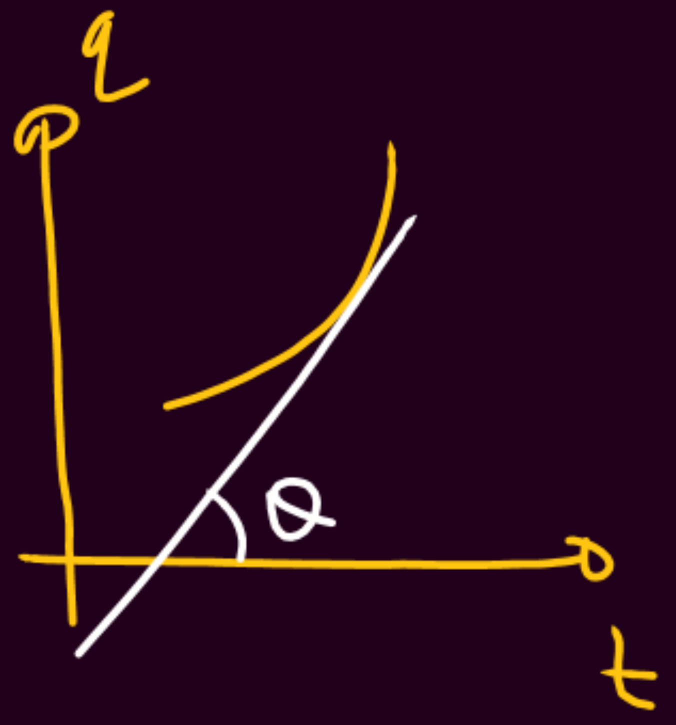
Current Electricity

Current

$$i_{av} = \frac{\Delta q}{\Delta t}$$

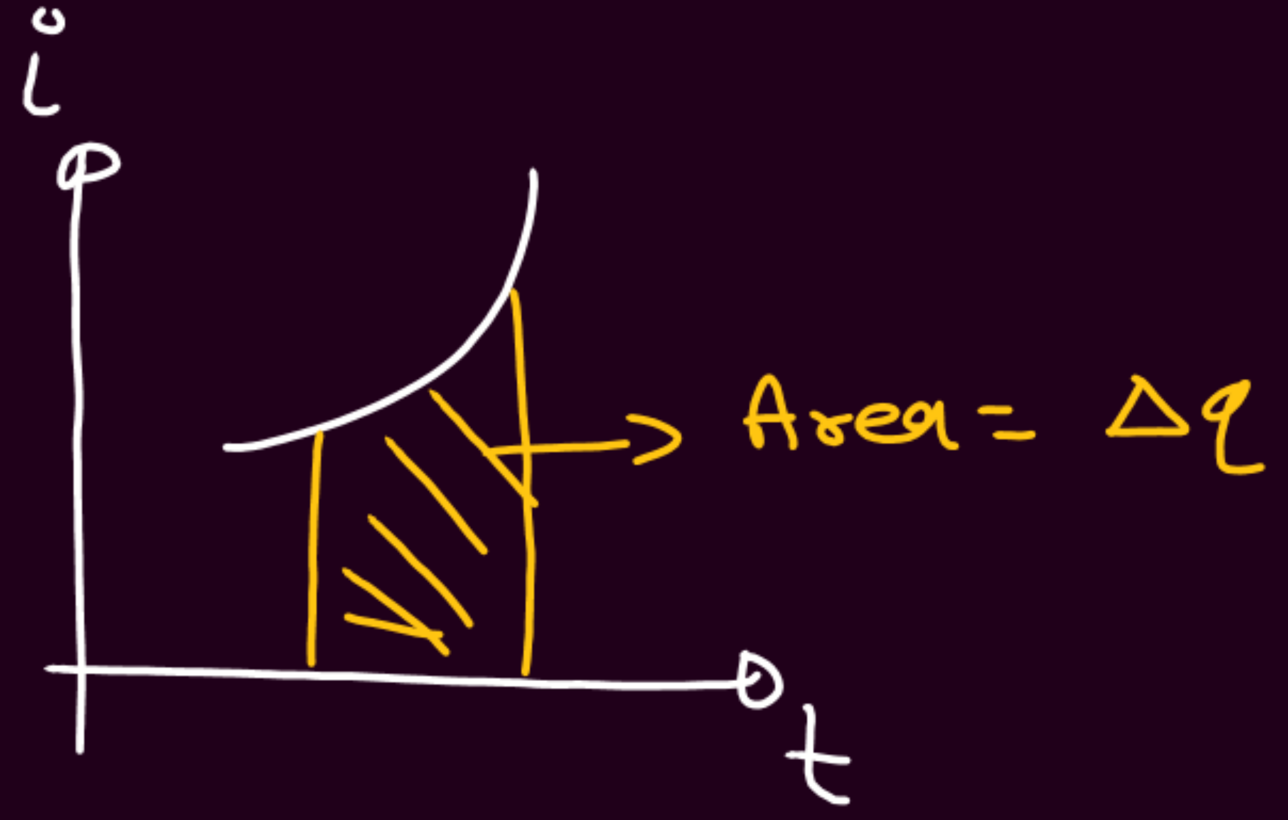
$$i_{inst} = \frac{dq}{dt}$$

$$1\,A = 1\,C/s$$



$$i = \frac{dq}{dt} = \tan\theta$$

$$\Delta q = \int i\,dt$$



$e = 1.6 \times 10^{-19}$ C

$m_e = 9.1 \times 10^{-31}$ kg

α - particle = He^{2+} pn np

Deutron pn

$$\beta \begin{cases} \beta_- \ (e^-) \text{ electron} \\ \beta_+ \ (e^+) \text{ positron} \end{cases}$$

Q $10^6 e^-$

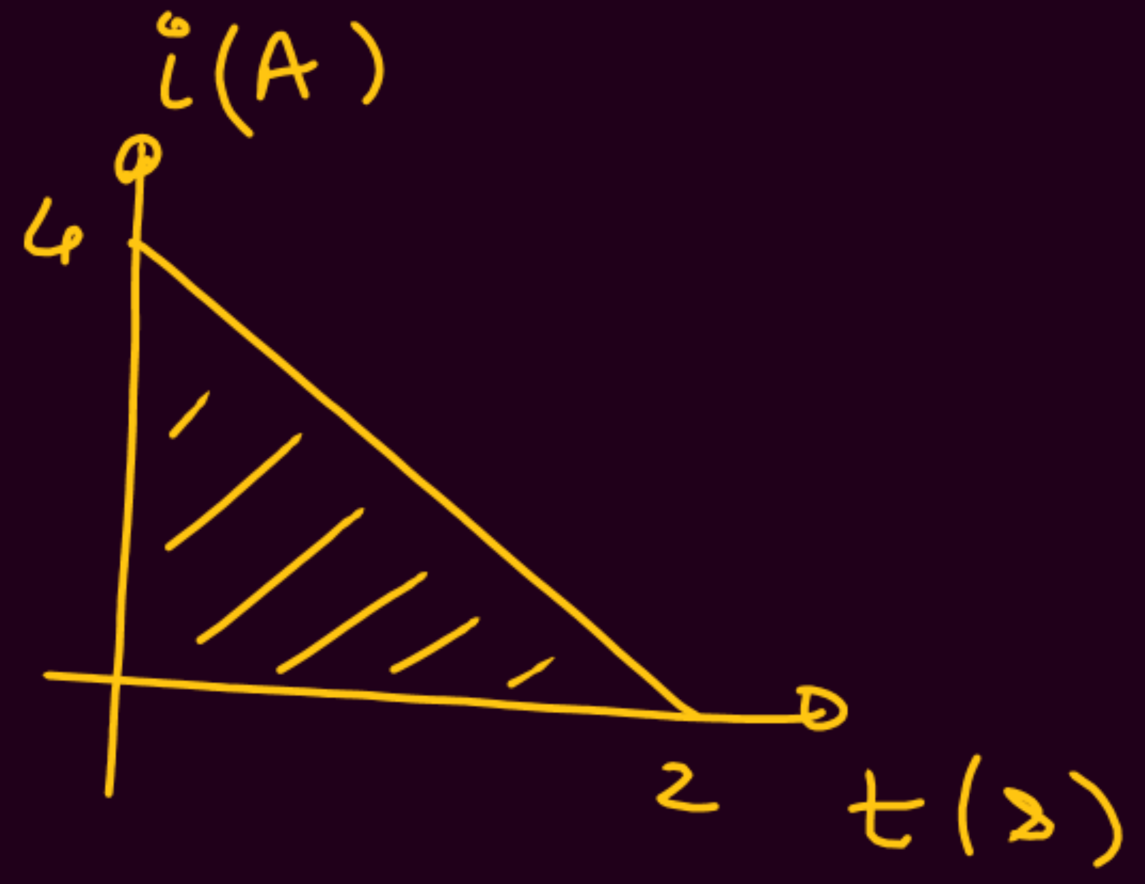
$10\ cm^2$

per min

$$i = \frac{10^6 \times (1.6 \times 10^{-19})}{60}$$

$$i = \frac{8}{3} \times 10^{-15}\ A$$

Q



$$\Delta q = \text{Area} = \frac{1}{2}(2)(4) = \underline{\underline{4C}}$$

Q: $q = (t^2 - 4t + 2)\ C$

Find 't' when $i = 0$

$$i = \frac{dq}{dt} = 2t - 4 = 0$$

$$t = 2s$$

Q: $q = (t^2 - 2t + 5)$

① i_{av} in $2s$

$t = 2s \qquad q = 2^2 - 2(2) + 5 = 5$

$t = 0 \qquad q = 0 - 0 + 5 = 5$

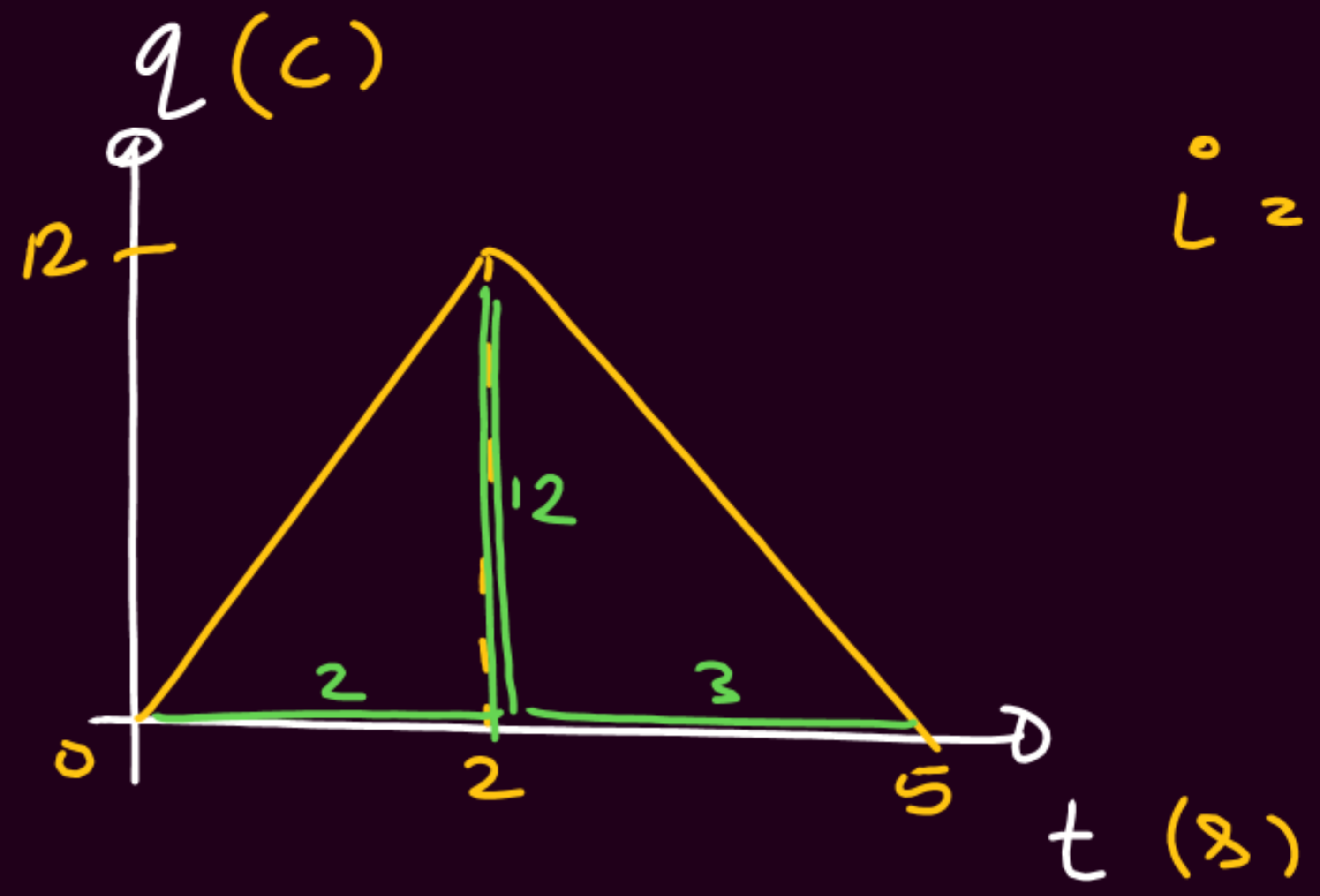
$$i_{av} = \frac{\Delta q}{\Delta t} = \frac{5-5}{2} = 0$$

② i at $3s$

$$i = \frac{dq}{dt} = 2t - 2$$

$t = 3s \qquad i = (2 \times 3) - 2 = 4A$

Q

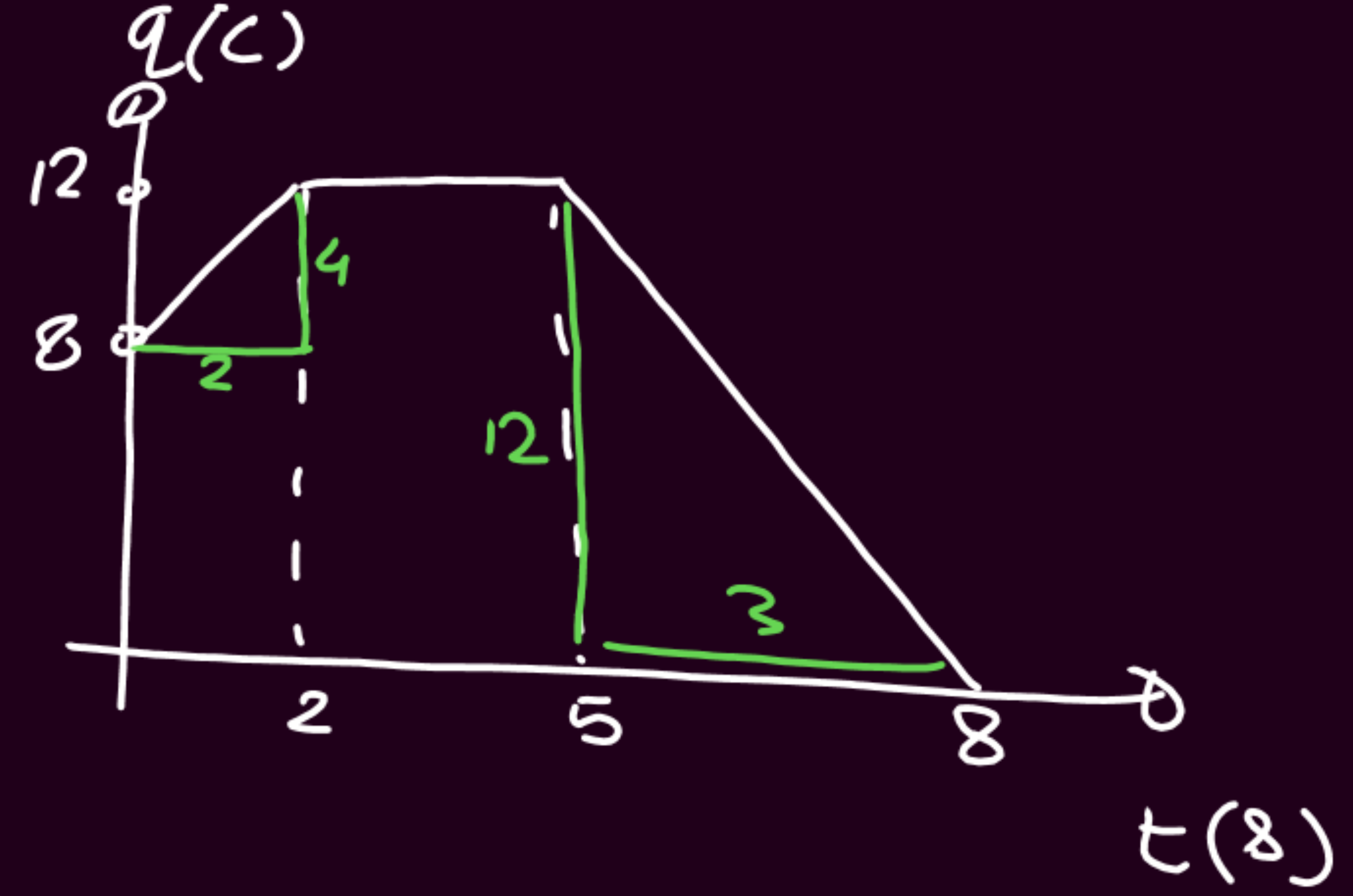


$i = \frac{dq}{dt} = \underline{\underline{\text{slope}}}$

$t = 1s \qquad i = \frac{12}{2} = 6A$

$t = 3s \qquad i = -\frac{12}{3} = -4A$

Q.



$t = 1s \qquad i = \frac{4}{2} = 2A$

$t = 3s \qquad i = 0$

$t = 7s \qquad i = -\frac{12}{3} = -4A$

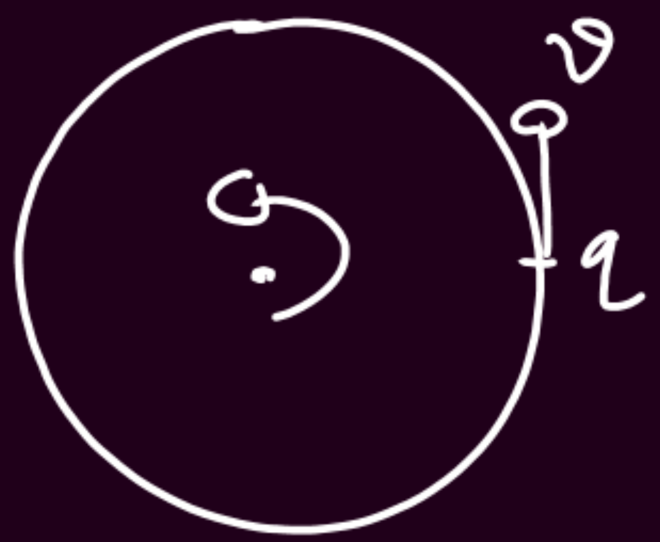
Sign convention

$\oplus \quad \xrightarrow{v} \quad \xrightarrow{i}$

$\ominus \quad \xrightarrow{v} \quad \xleftarrow{i}$

Point charge in UCM

UCM with uniform Speed



$$\boxed{i = qf = \frac{q}{T} = \frac{q\omega}{2\pi} = \frac{qv}{2\pi r}}$$

Q e^- gr state of H-atom

$$i = \frac{q v}{2\pi r} = \frac{(1.6\times10^{-19})(2.18\times10^{6})}{2(3.14)(0.53\times10^{-10})}$$

$$i = \frac{\cancel{1.6}\times\cancel{2.18}}{\cancel{2}(\cancel{3.14})(\cancel{0.53})}(10^{-3}) = \underline{10^{-3}\,A}$$

Current Density ($\vec{j}$)

$$\boxed{j = \frac{i}{A}}$$

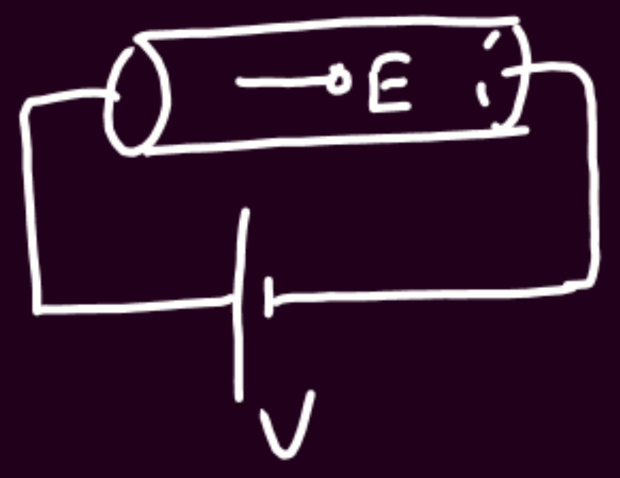
$$i = \vec{j} \cdot \vec{A}$$

Microscopic View

Conductor → free e^-
[in Abundance]

→ Random motion

→ $\boxed{\vec{v}_{av} = 0}$



V = Voltage = Potential difference (P.D.)

