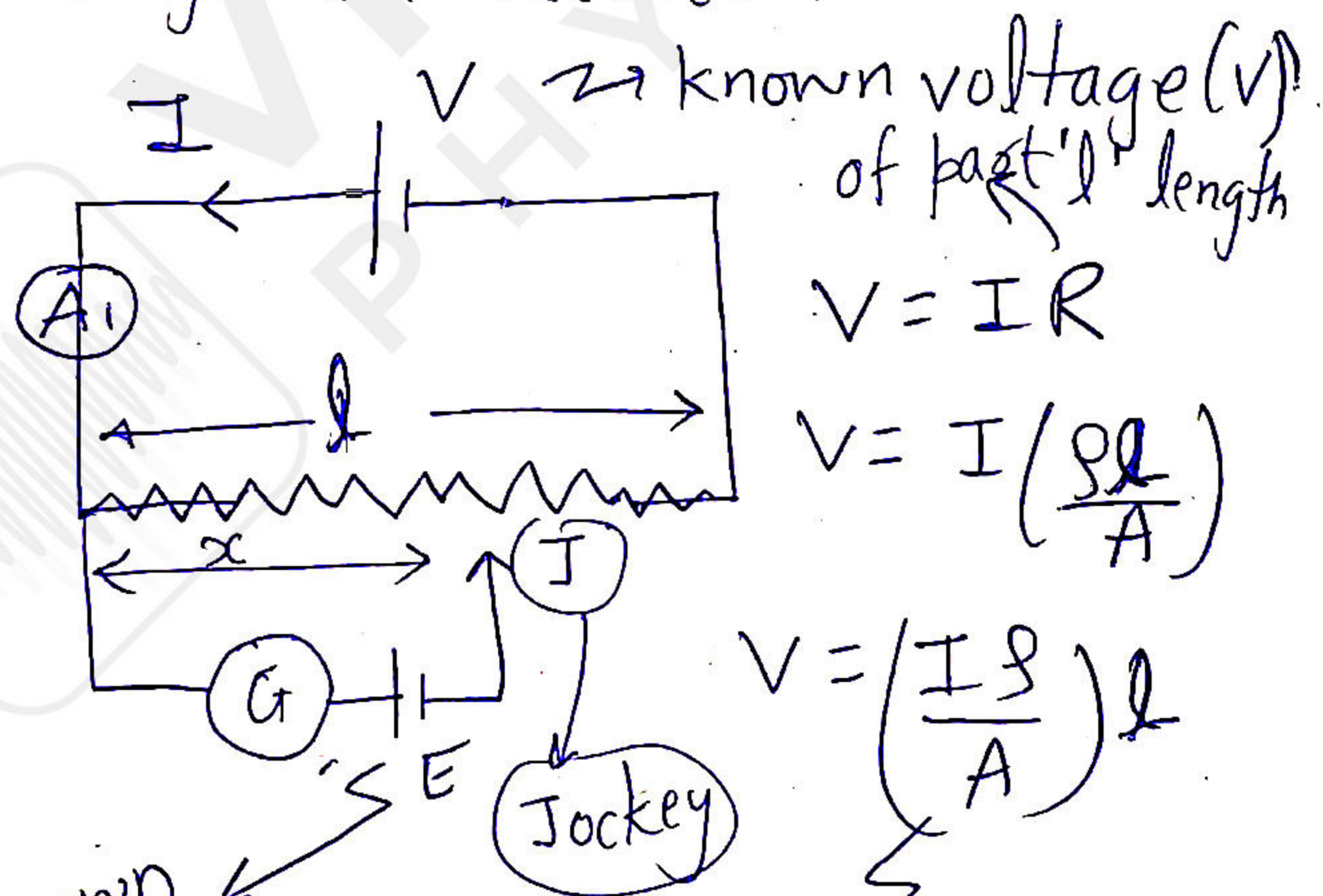
Connected in series with the current, so to get value

Voltmeter:

→ ideal resistance =  $\infty$

When Jockey is balanced so to get value of  $x$

Connected parallel with element to get the result.



if  $I$  is constant

$$V = K l$$

$$V \propto l$$

potential difference directly proportional to length.