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

→ Thermal speed $\sim 10^5$ m/s

→ Drift speed $\sim 10^{-4}$ m/s (v_d)

→ Relaxation time $\tau \sim 10^{-14}$ s

→ Mean free path $\lambda \sim 10$ Å

① $\boxed{v_d = \frac{eE}{m}\tau}$

② $\boxed{i = neAv_d}$

n = no. of free e^- per unit volume

nA = ——— " ——— length

③ $\frac{i}{A} = ne\left(\frac{eE\tau}{m}\right)$

$\boxed{\vec{j} = \sigma\vec{E}}$

Microscopic form of Ohm's law

$\sigma = \frac{ne^2\tau}{m}$ = Electrical Conductivity

④ $\boxed{\rho = \frac{m}{ne^2\tau}}$ = Resistivity (Specific Resistance)

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

⑤ $\frac{i}{A} = \frac{1}{\rho}\left(\frac{V}{l}\right)$

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

$\boxed{i = \frac{1}{R}V}$ Ohm's law

$\boxed{i \propto V}$

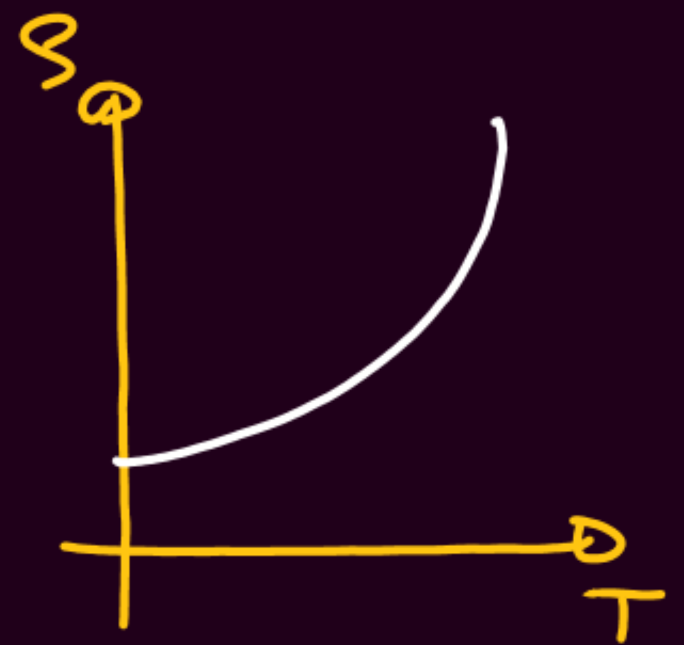
6. Mobility (μ)

$$\boxed{\mu = \frac{v_d}{E}} = \frac{e\tau}{m} = \frac{\sigma}{ne}$$

$$\boxed{\sigma = ne\mu}$$

Resistivity

Metals



$\boxed{Cu}$

As Temp ↑

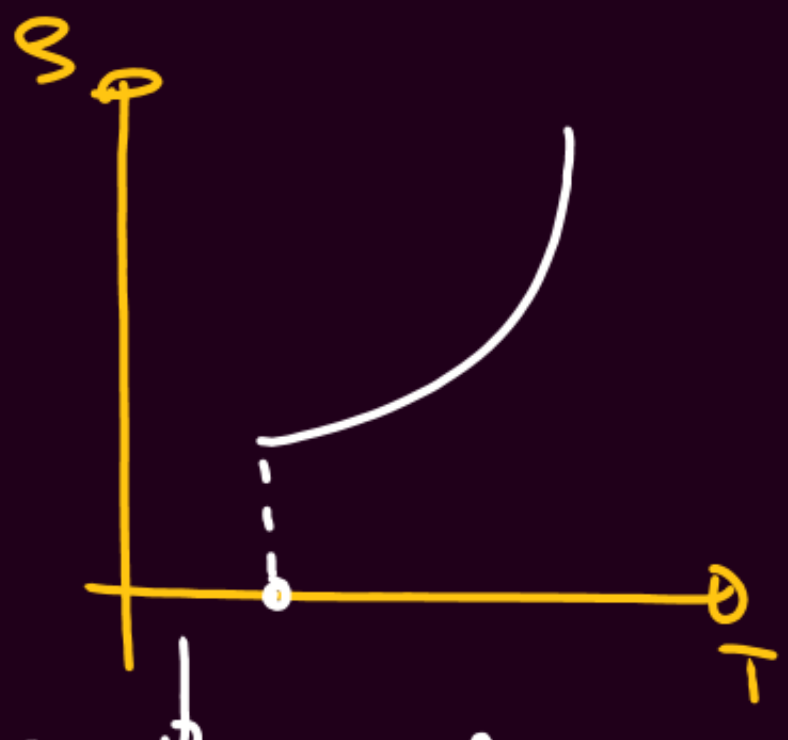
Collision → frequent

$\tau \downarrow$

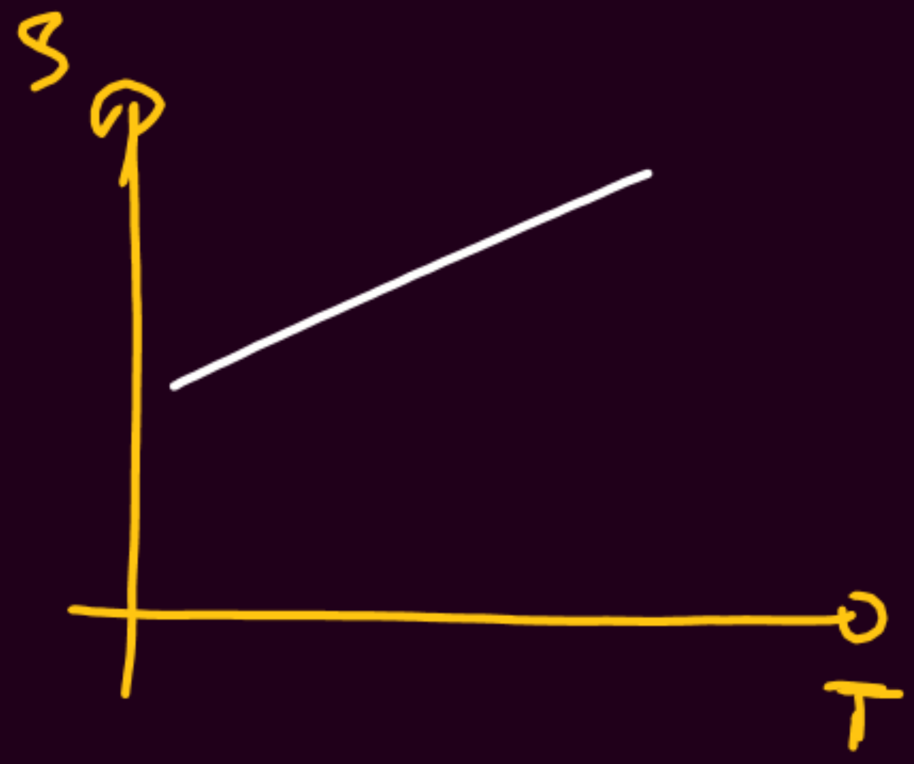
$$\rho = \frac{m}{ne^2\tau}$$

$\boxed{\rho \uparrow}$

$\boxed{\alpha = (+)}$



Superconductivity



Alloy → nichrome

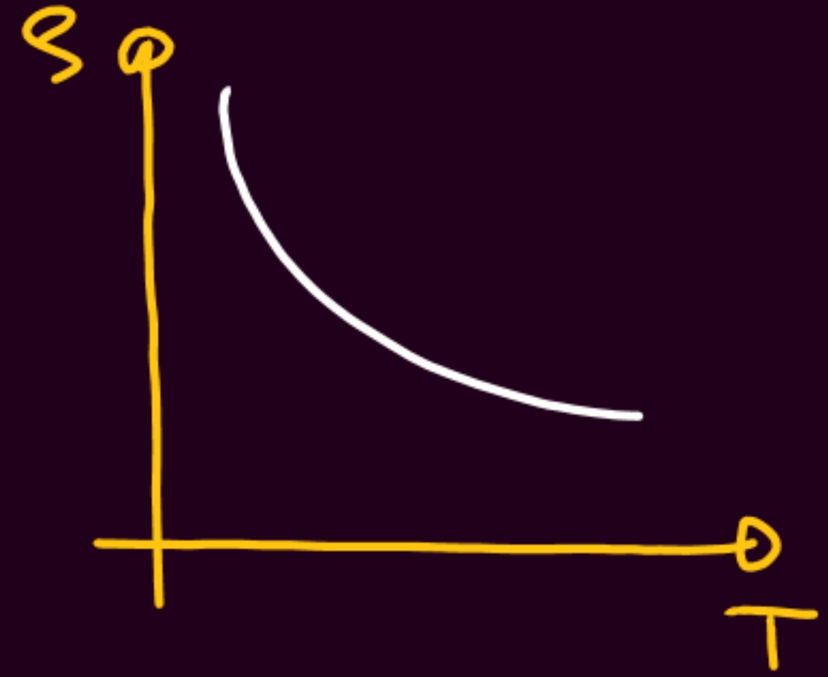
$$\rho = \rho_0(1 + \alpha\Delta\theta)$$

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

α = Temp. Coeff of Resistance

SC / Insulator / Dielectric

$\boxed{Si / Ge}$

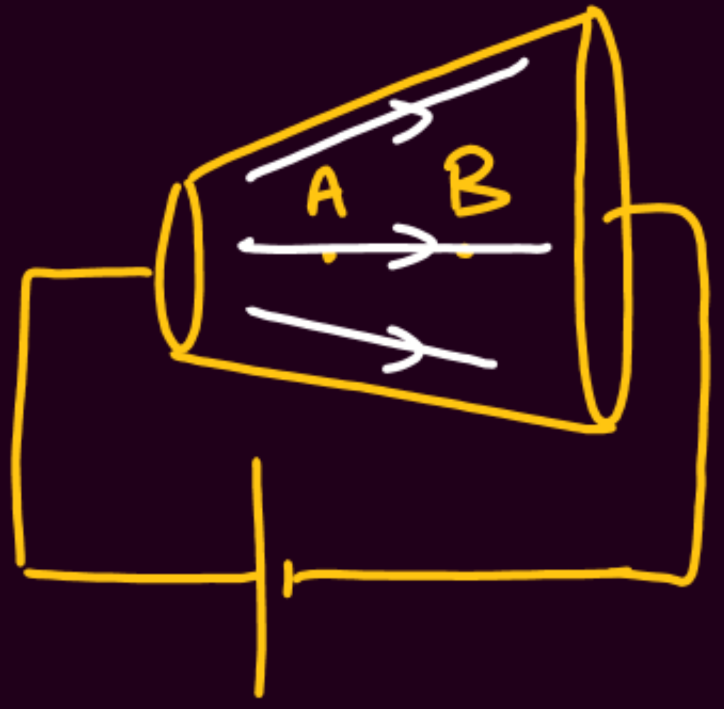


As Temp ↑

$n \uparrow$ [no. of charge carrier]

$$\rho = \frac{m}{ne^2\tau}$$

$\boxed{\rho \downarrow}$ $\boxed{\alpha = (-)}$



$i_A = i_B$ [Series]

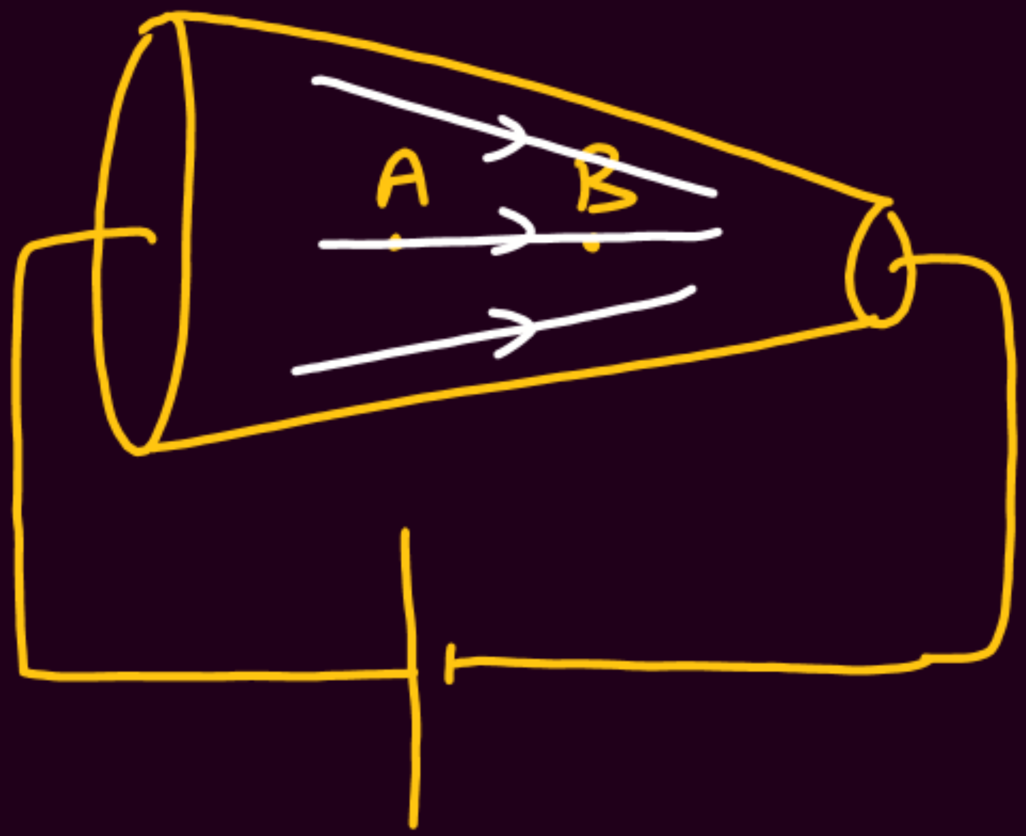
$j_A > j_B$ $\left[j = \frac{i}{A} \right]$

$E_A > E_B$ $\left[j = \sigma E \right]$

$V_A > V_B$

$v_{d_A} > v_{d_B}$ $\left[i = neAv_d \right]$

$\boxed{\text{Potential}}$



$i_A = i_B$

$j_A < j_B$

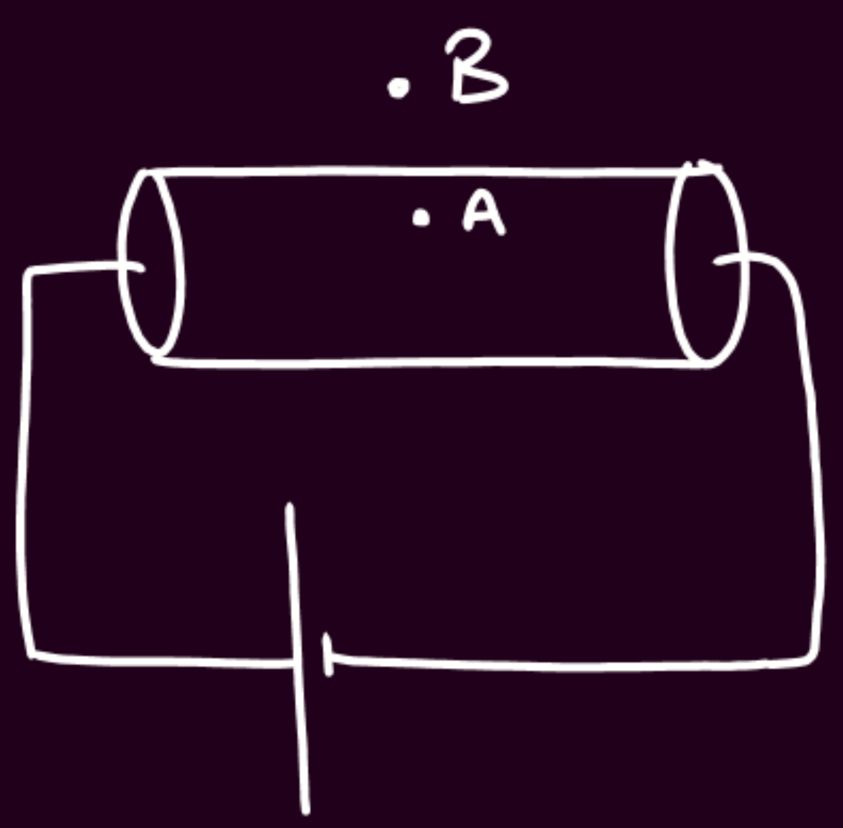
$E_A < E_B$

$V_A > V_B$

$v_{d_A} < v_{d_B}$

Conductor → Electrostatic $\boxed{E_{in} = 0}$

Conductor → Current $\boxed{E_{in} \neq 0}$



1) $E = 0$ $B = 0$

2) $E \neq 0$ $B \neq 0$ A

3) $E = 0$ $B \neq 0$ B

4) $E \neq 0$ $B = 0$

Q. 2 A

$4 cm^2$

$10^{22} / cm^3$

$i = neAv_d$

$2 = (10^{22} \times 10^6)(1.6 \times 10^{-19})(4 \times 10^{-4})\, v_d$

$v_d = \frac{\cancel{2}}{1.6 \times \cancel{4}_2 \times 10^5} = 0.3 \times 10^{-5}$ m/s

$= 3 \times 10^{-6}$ m/s

$1 cm = 10^{-2} m$

$1 cm^2 = 10^{-4} m^2$

$1 cm^3 = 10^{-6} m^3$

$[4 cm^2 = 4 \times 10^{-4} m^2]$

$\left[\frac{10^{22}}{cm^3} = \frac{10^{22}}{10^{-6} m^3}\right]$

Physics

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2, 4, 9

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1, 2, 6 to 12

14, 15,

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13, 14, 26,

30,

Q. $i = neAv_d$

$4 = (nA)(1.6\times10^{-19})\,10^{-4}$

$(nA) = \frac{4}{1.6}\times10^{23} = 2.5\times10^{23}/m$

1 $\boxed{10\Omega} \longrightarrow \boxed{12\Omega}$ R

R_0 $200^\circ C$ $\theta = ?$

$$R = R_0(1 + \alpha\,\Delta\theta)$$

1 $\alpha = 10^{-3}/^\circ C$

$$12 = 10\,(1 + 10^{-3}\,\Delta\theta)$$

$$1.2 = 1 + 10^{-3}\,\Delta\theta$$

$$0.2 = 10^{-3}\,\Delta\theta$$

$$\Delta\theta = 200^\circ C$$

$$\boxed{\theta_f = 400^\circ C}$$

---

2 $\boxed{10\Omega} \longrightarrow \boxed{30\Omega}$ R_2

R_1 $200^\circ C$ $\theta = ?$

$$R = R_0(1 + \alpha\,\theta)$$

R_0 → Resistance at $0^\circ C$

$$\boxed{\frac{R_2}{R_1} = \frac{1 + \alpha\theta_2}{1 + \alpha\theta_1}}$$

$\boxed{\theta_1 / \theta_2 \quad ^\circ C}$

2 $\alpha = 10^{-3}/^\circ C$

$$\frac{3\cancel{0}}{1\cancel{0}} = \frac{1 + 10^{-3}\theta_2}{1 + 10^{-3}(200)}$$

$$3.6 = 1 + 10^{-3}\,\theta_2$$

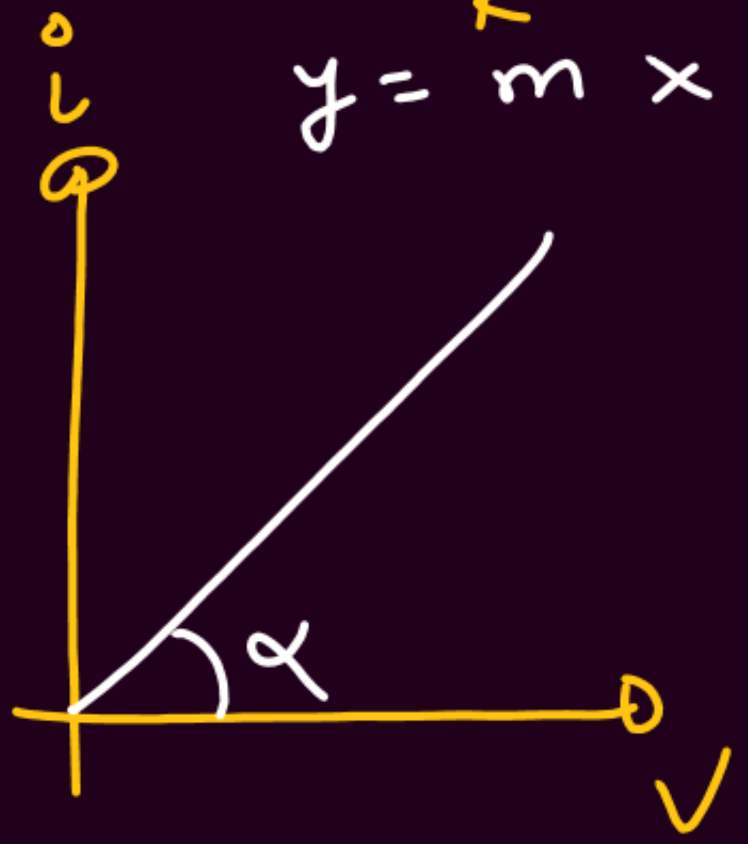
$$2.6 = 10^{-3}\,\theta_2$$

$$\boxed{2600^\circ C = \theta_2}$$

Ohm's law

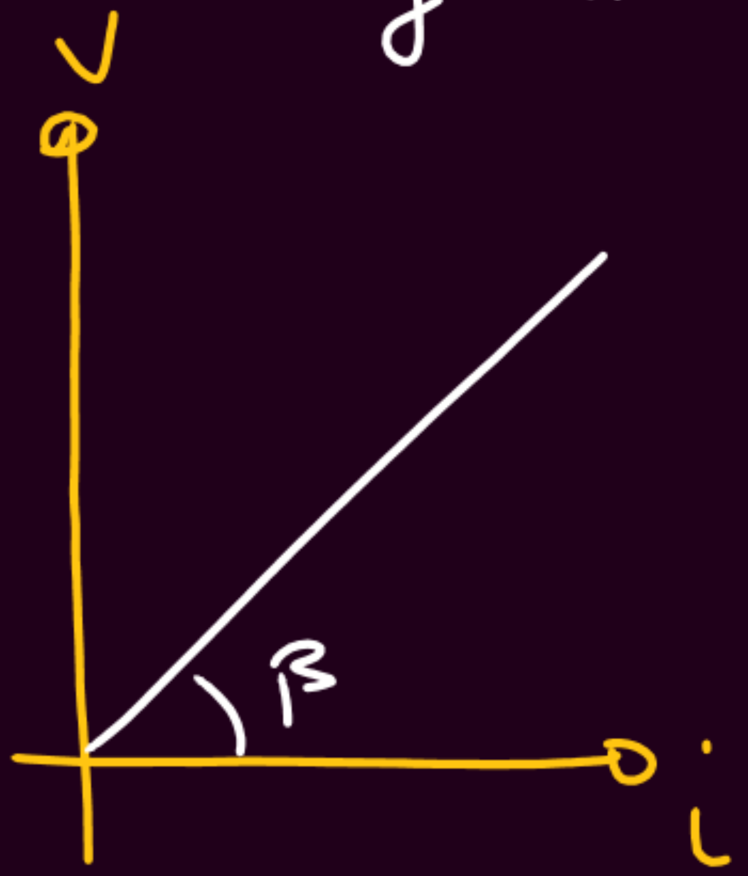
$$i = \frac{1}{R}(V)$$

$$y = m\,x$$



$$V = (R)\,i$$

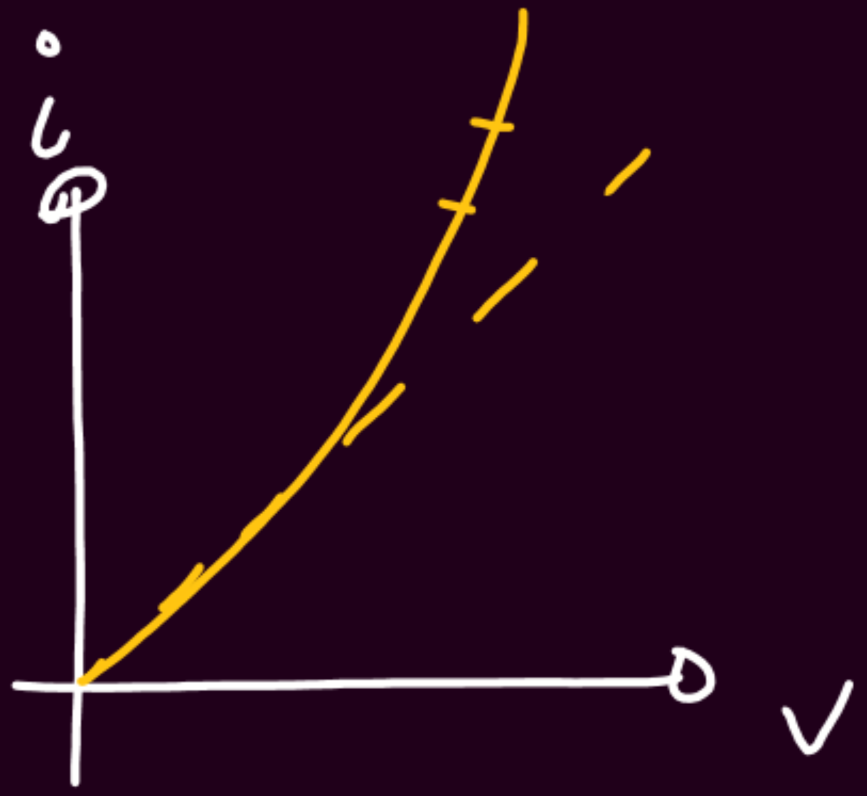
$$y = m\,x$$



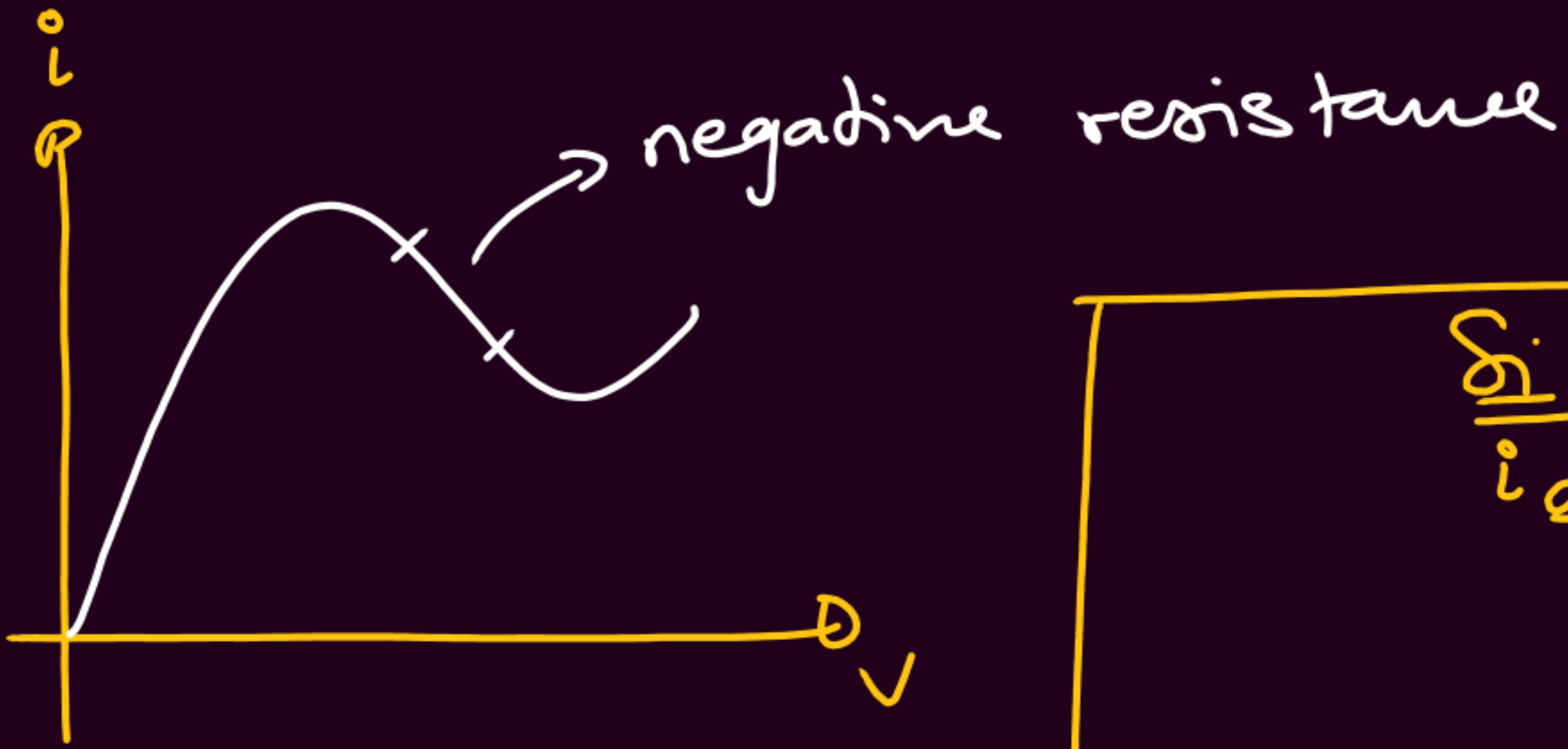
$$\text{slope} = \tan\alpha = \left(\frac{1}{R}\right)$$

$$\text{slope} = \tan\beta = R$$

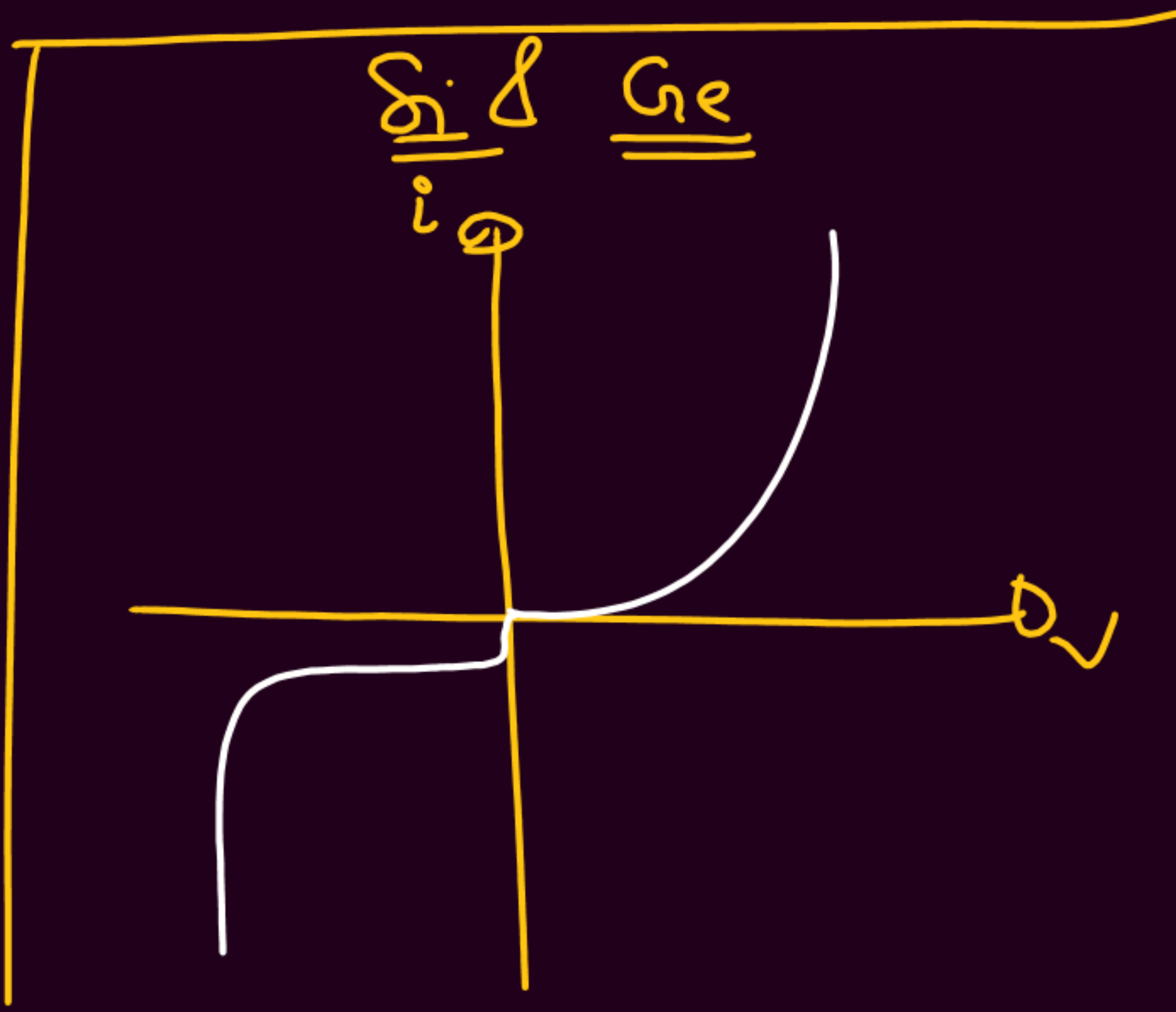
Dynamic Resistance $r_d = \frac{\Delta V}{\Delta i}$

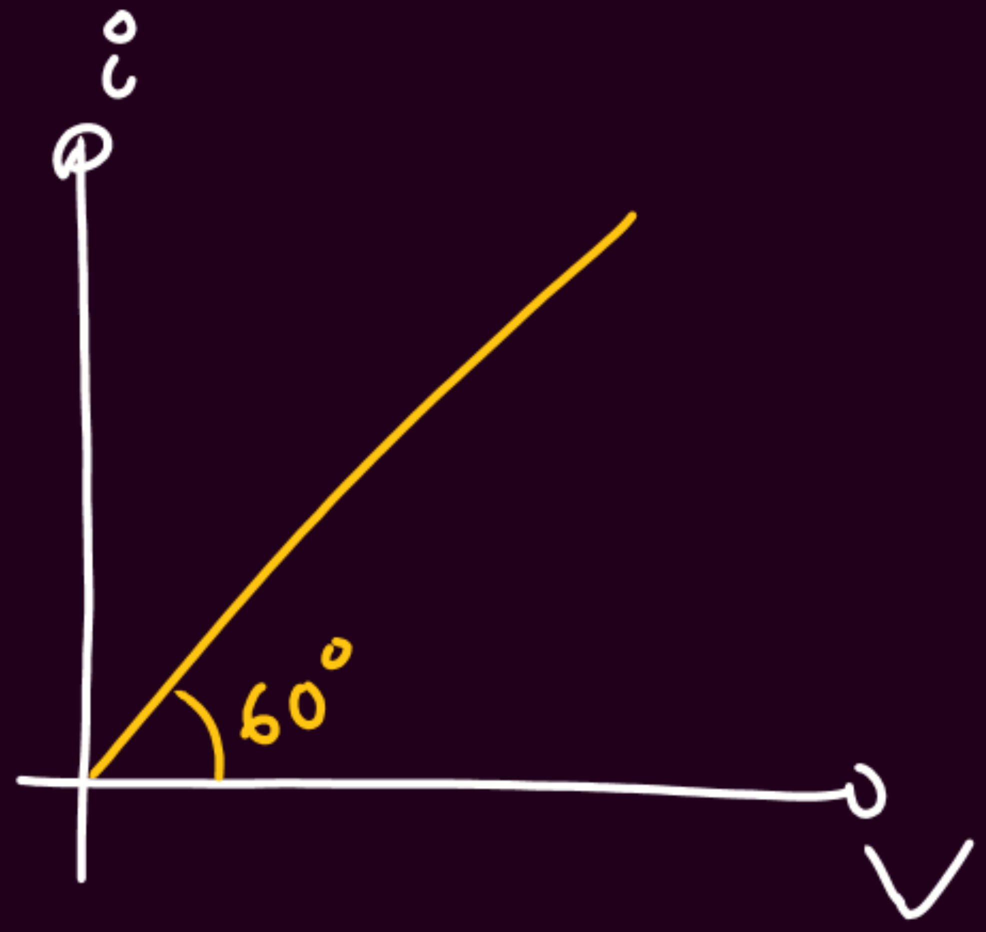


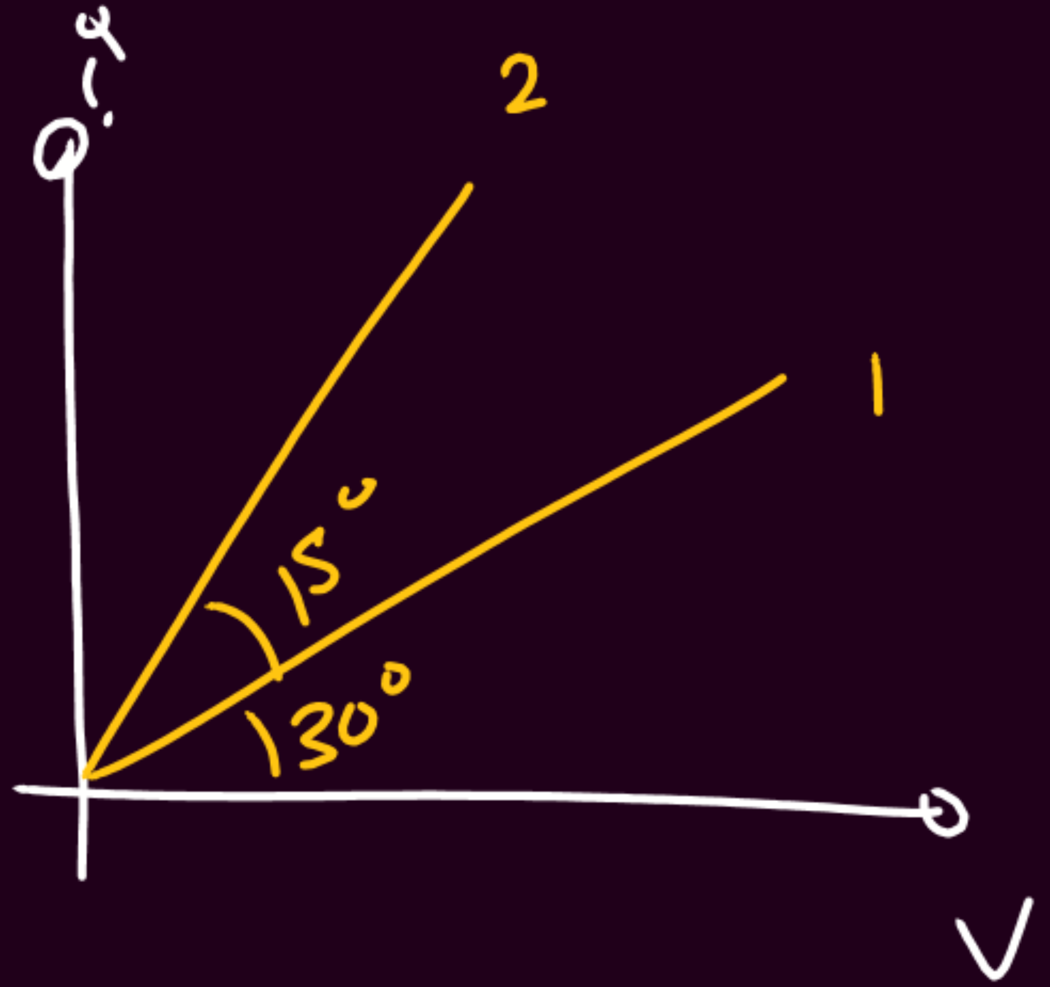
ohm's law → "ohmic"



GaAs







$$\frac{R_2}{R_1} = \frac{1}{\sqrt{3}}$$

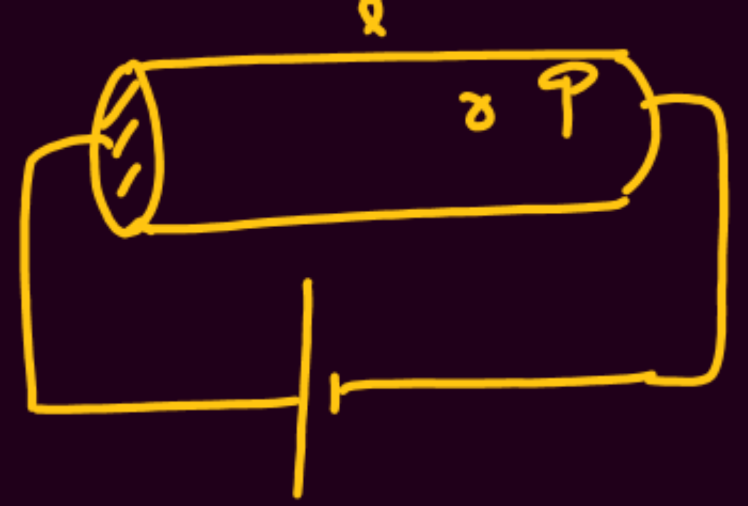
$$R = \frac{1}{\tan 60^\circ} = \frac{1}{\sqrt{3}}$$

$$R_1 = \frac{1}{\tan 30^\circ} = \frac{\sqrt{3}}{1}$$

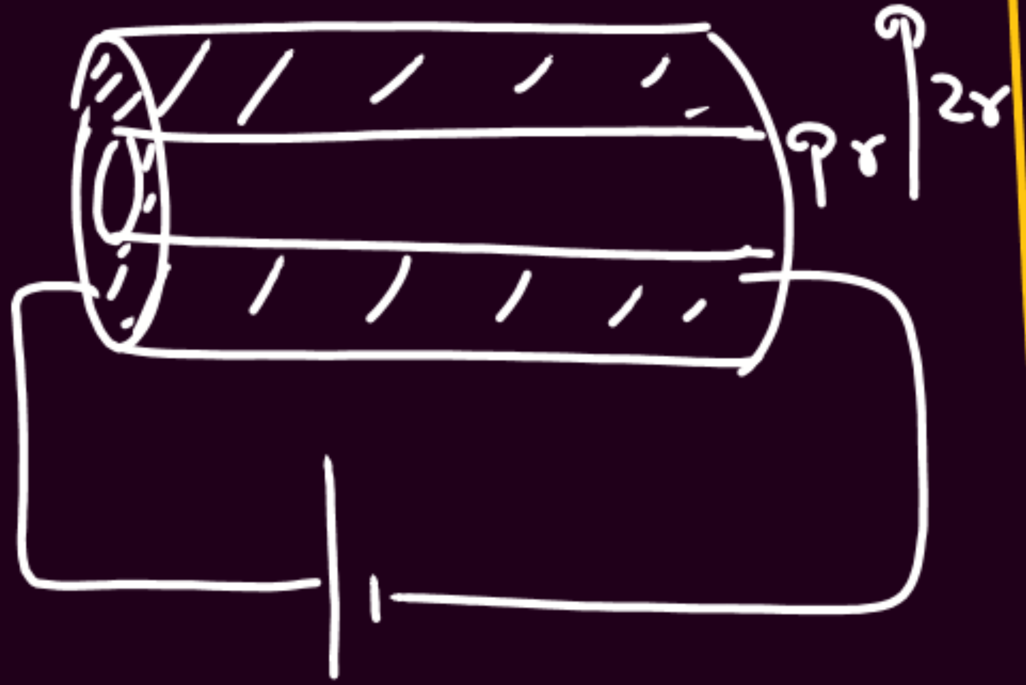
$$R_2 = \frac{1}{\tan 45^\circ} = 1$$

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

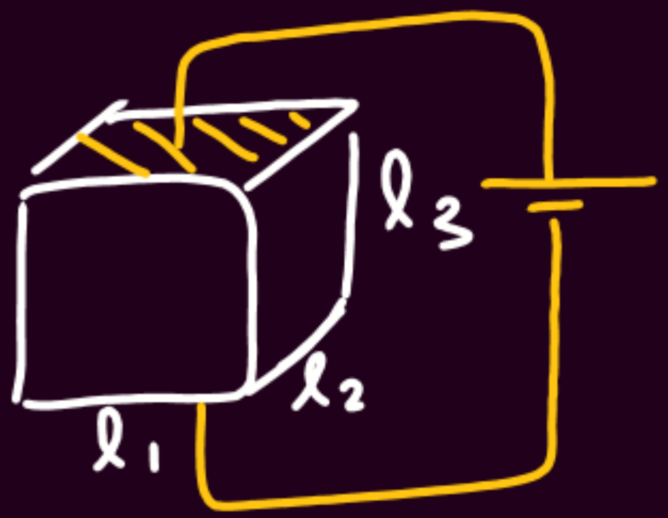
- → length
- → Area
- → material
- → Temp.



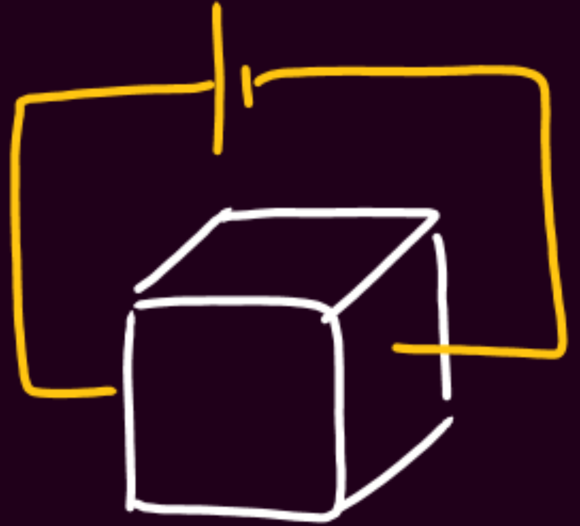
$$R = \frac{\rho l}{\pi r^2}$$



$$R = \frac{\rho l}{\pi\left((2r)^2 - r^2\right)} = \frac{\rho l}{3\pi r^2}$$

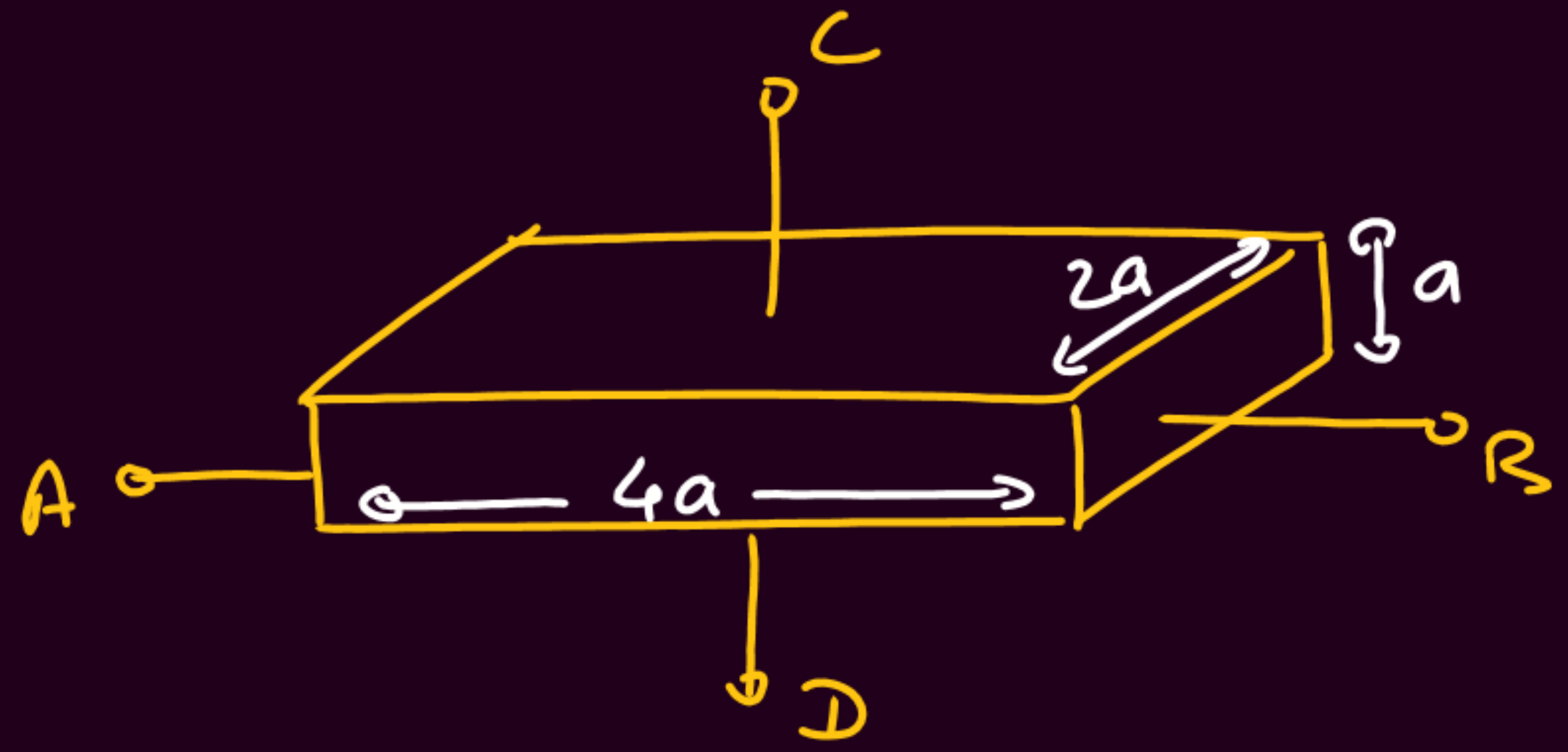


$$R = \frac{\rho\, l_3}{l_1 l_2}$$



$$R = \frac{\rho\, l_1}{l_2 l_3}$$

$$R = \frac{\rho\, l_2}{l_1 l_3}$$



$$R_{AB} = \frac{S\,(4a)}{a\,(2a)} = \frac{2S}{a}$$

$$R_{CD} = \frac{S\,(a)}{(2a)(4a)} = \frac{S}{8a}$$

$$\frac{R_{AB}}{R_{CD}} = \frac{2}{1/8} = \frac{16}{1}$$

$\underline{\underline{\text{wire}}}$ $(l, r) \longrightarrow R_0 = \dfrac{\rho l}{\pi r^2}$