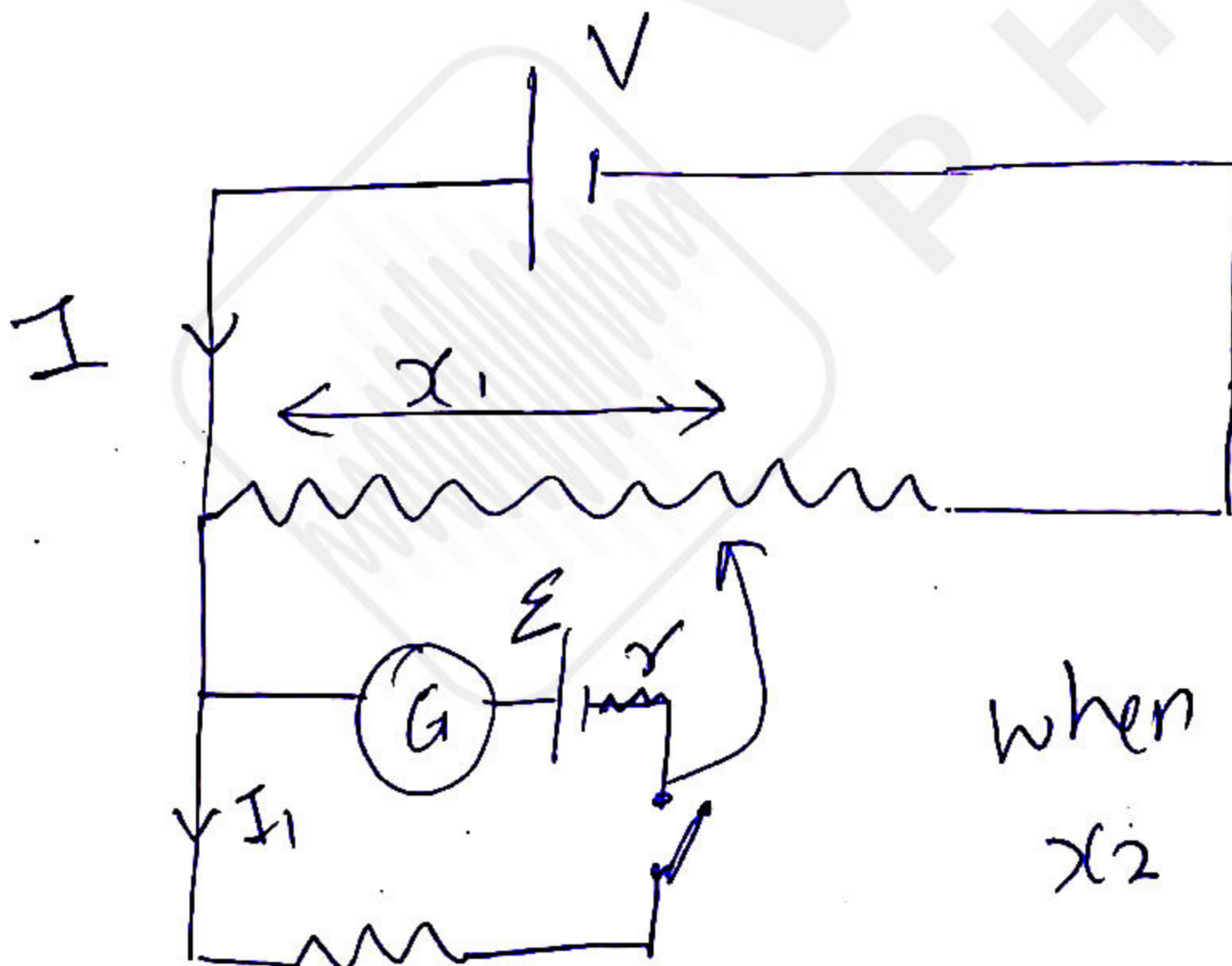
Now

$$E = kx$$

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

so if we have two battery,  $E_1$  &  $E_2$

$$\text{so, } \frac{E_1}{E_2} = \frac{x_1}{x_2}$$



when switch close,  
 $x_2$  is balanced point

so, ' $r$ '  
can be found

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

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