(Double , Half)

$$R = \frac{\rho(2l)}{\pi\left(\frac{r}{2}\right)^2} = \underline{\underline{8R_0}}$$

Wire

- Volume Const
  - Stretched
  - melt & recast
  - Drawn into

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

$$\boxed{R = \frac{\rho l^2}{V} = \frac{\rho V}{A^2} = \frac{\rho V}{\pi^2 r^4}}$$

$$\frac{\Delta R}{R} = 2\left(\frac{\Delta l}{l}\right) = -2\left(\frac{\Delta A}{A}\right) = -4\left(\frac{\Delta r}{r}\right)$$

1. if $l \to 2l$ then $R \to 4R$
2. if $A \to 2A$ then $R \to \frac{R}{4}$
3. if $r \to 2r$ then $R \to \frac{R}{16}$
4. if $l \uparrow$ by 2% then $R \uparrow$ by 4%
5. if $A \uparrow$ by 2% then $R \downarrow$ by 4%
6. if $r \uparrow$ by 2% then $R \downarrow$ by 8%

Equivalent ρ / σ

① Series

[Assume - Area]

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

$$\frac{\rho_{eq}(l_1+l_2)}{A} = \frac{\rho_1 l_1}{A} + \frac{\rho_2 l_2}{A}$$

$$\boxed{\rho_{eq} = \frac{\rho_1 l_1 + \rho_2 l_2}{l_1 + l_2}}$$

$$\frac{(l_1+l_2)}{\sigma_{eq} A} = \frac{l_1}{\sigma_1 A} + \frac{l_2}{\sigma_2 A}$$

$$\boxed{\sigma_{eq} = \frac{l_1 + l_2}{\frac{l_1}{\sigma_1} + \frac{l_2}{\sigma_2}}}$$

② Parallel

[Assume - length]

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

$$\frac{A_1+A_2}{\rho_{eq}\, l} = \frac{A_1}{\rho_1 l} + \frac{A_2}{\rho_2 l}$$

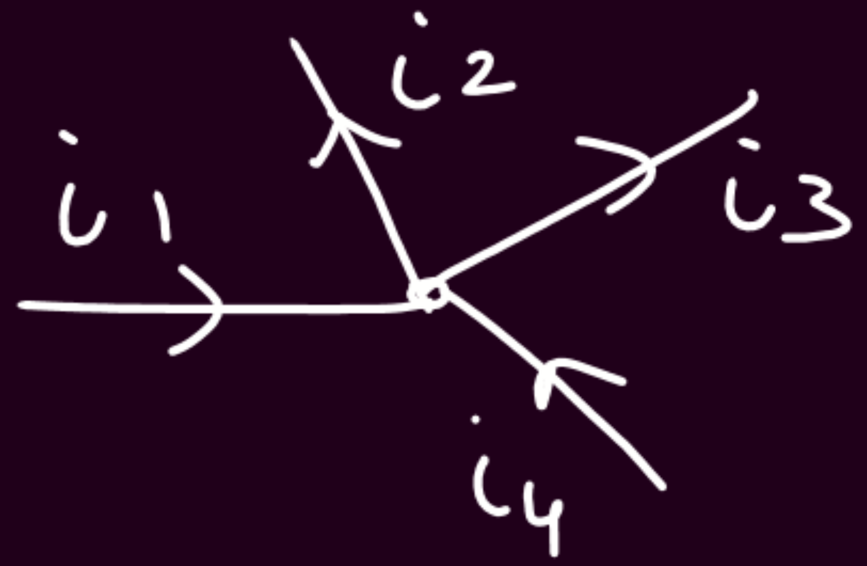
$$\boxed{\rho_{eq} = \frac{A_1 + A_2}{\frac{A_1}{\rho_1} + \frac{A_2}{\rho_2}}}$$

$$\frac{\sigma_{eq}(A_1+A_2)}{l} = \frac{\sigma_1 A_1}{l} + \frac{\sigma_2 A_2}{l}$$

$$\boxed{\sigma_{eq} = \frac{\sigma_1 A_1 + \sigma_2 A_2}{A_1 + A_2}}$$

Kirchoff's current law (KCL) [Junction law]

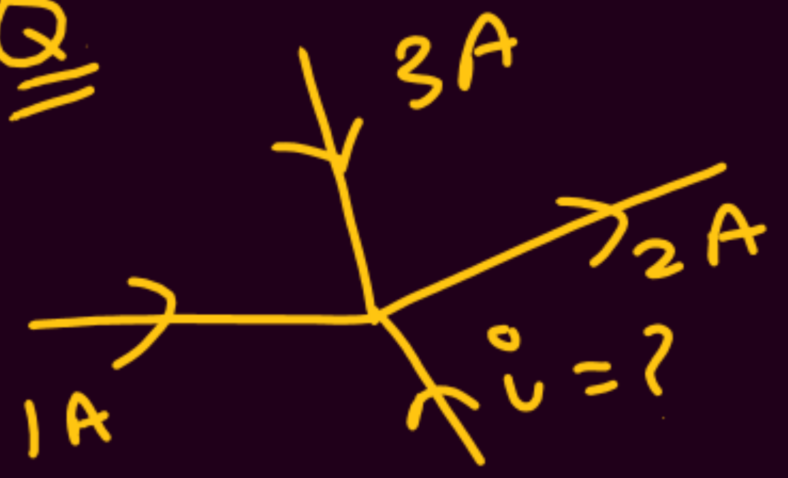
→ law of conservation of q



Total incoming = Total outgoing

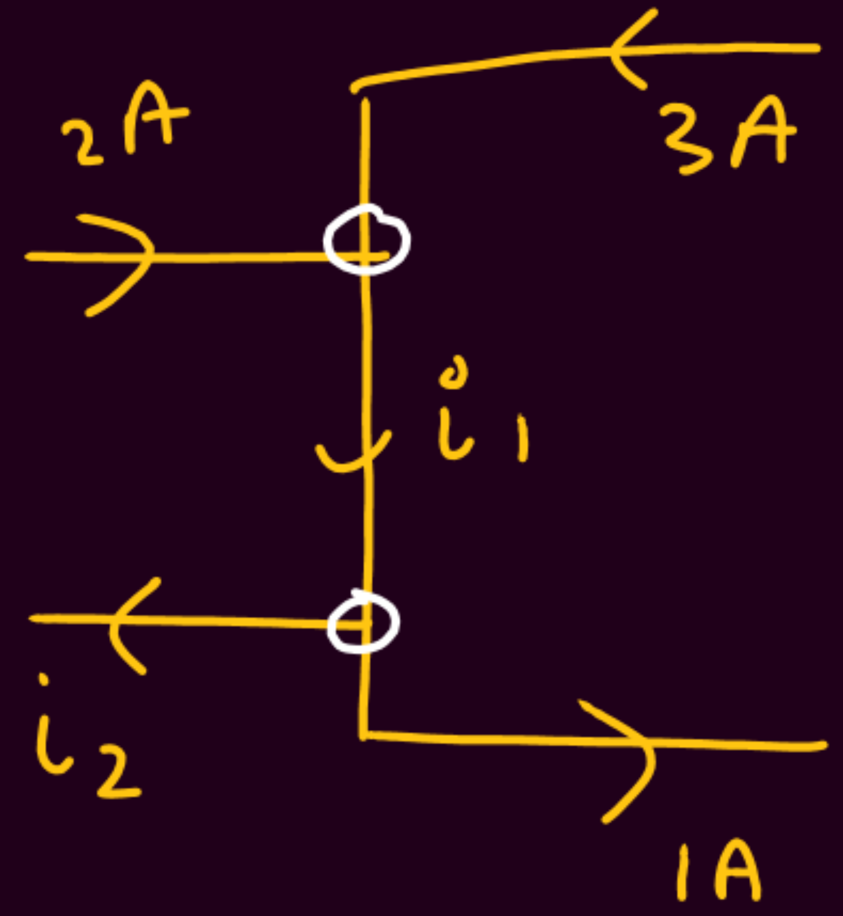
$$i_1 + i_4 = i_2 + i_3$$

Q



$$1+3+i=2$$

$$\boxed{i=-2A}$$



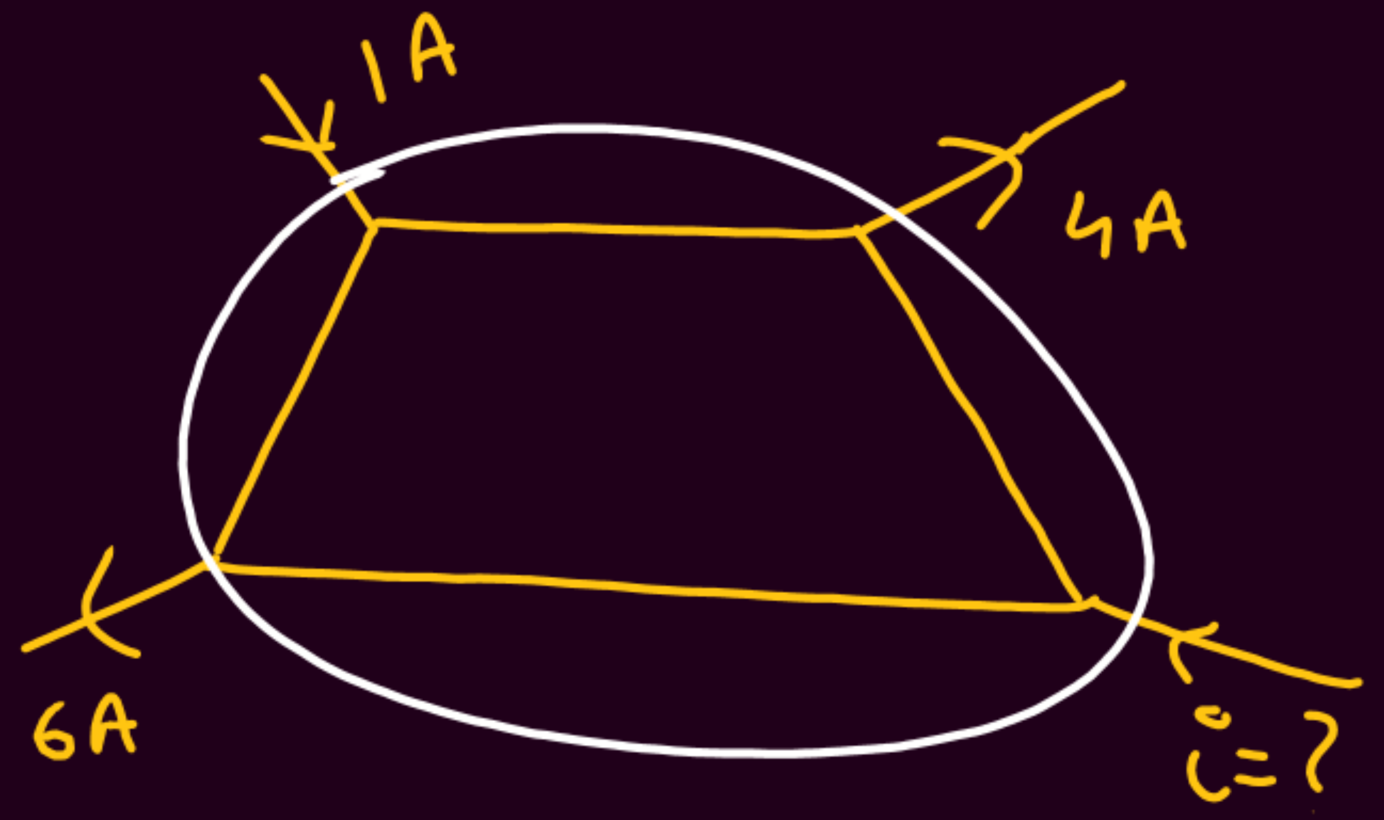
$$2+3=i_1$$

$$\boxed{i_1=5A}$$

$$i_1=i_2+1$$

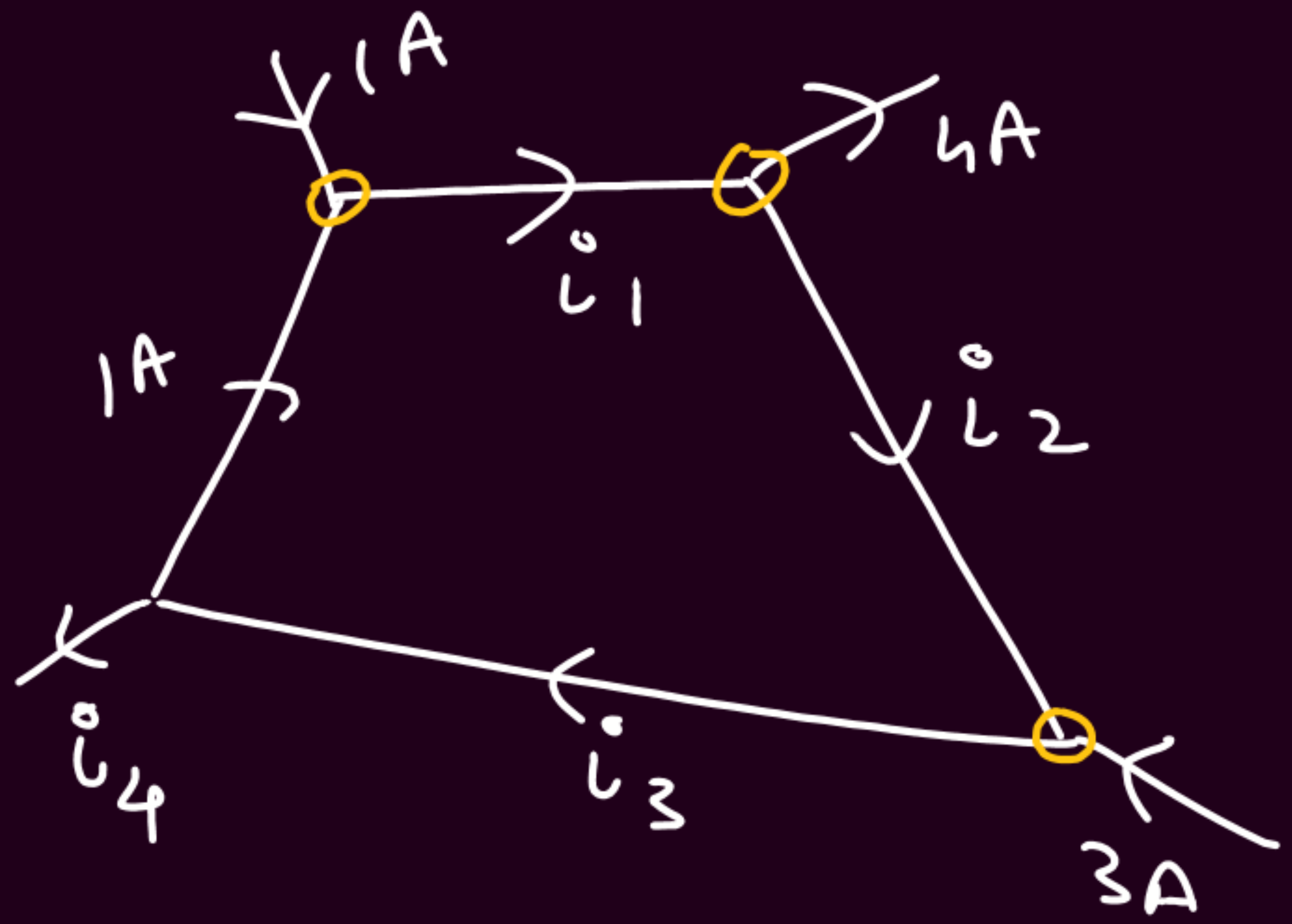
$$5=i_2+1$$

$$\boxed{i_2=4A}$$



$$1+i=6+4$$

$$i=9A$$



$$1 + 1 = i_1 \qquad \boxed{i_1 = 2A}$$

$$i_1 = 4 + i_2 \qquad \boxed{i_2 = -2A}$$

$$\begin{cases} i_2 + 3 = i_3 \\ -2 + 3 = i_3 \end{cases} \qquad \boxed{i_3 = 1A}$$

$$i_3 = i_4 + 1 \qquad \boxed{i_4 = 0}$$

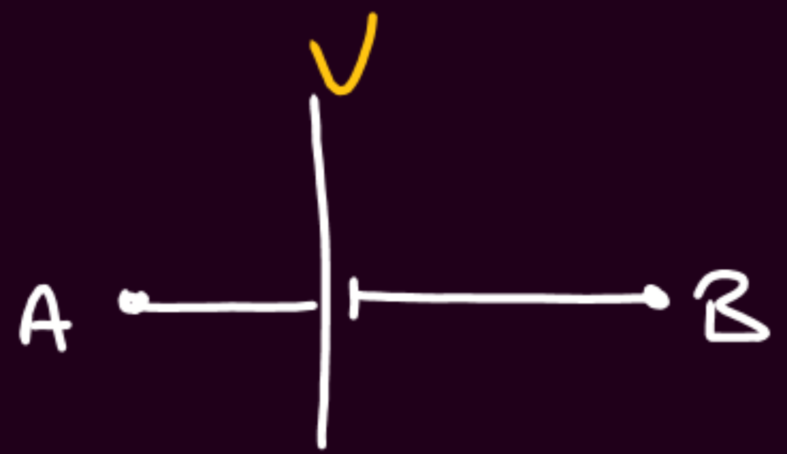
$$1 = i_4 + 1$$

Sign convention

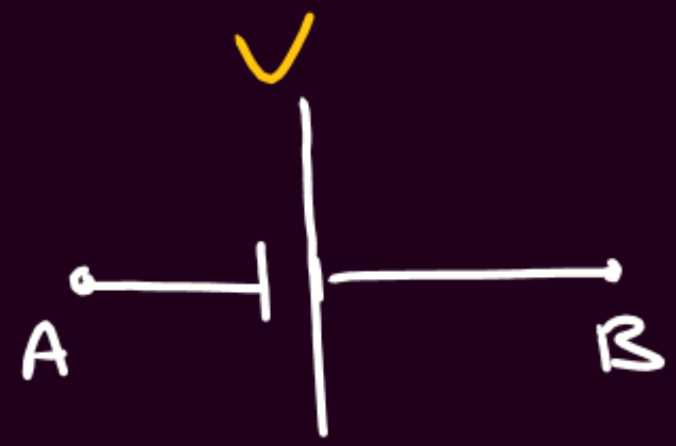
→ P.D betⁿ A & B
→ Potential of A wrt B

[B to A]

$$\boxed{V_{AB} = V_A - V_B}$$



$V_{AB} = V$



$V_{AB} = -V$

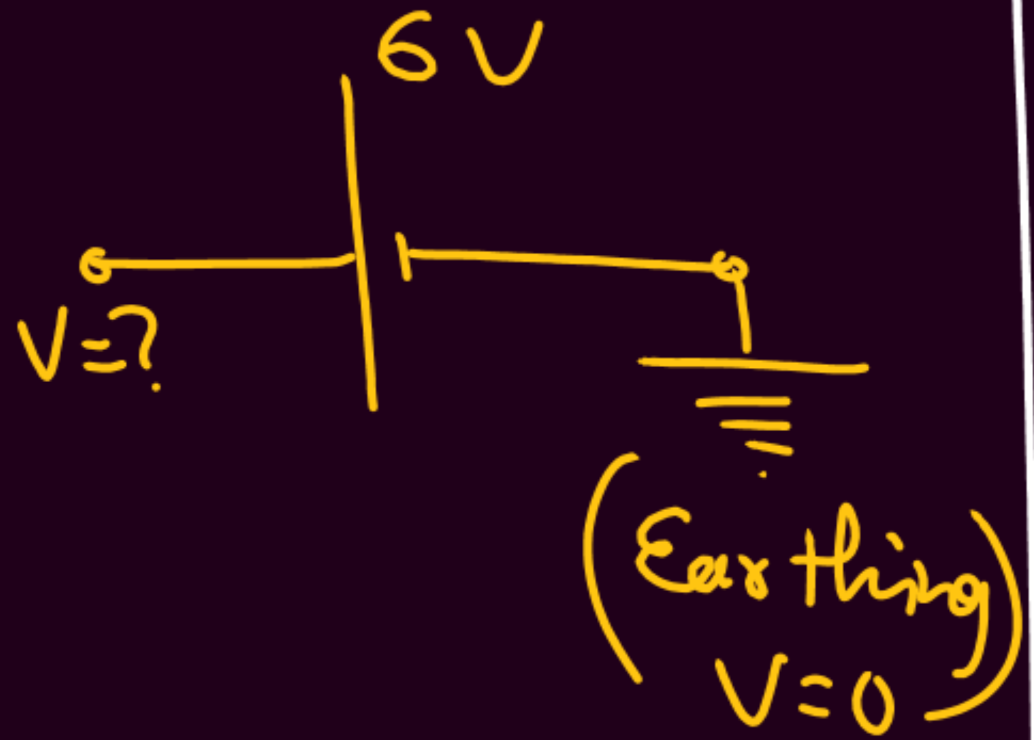
$V_{AB} = iR$

$V_{AB} = -iR$

$$V = 2 + 10$$

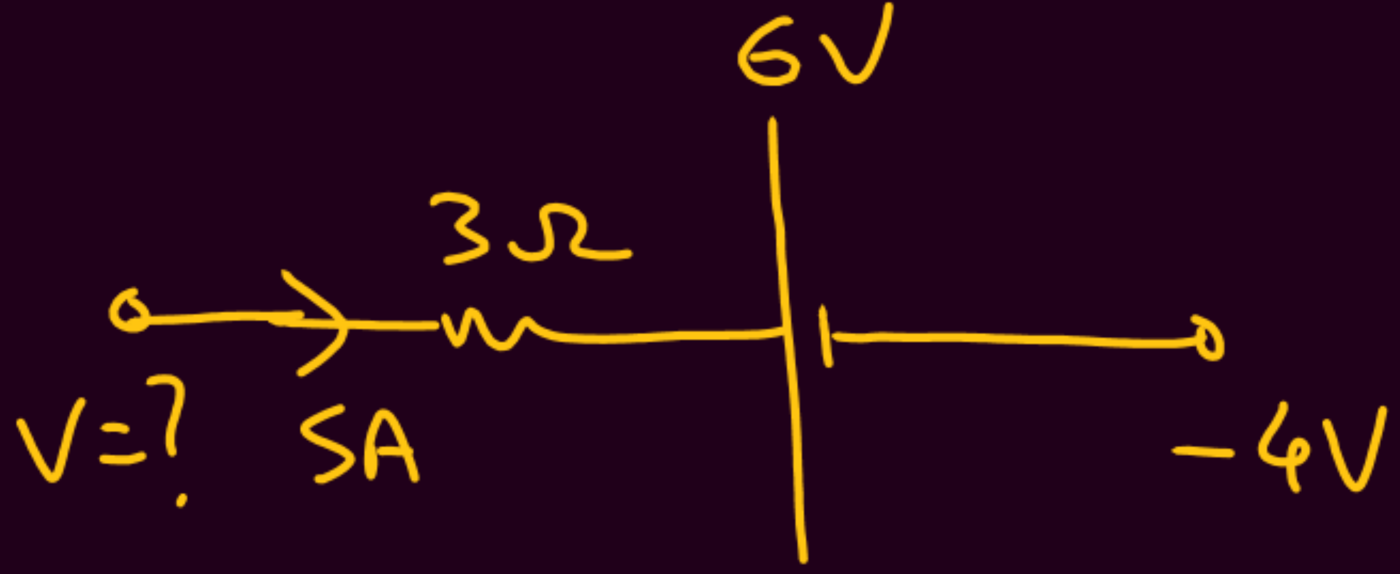
$$V = -10 - 4$$

$$V = 1 + (2)(3) = \underline{\underline{7V}}$$



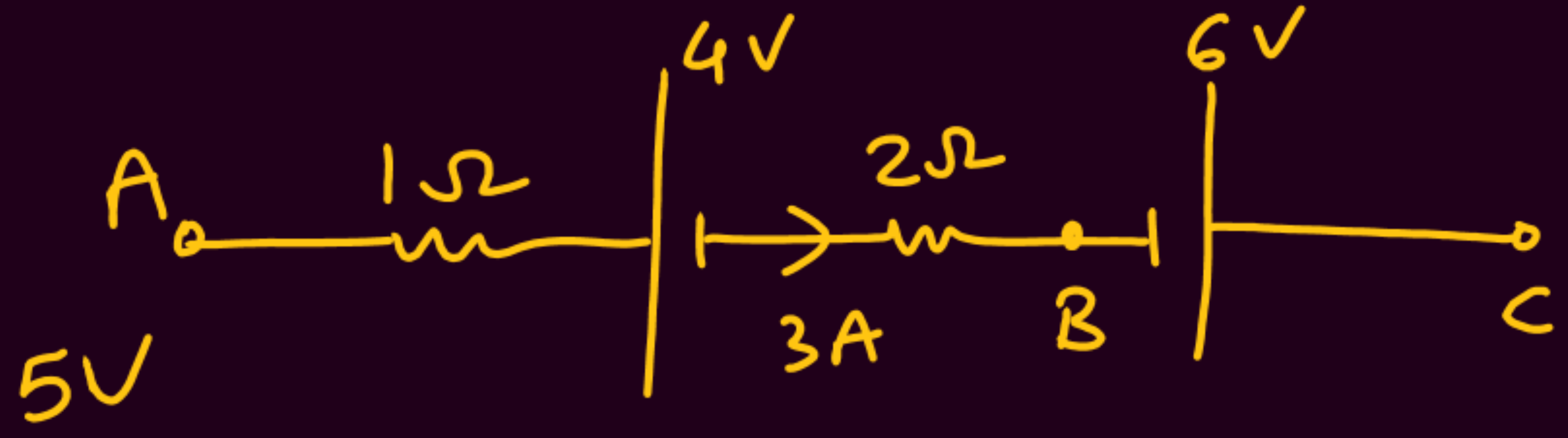
$$V = 0 + 6$$

$$V = 3 - 6 + 10 = 7V$$



$$V = -4 + 6 + (5)(3)$$

$$\underline{V = 17V}$$

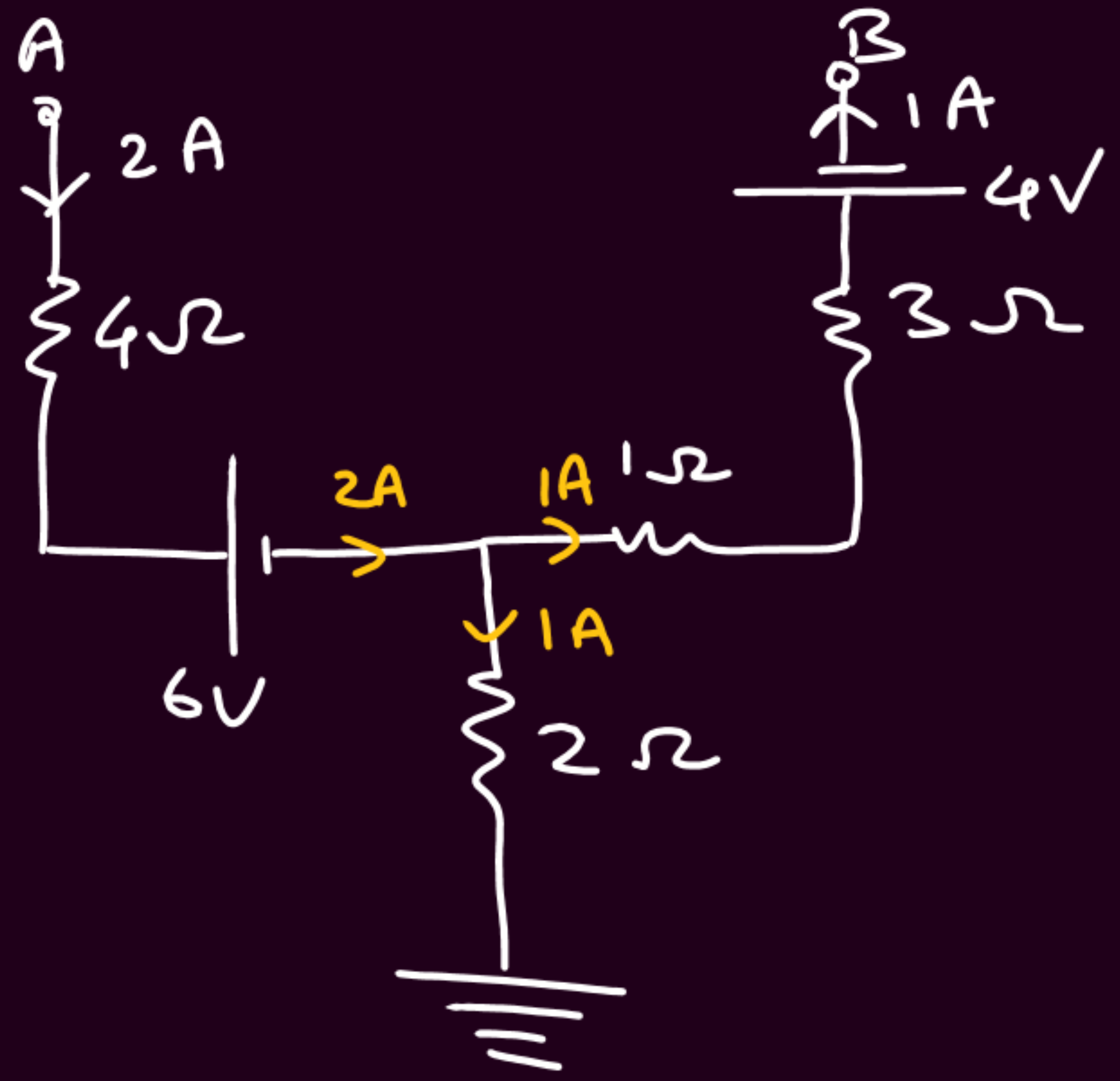


given $V_A = 5V$

$$V_B = 5 - (3)(1) - 4 - (3)(2) = -8V$$

A $V_C = \underbrace{5 - (3)(1) - (4) - (3)(2)} + 6$

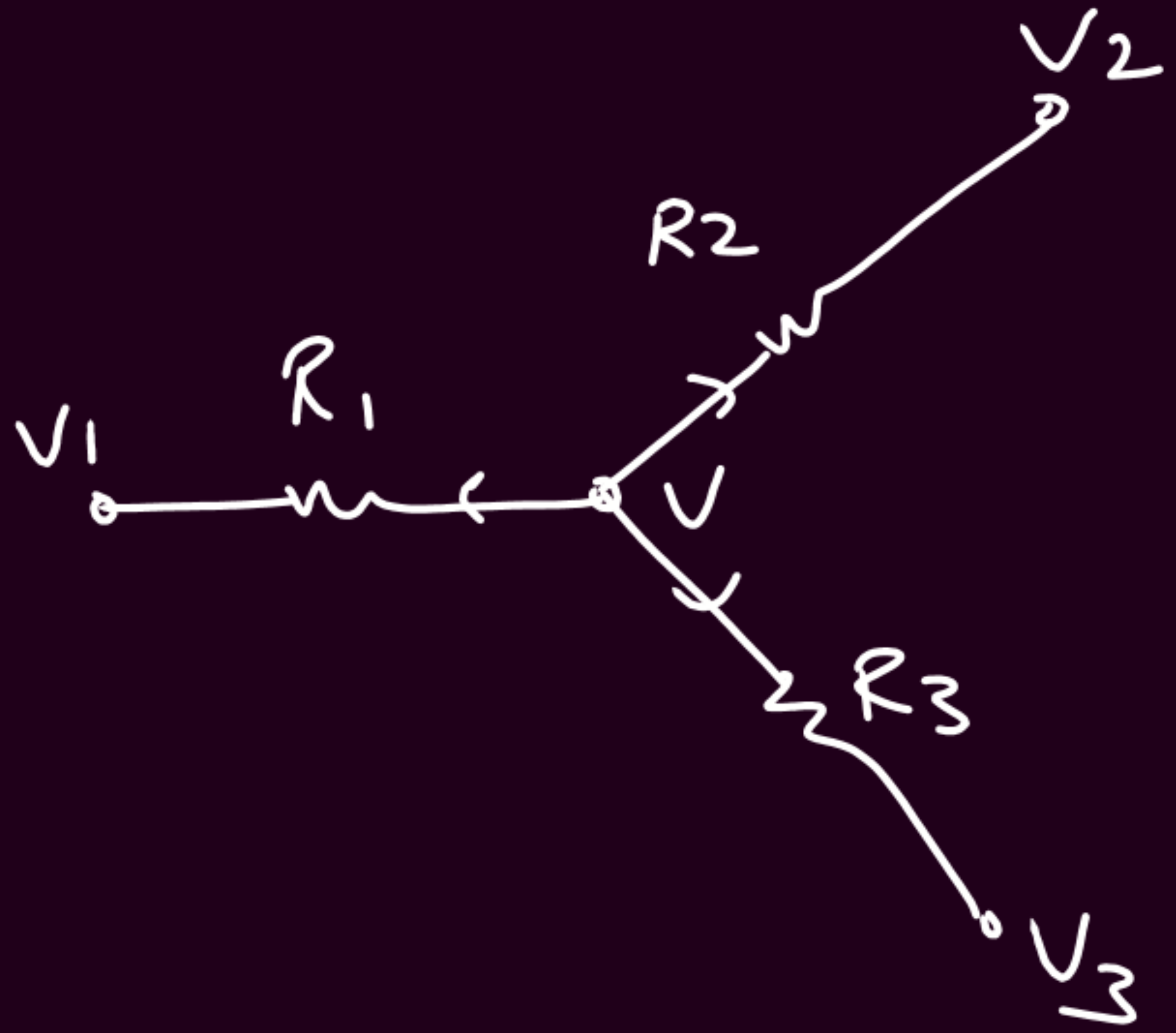
B $V_C = -8 + 6$



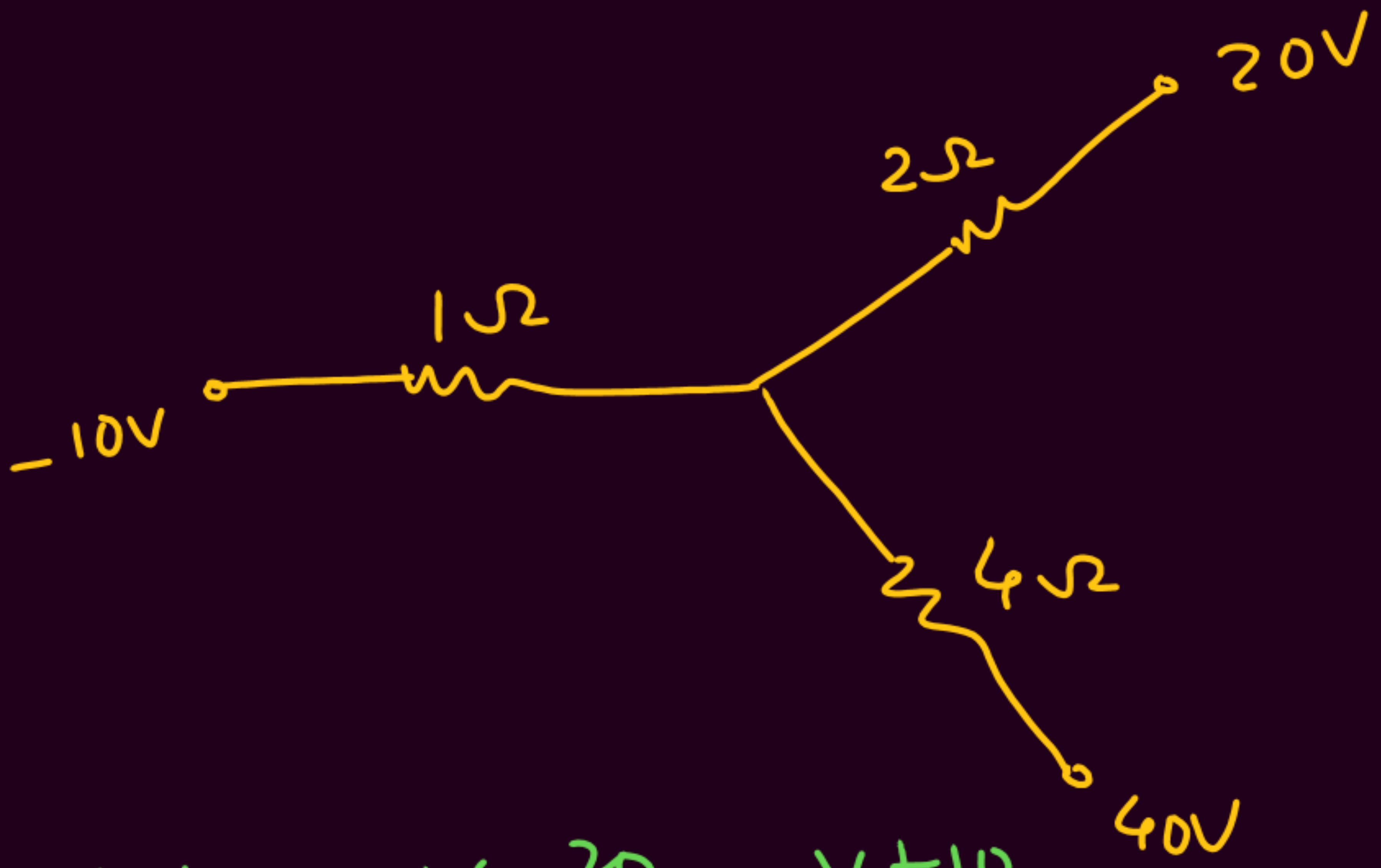
$$V_A = 0 + (1)(2) + 6 + (2)(4) = 16\,V$$

$$V_B = 0 + (1)(2) - (1)(2) - (1)(3) - 4 = \underline{-6V}$$

Junction Potential



$$\frac{V-V_1}{R_1}+\frac{V-V_2}{R_2}+\frac{V-V_3}{R_3}=0$$



$$\frac{V-40}{4}+\frac{V-20}{2}+\frac{V+10}{1}=0$$

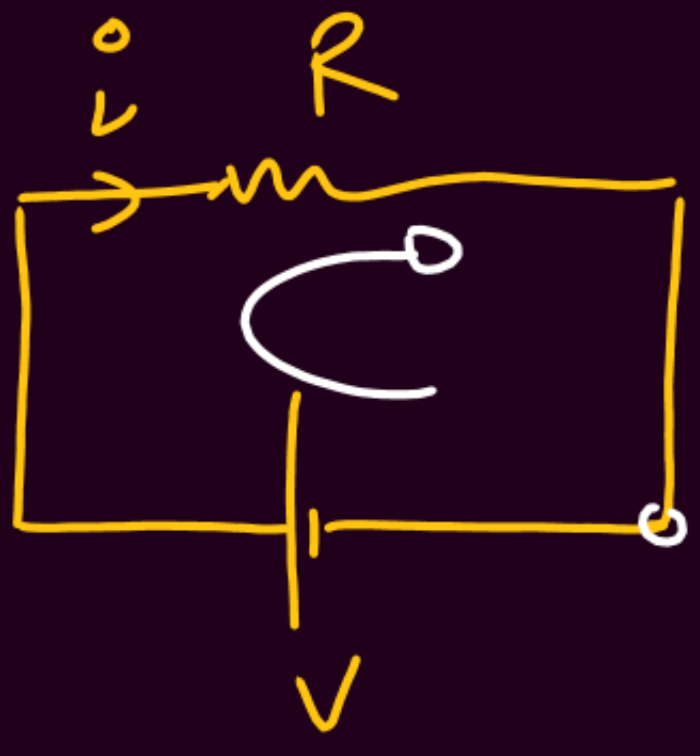
$$(V-40)+2(V-20)+4(V+10)=0$$

$$7V=40$$

$$\boxed{V=\frac{40}{7}\,V}$$

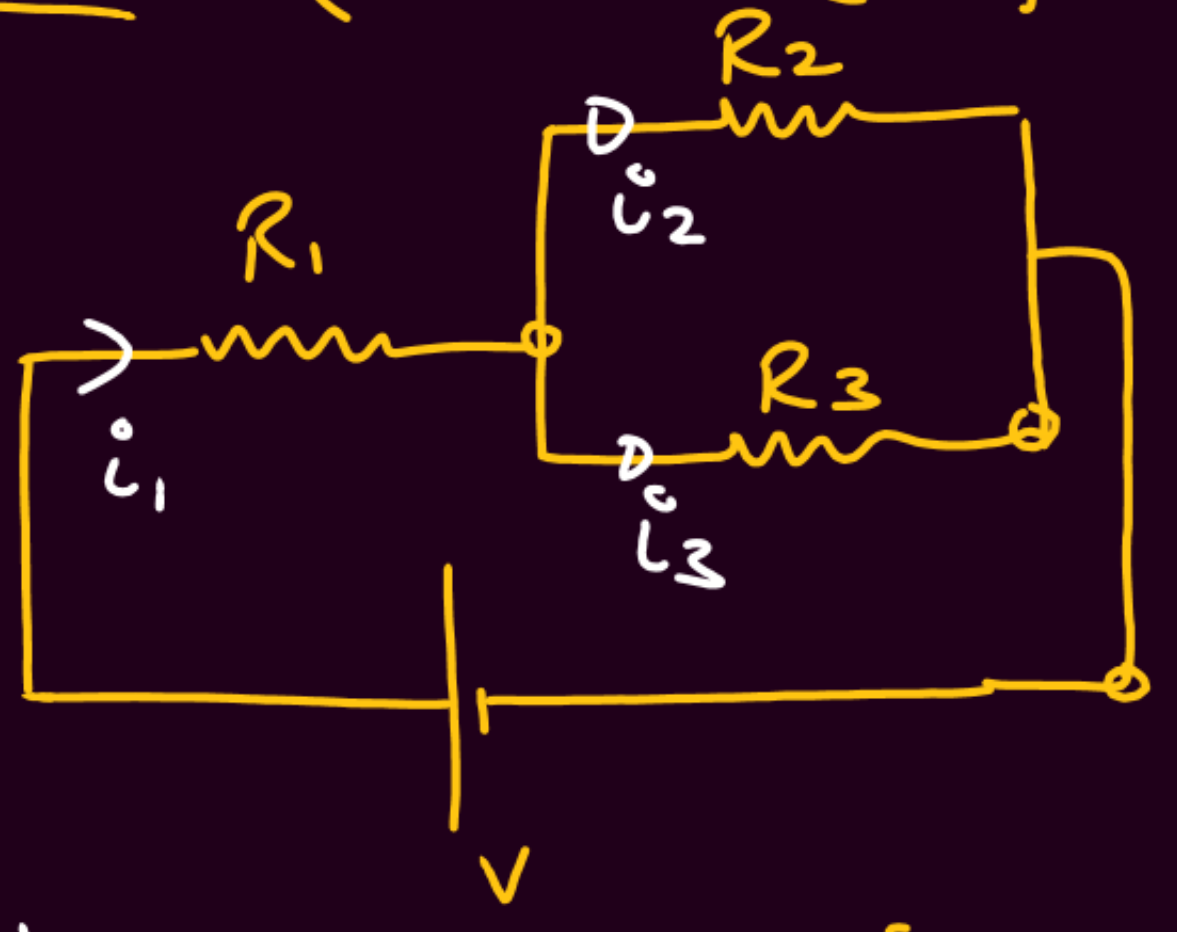
$$i_{4\Omega}=\frac{V-40}{4}=\frac{\frac{40}{7}-40}{4}=\frac{-60}{7}\,A$$

Kirchoff's Voltage Law (KVL) [loop law]



$$V - iR = 0$$

$$V = iR$$



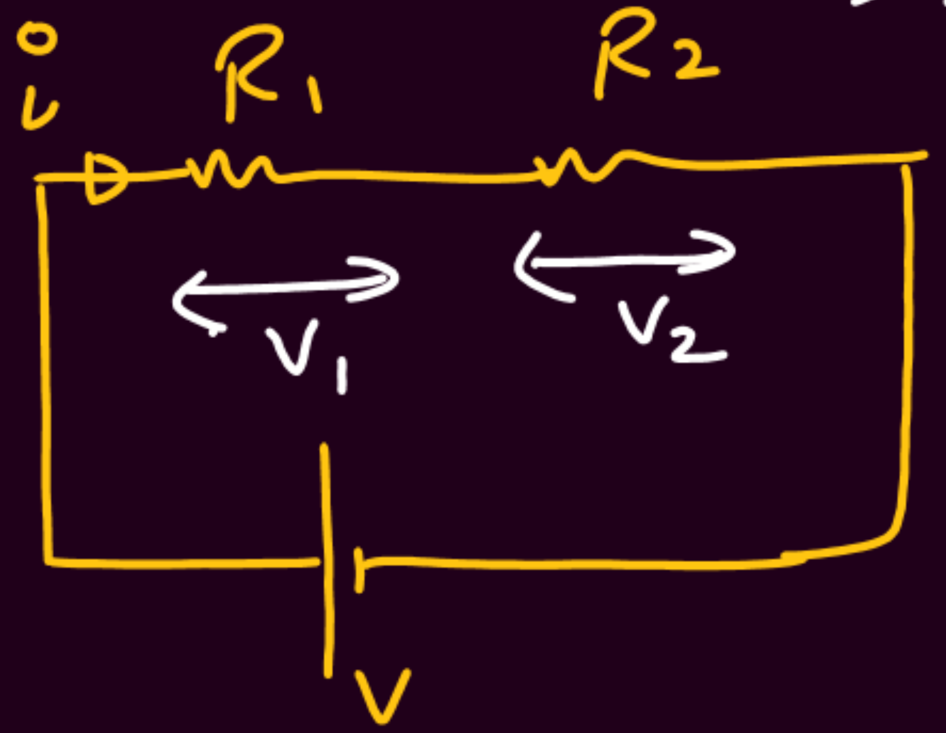
KVL ① $V - i_1R_1 - i_2R_2 = 0$

KVL ② $i_3R_3 - i_2R_2 = 0$

KCL ③ $i_1 = i_2 + i_3$

Series Combination

→ Same Current
→ No Branching



$R_{eq} > R_1$

$R_{eq} > R_2$

① $R_{eq} = R_1 + R_2$

② n-identical in series $\boxed{R_{eq} = nR}$

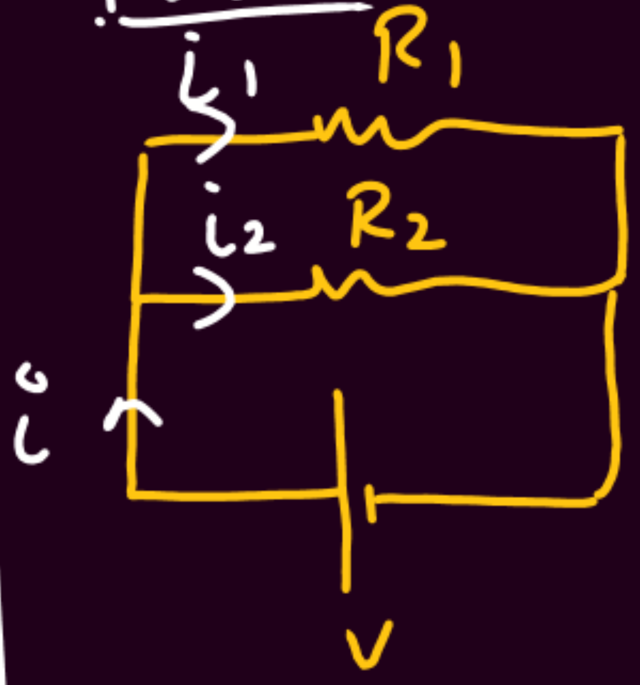
③ $V_1 = iR_1$

$$V_1 = \frac{VR_1}{(R_1+R_2)}$$

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

Parallel Combination

→ Same P.D.
→ Bet^n Same points



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

$$\boxed{R_{eq} = \frac{R_1R_2}{R_1+R_2}}$$

$R_{eq} < R_1$

$R_{eq} < R_2$

② n-identical in parallel

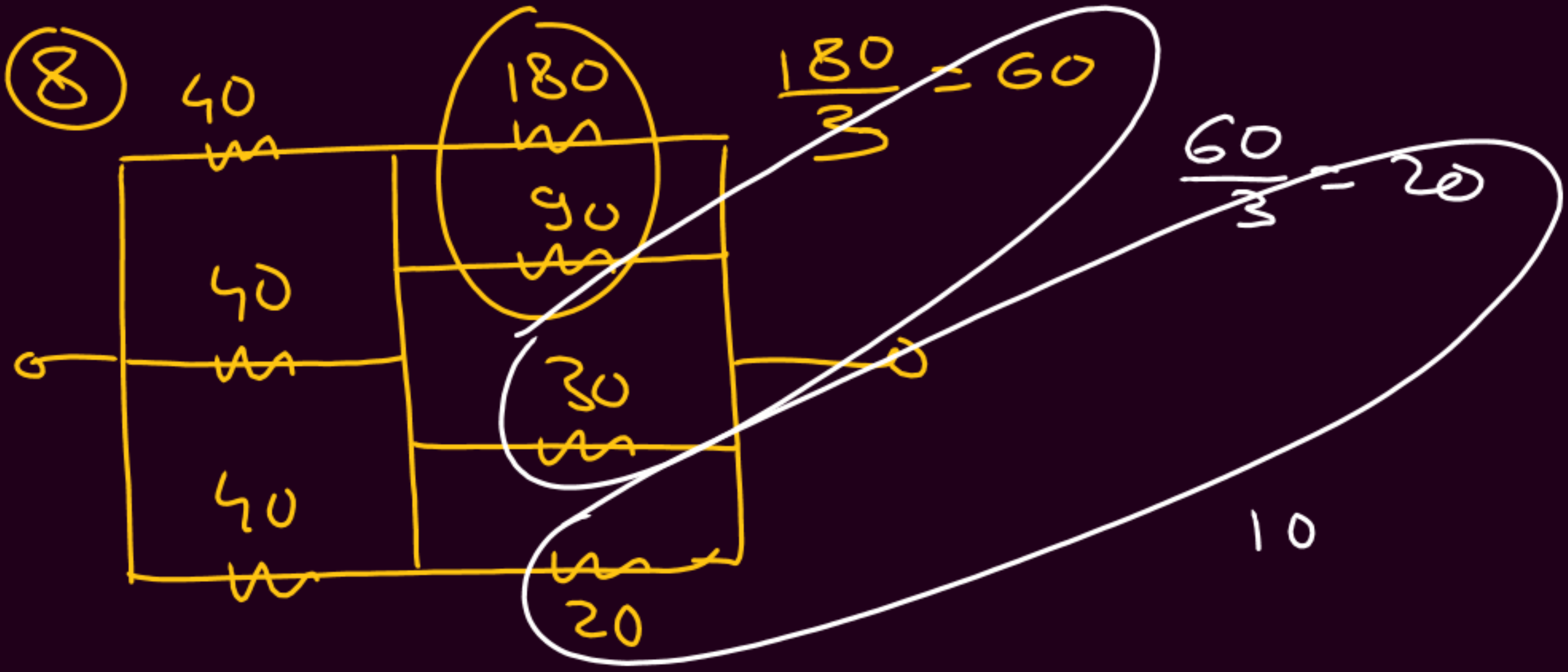
$$R_{eq} = \frac{R}{n}$$

③ $i_1R_1 = i_2R_2$

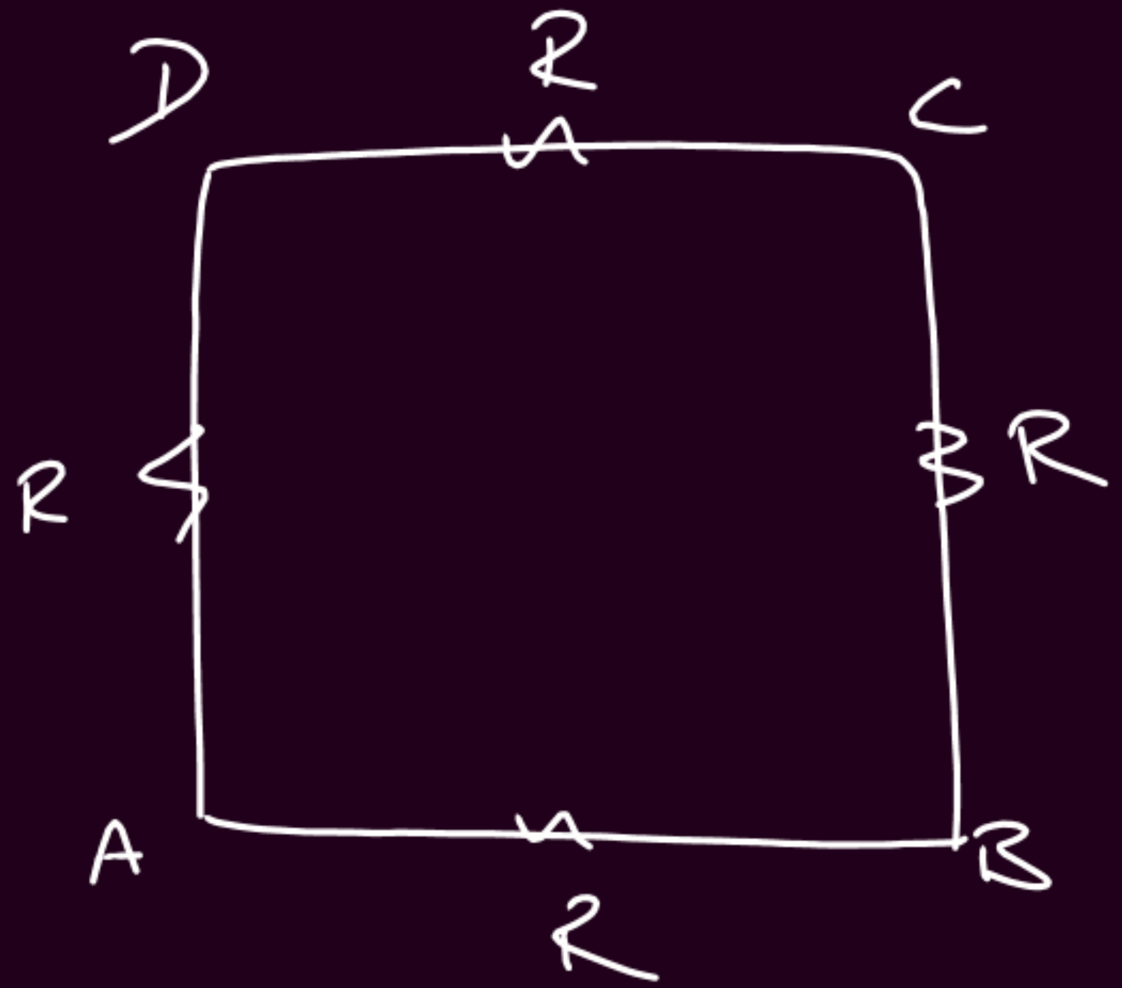
$$\boxed{i_1 = \frac{iR_2}{R_1+R_2}}$$

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

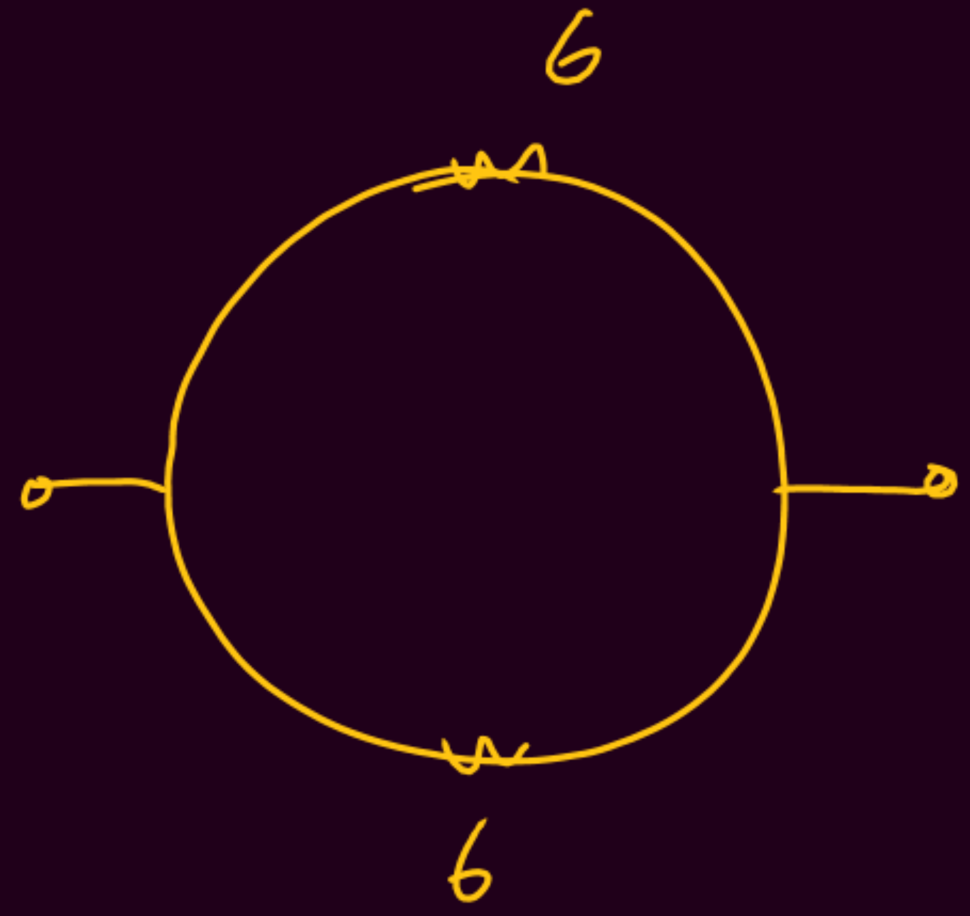
8

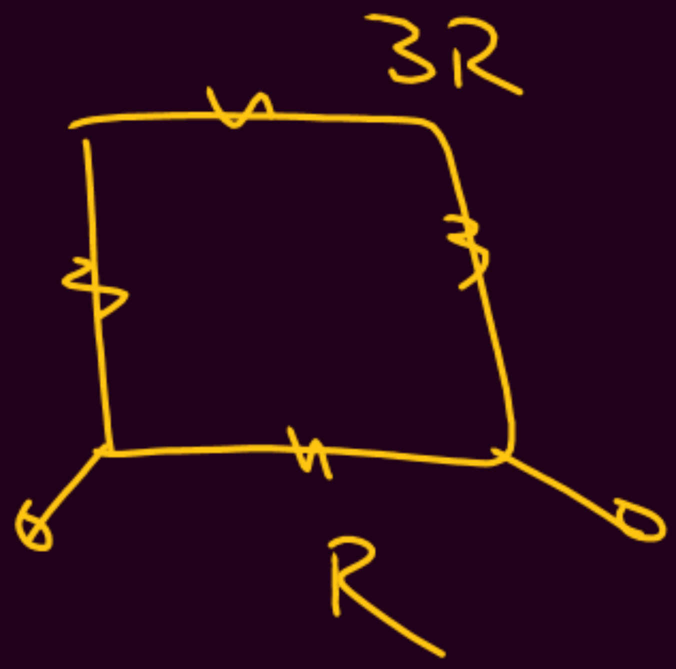


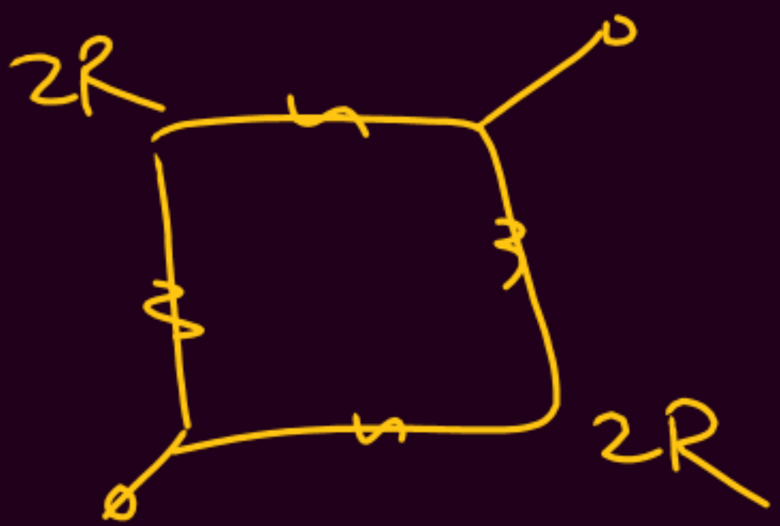
$$\frac{40}{3} + 10 = \frac{70}{3}\,\Omega$$



$$\frac{R_{AB}}{R_{AC}} = ? \quad \frac{3}{4}$$



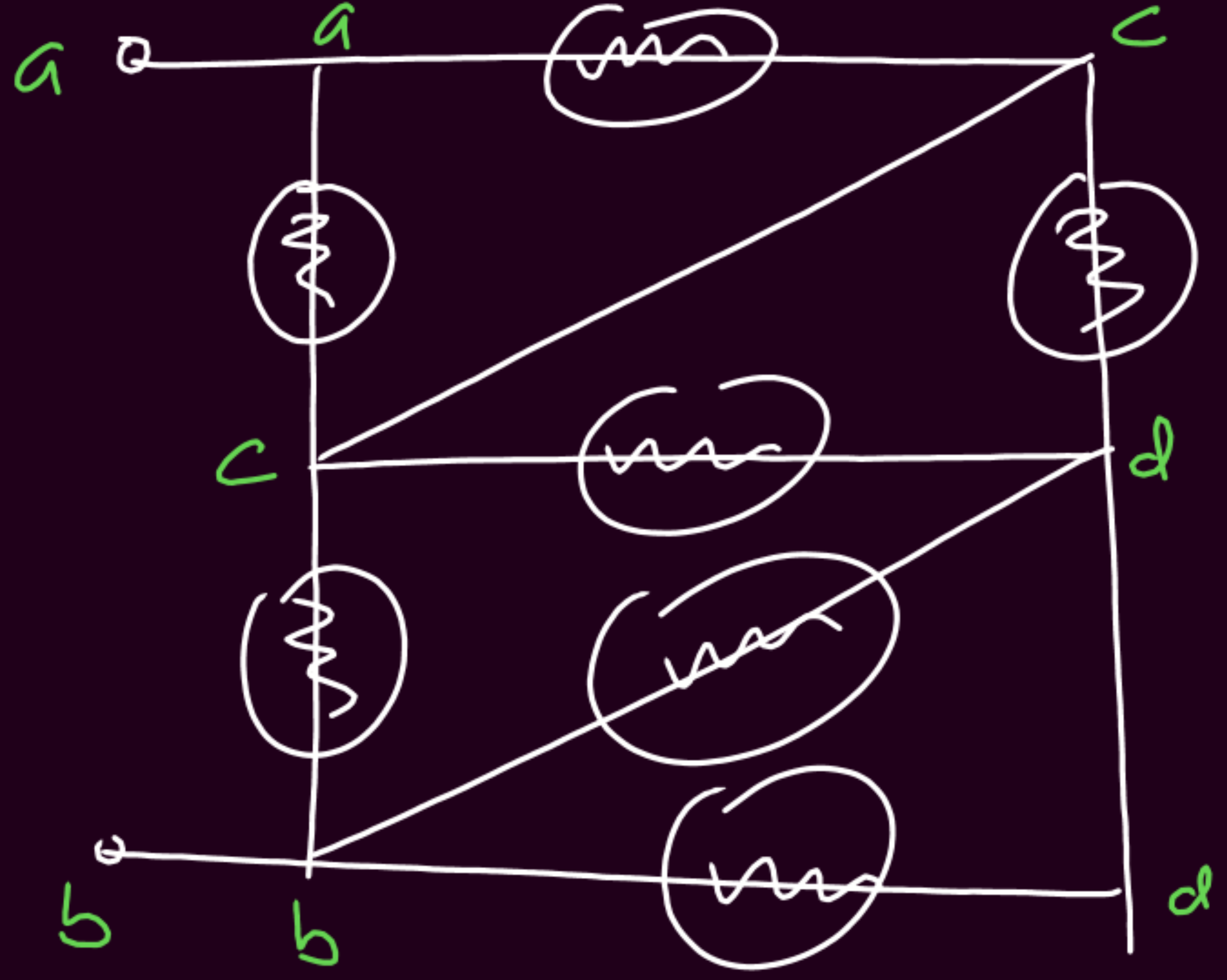




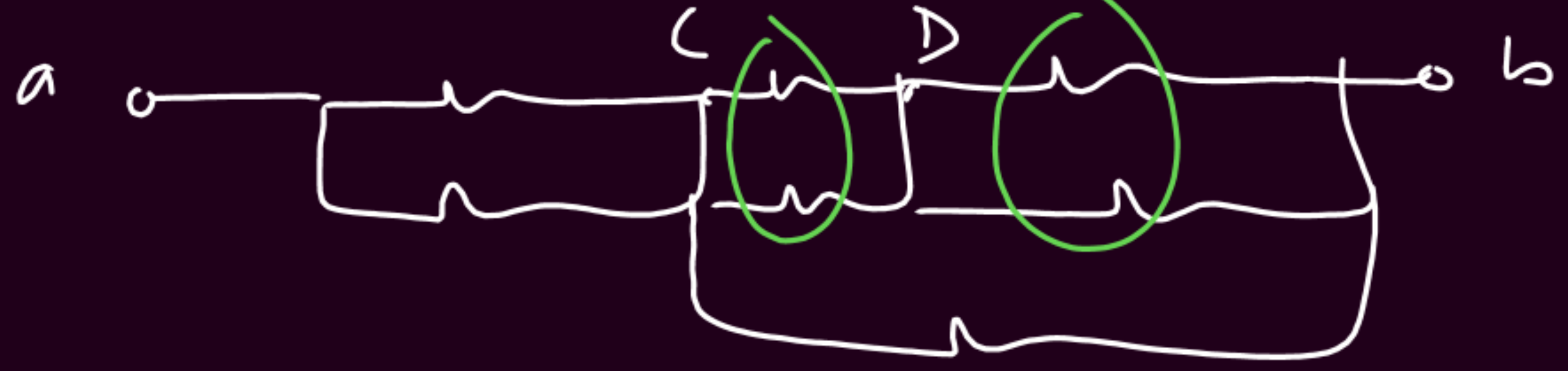
$$R_{AB} = \frac{3R}{4}$$

$$R_{AC} = R$$

$$R_{eq} = 3\Omega$$



$$R/2 + R/2 = R$$



$$\frac{R}{2} + R/2 = \underline{\underline{R}}$$

Wheatstone Bridge

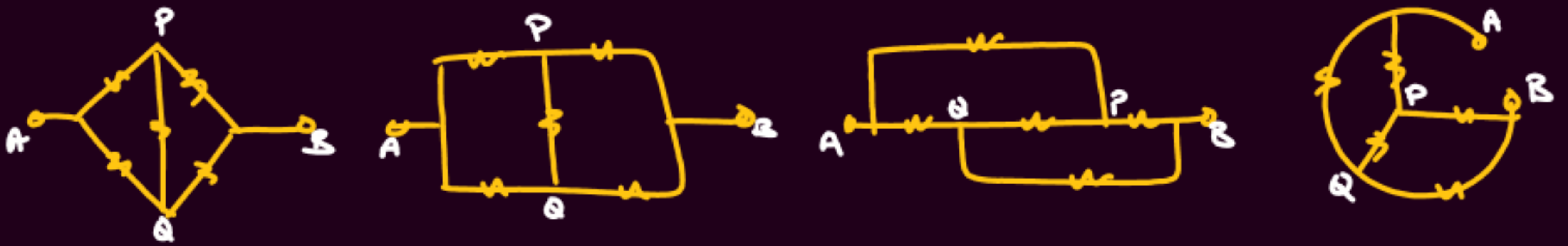
Balanced WSB

$\boxed{V_P = V_Q}$

if $i_g = 0$

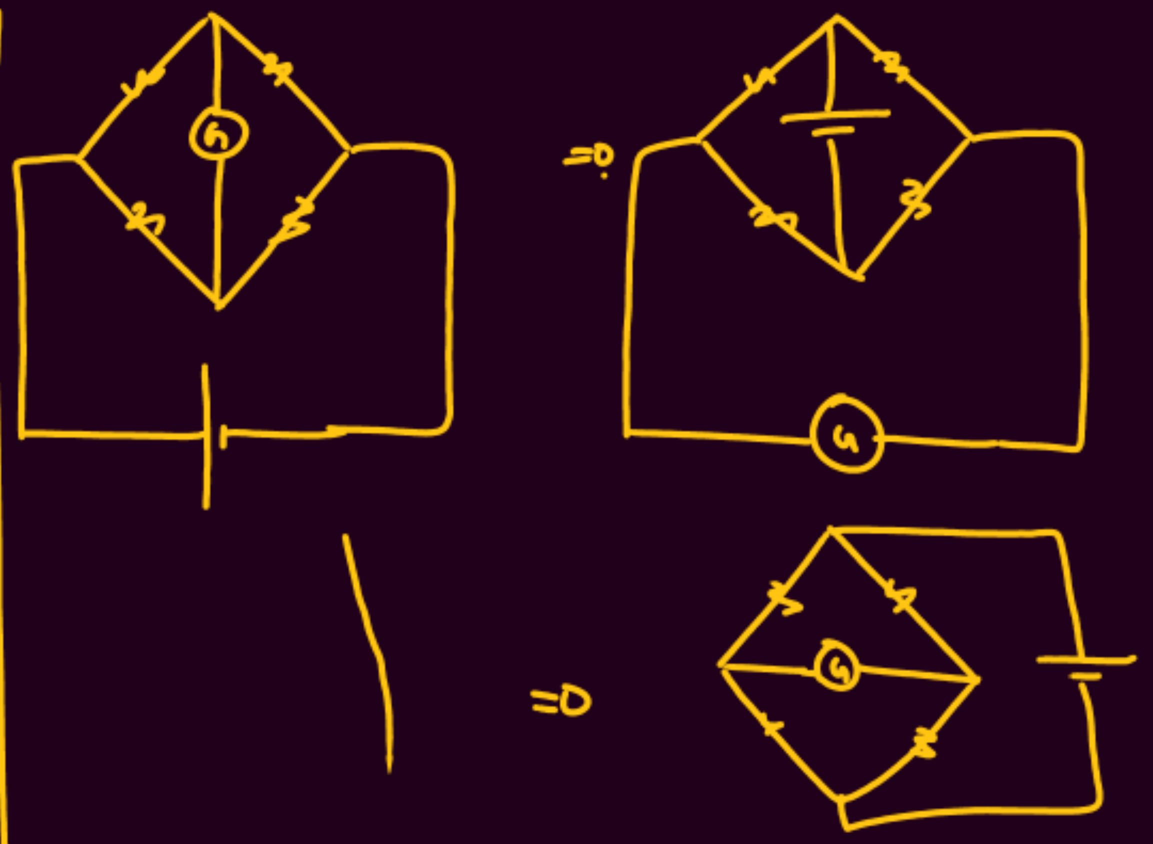
then $\frac{R_1}{R_2} = \frac{R_3}{R_4}$

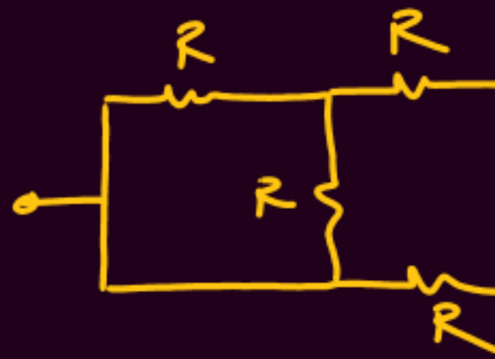
and vice versa

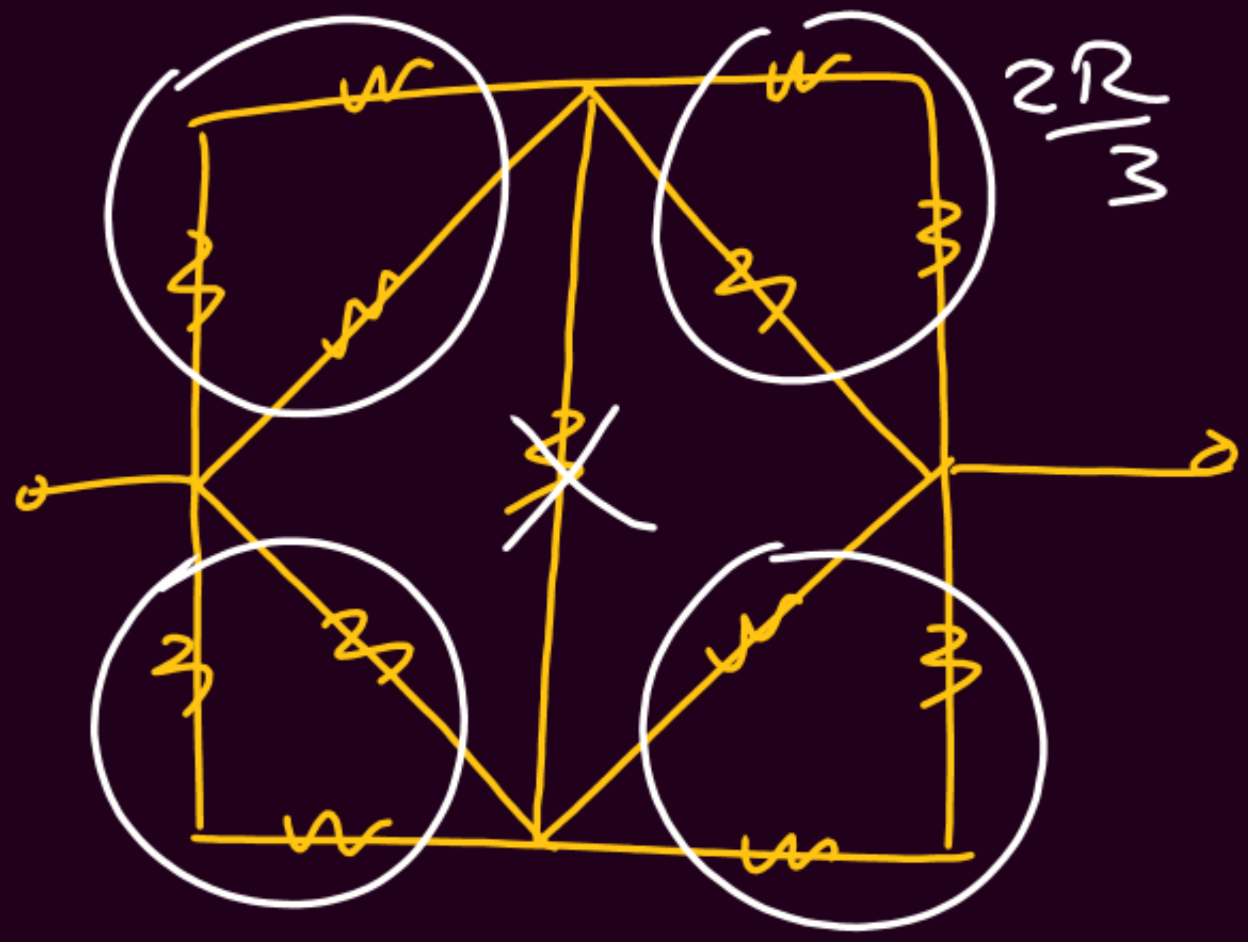


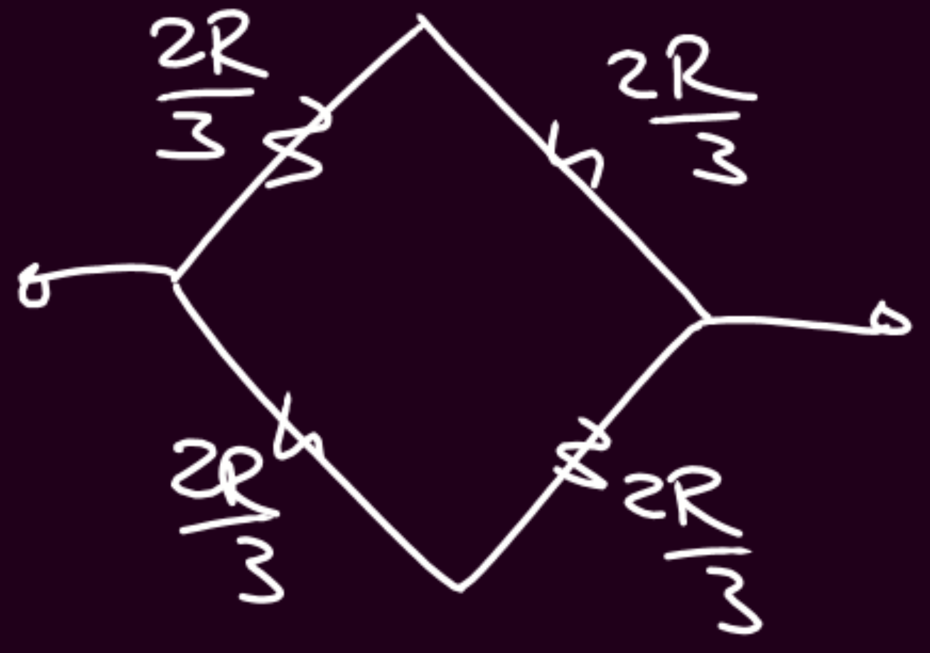
Extended WSB

⇒

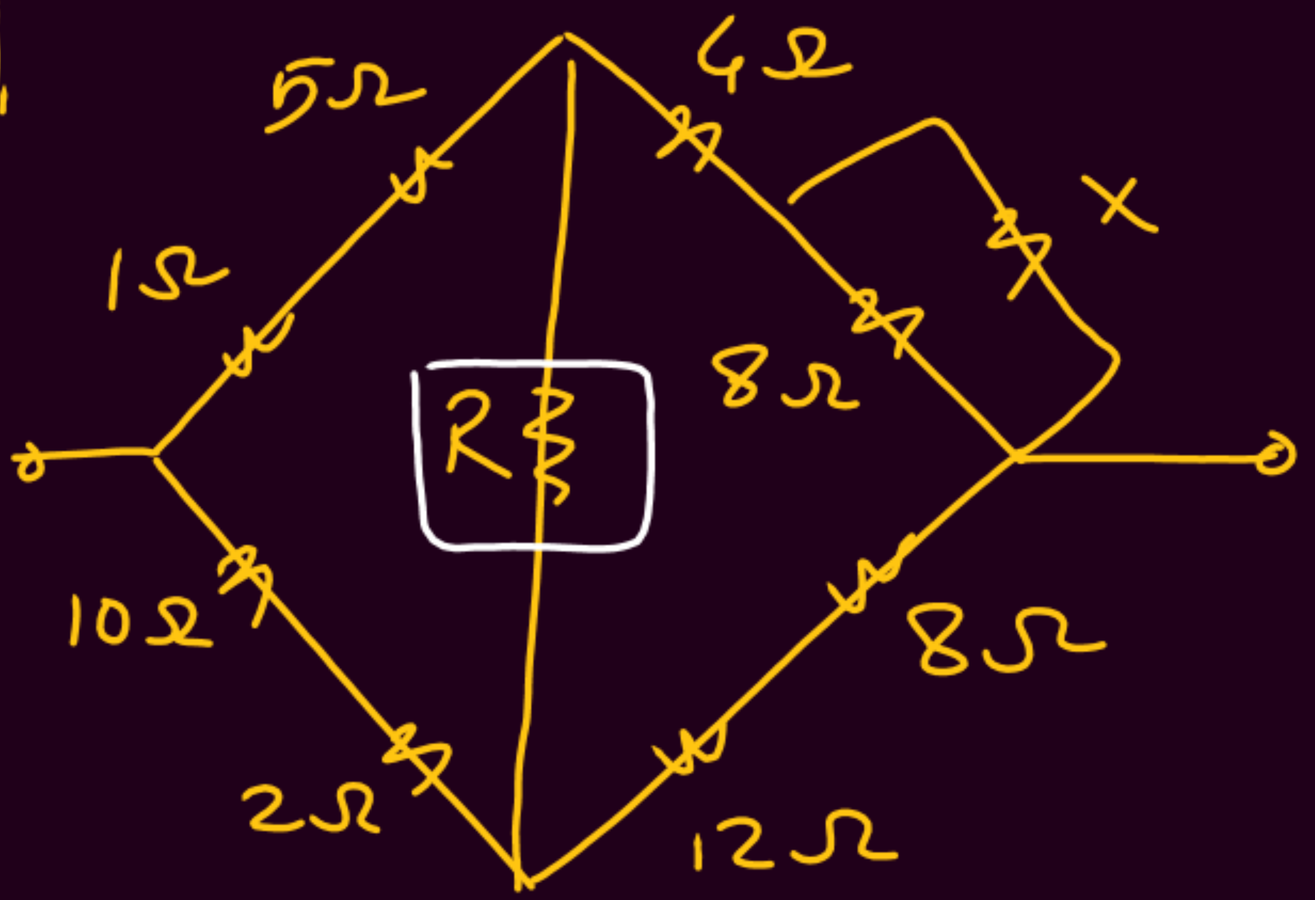




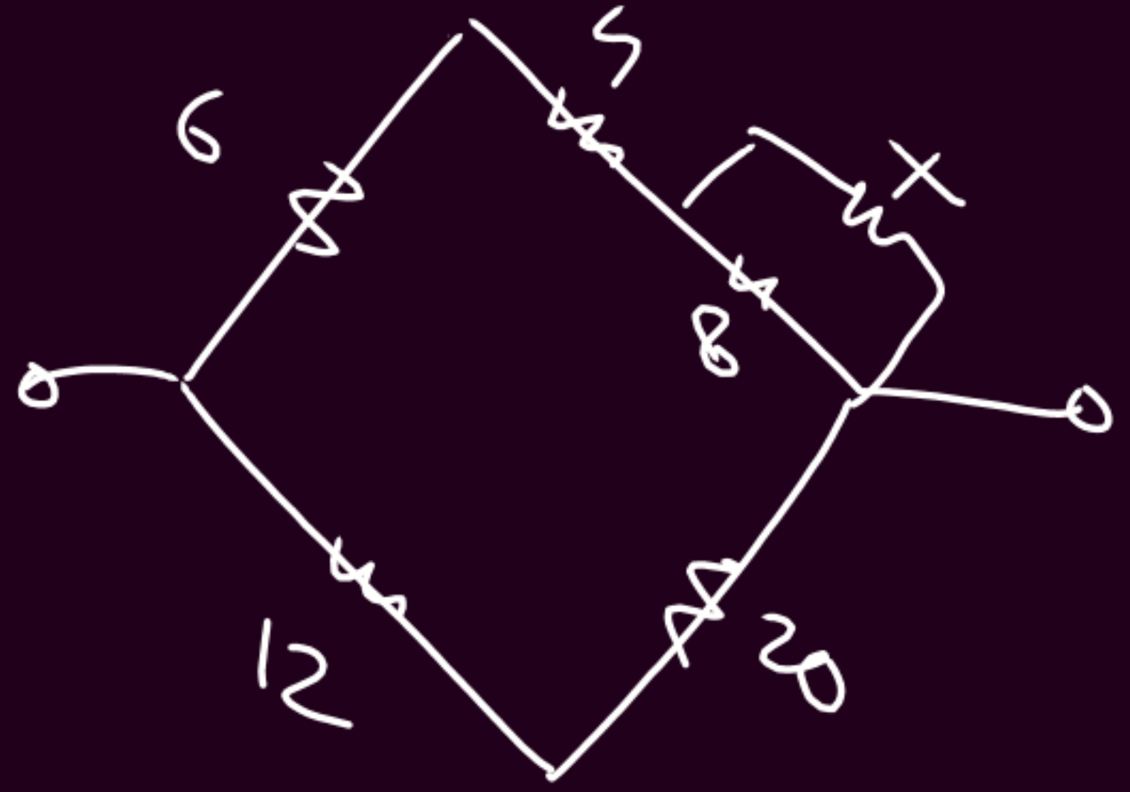




$$R_{eq} = \frac{2R}{3}$$



if current through R is 'O' then find x ?

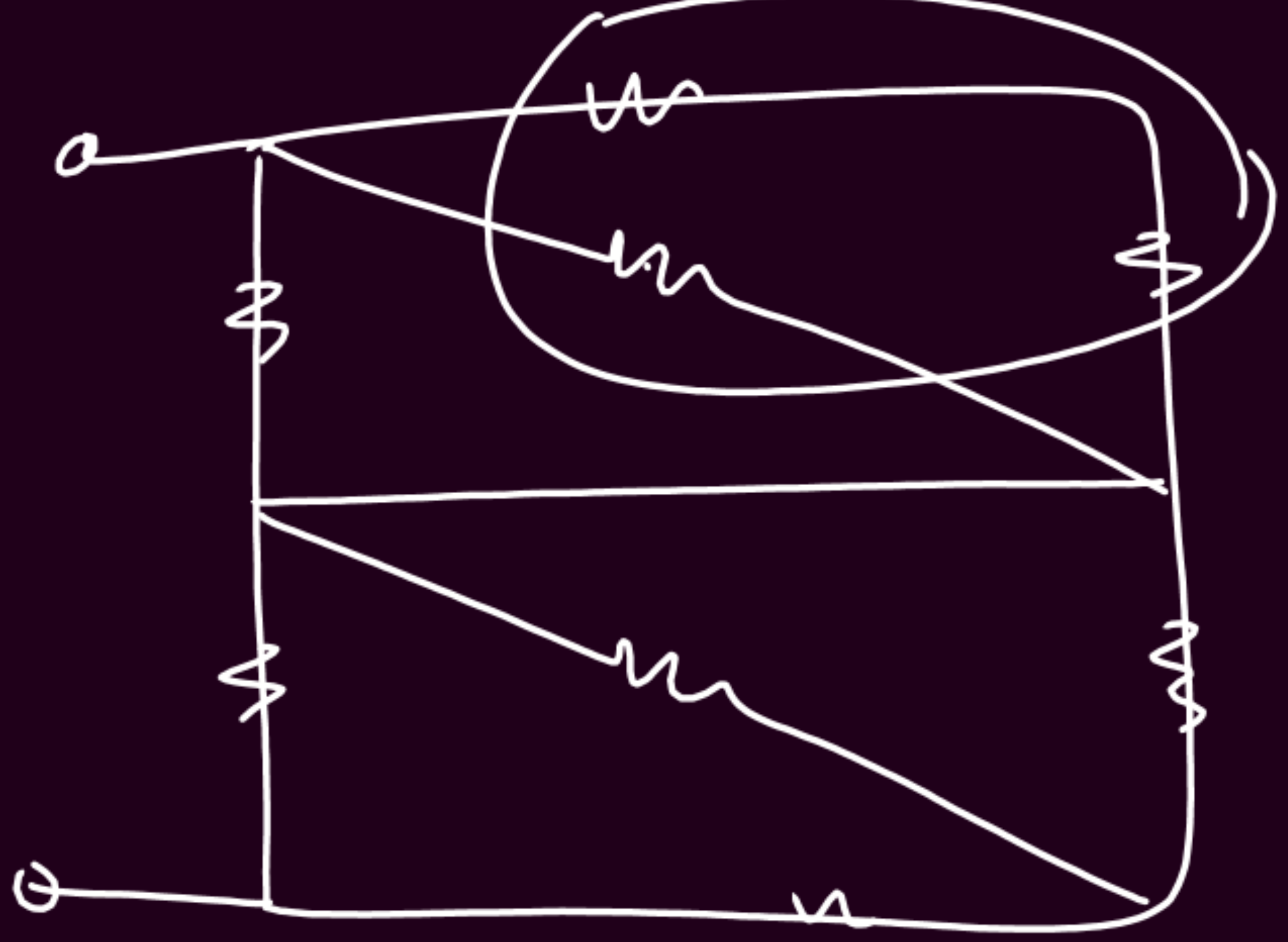


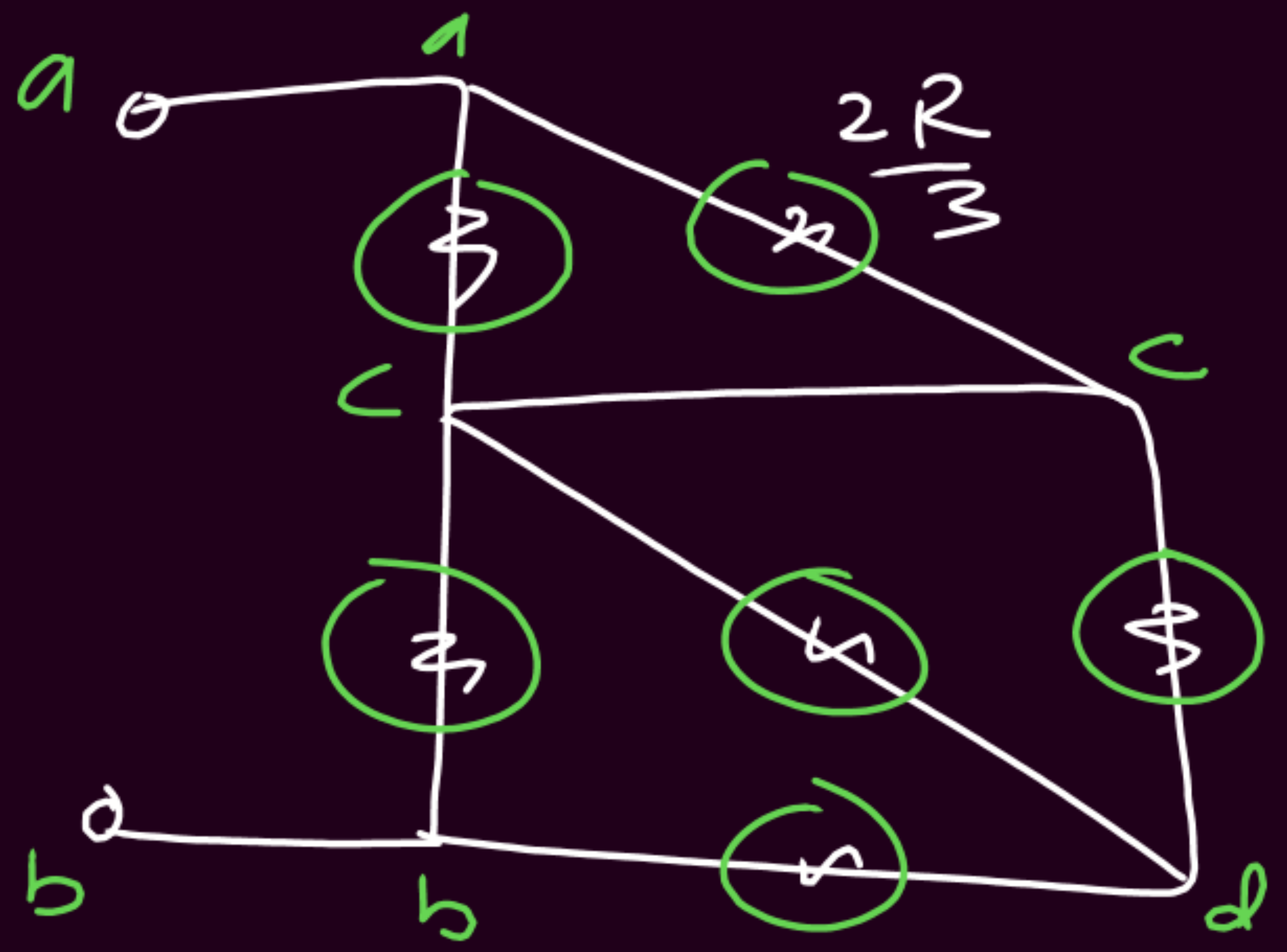
$$\frac{6}{12} = \frac{4 + \frac{8x}{8+x}}{20}$$

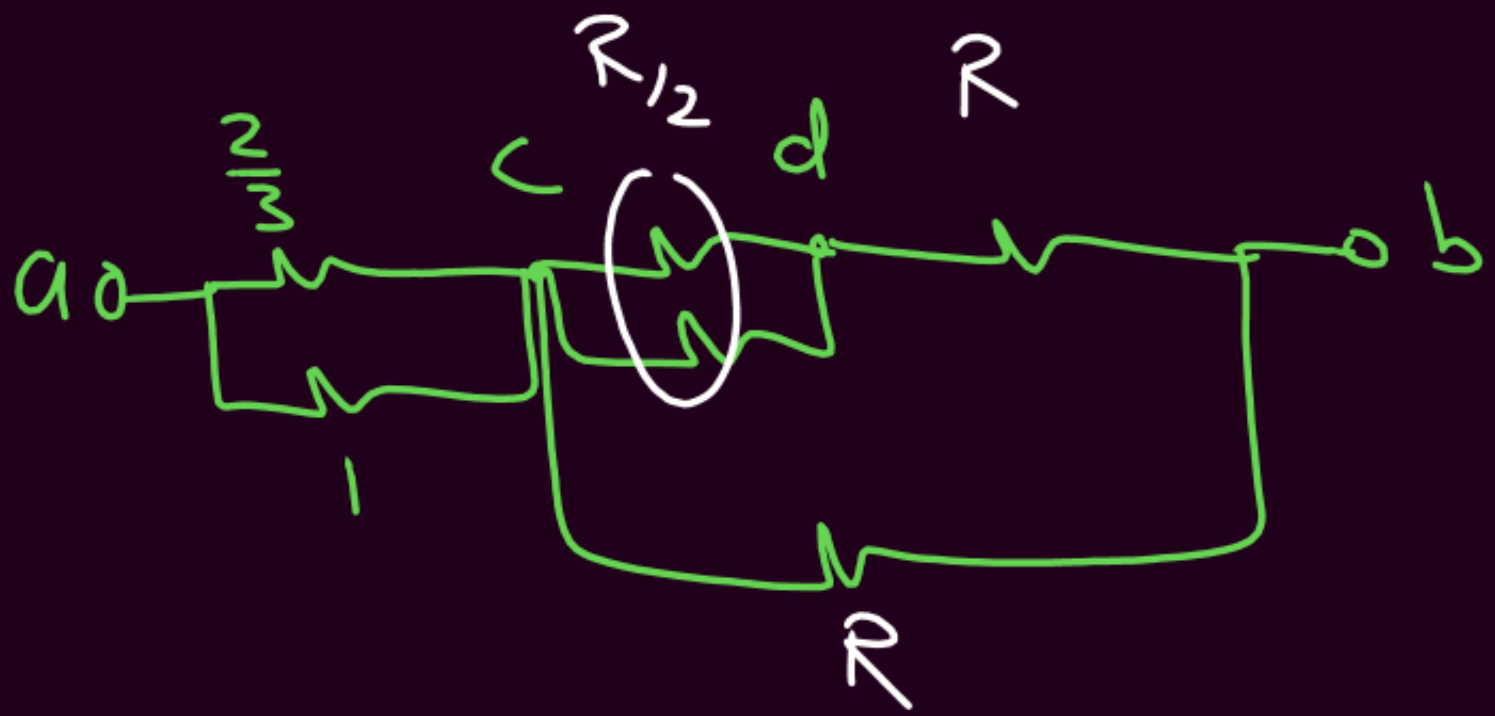
$$10 = 4 + \frac{8x}{8+x}$$

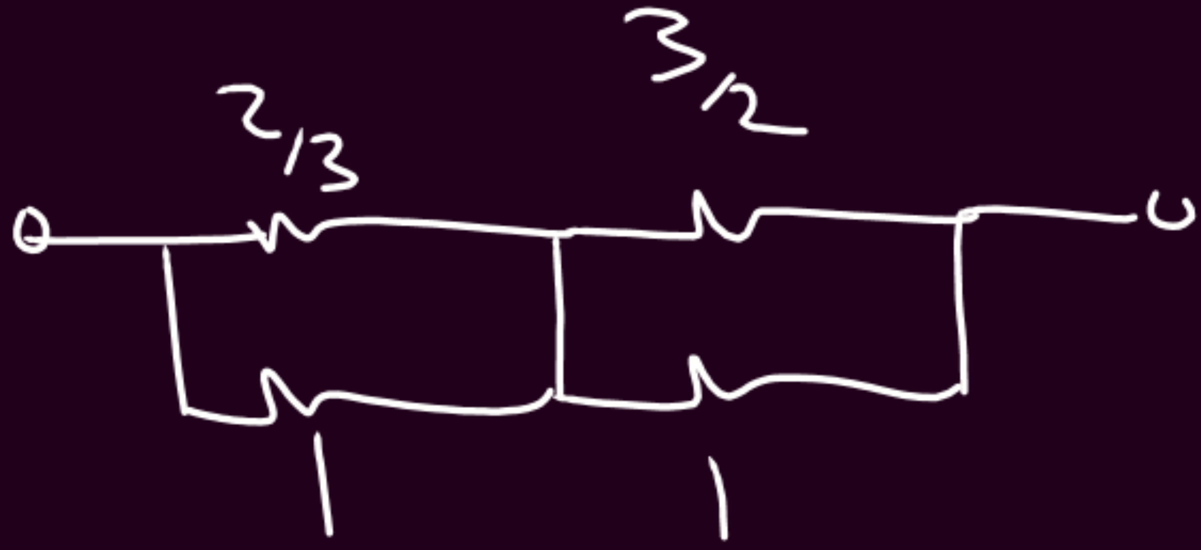
$$6 = \frac{8x}{8+x}$$

$$\boxed{x = 24\,\Omega}$$









$\frac{2}{5} + \frac{3}{5} = 1$

Q. Left gap = 20Ω

Balancing $\Rightarrow$ 40 cm

$x = ?$

$$\frac{20}{40} = \frac{x}{60}$$

$$\boxed{x = 30\Omega}$$

Q

$$\frac{x}{20} = \frac{R}{80}$$

$$\frac{x+10}{30} = \frac{R}{70}$$

$$\frac{x}{\cancel{20}} \quad \frac{3\cancel{0}}{x+10} = \frac{\cancel{R}}{\underset{4}{\cancel{80}}} \quad \frac{7\cancel{0}}{\cancel{R}}$$

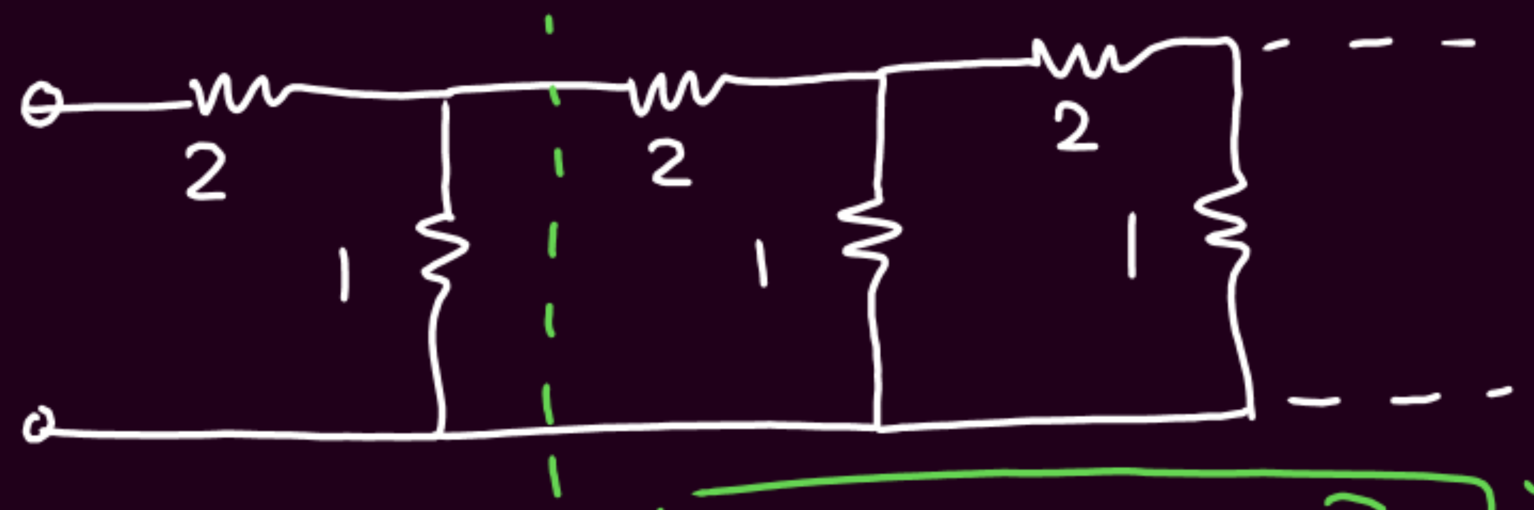
$$\frac{3x}{x+10} = \frac{7}{4}$$

$$12x = 7x + 70$$

$$5x = 70$$

$$\boxed{x = 14\Omega}$$

ctra



$$2 < R_{eq} < 3$$

$$+ R_2 = X$$

3

$$\frac{x(1)}{x+1} + 2 = x$$

$$x = (x-2)(x+1)$$

$$x = x^2 + x - 2x - 2$$

$$x^2 - 2x - 2 = 0$$

$$ax^2 + bx + c = 0$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

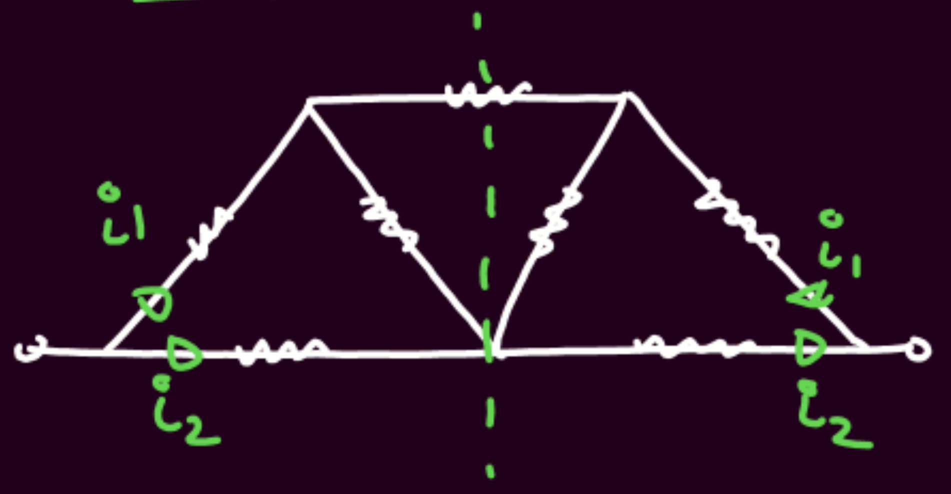
$$x = \frac{-(-2) \pm \sqrt{4 - 4(1)(-2)}}{2(1)}$$

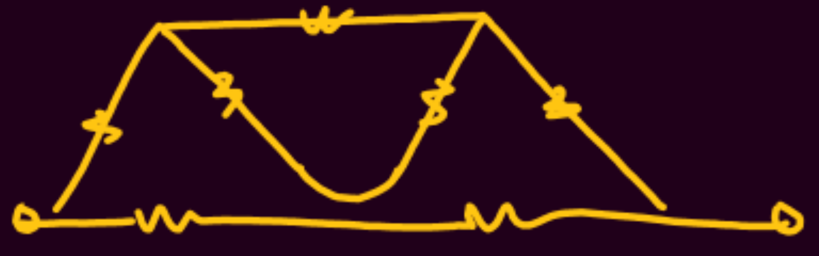
$$x = \frac{2 \pm \sqrt{12}}{2} = \frac{2 \pm 2\sqrt{3}}{2}$$

$$x = (1 \pm \sqrt{3})$$

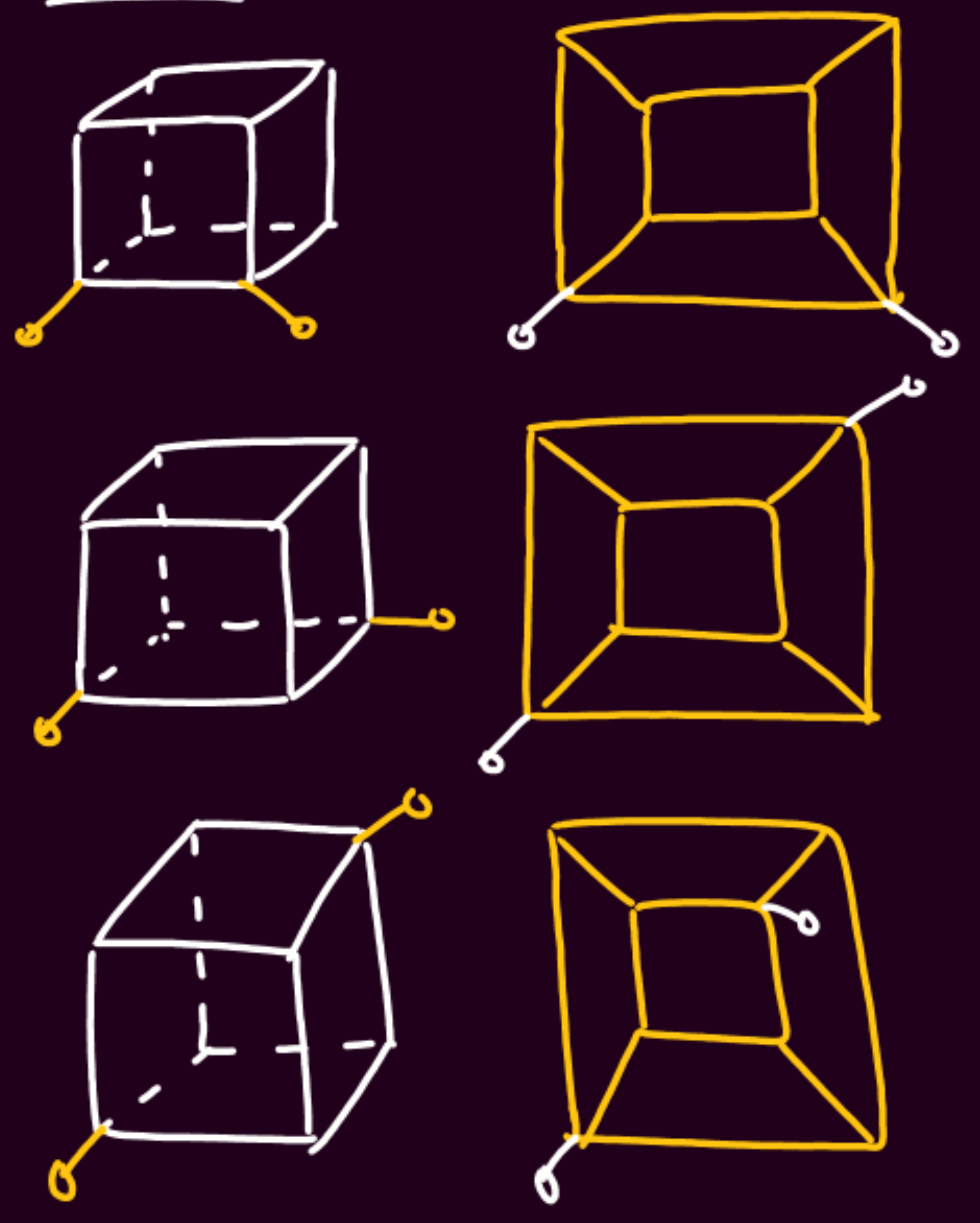
$$\boxed{R_{eq} = (1 + \sqrt{3})}$$

VPS → Current Division

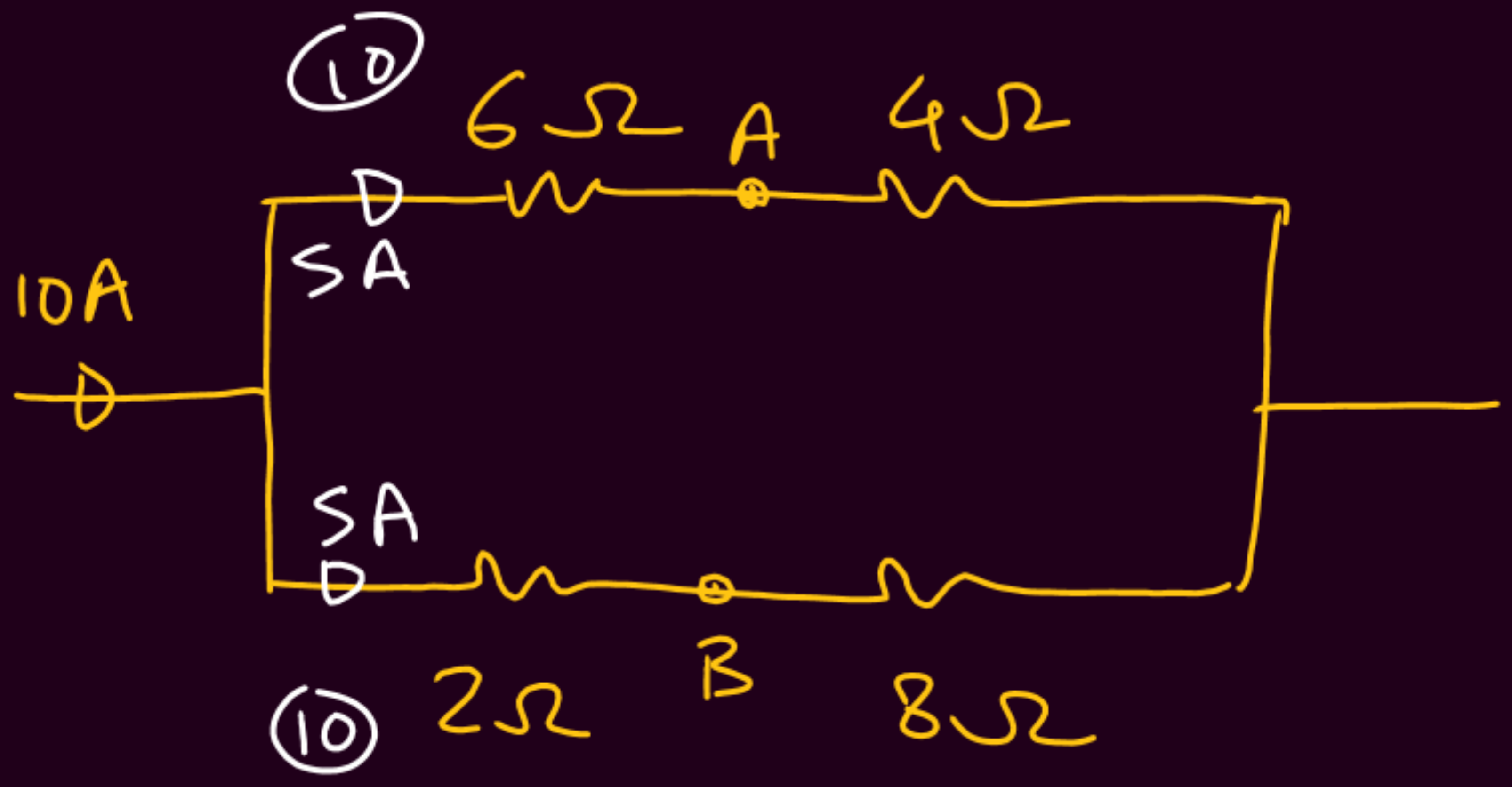




Cube

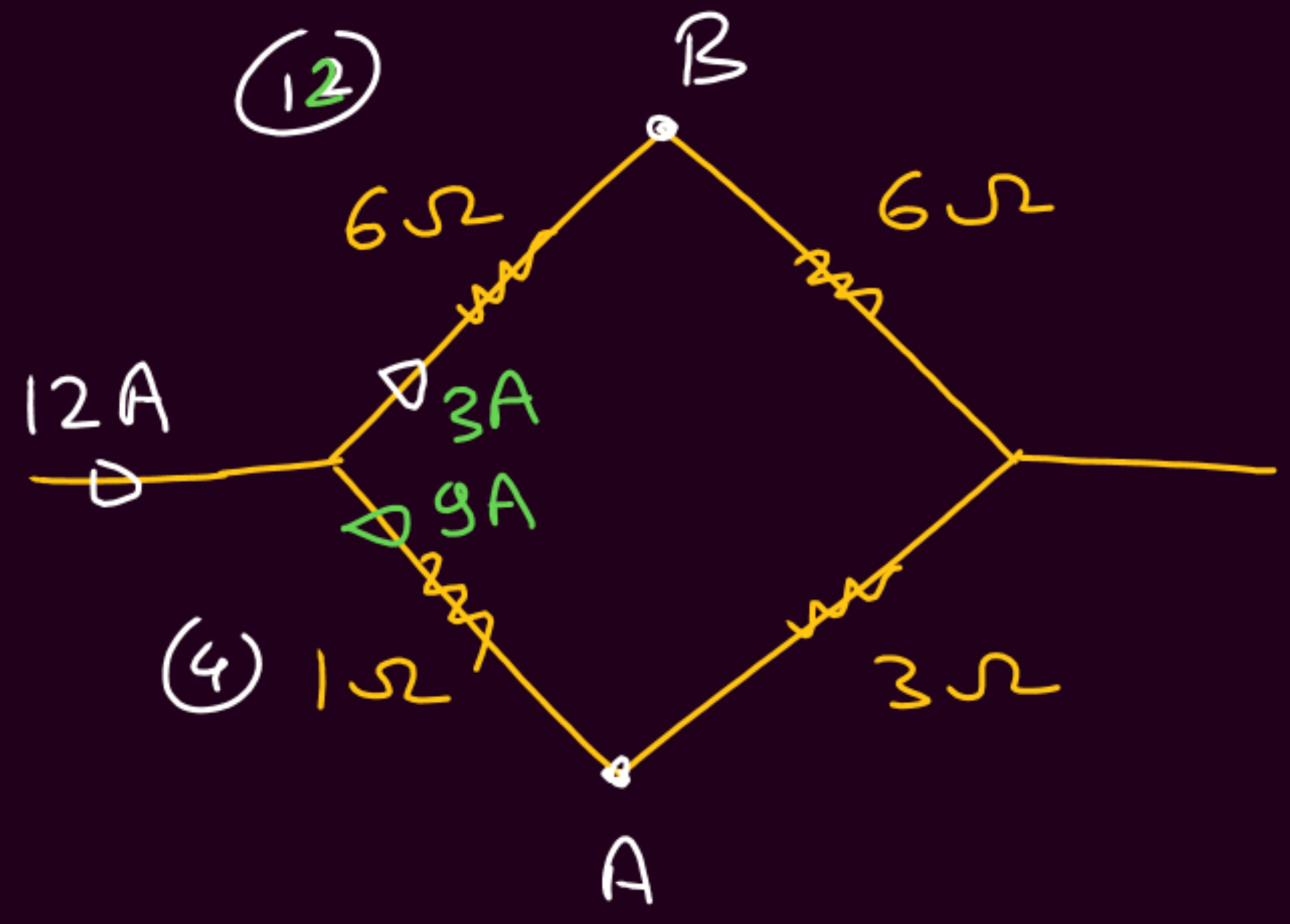


	R_{eq}	C_{eq}
Edge	$\frac{7R}{12}$	$\frac{12C}{7}$
Face diagonal	$\frac{3R}{4}$	$\frac{4C}{3}$
Body diagonal	$\frac{5R}{6}$	$\frac{6C}{5}$



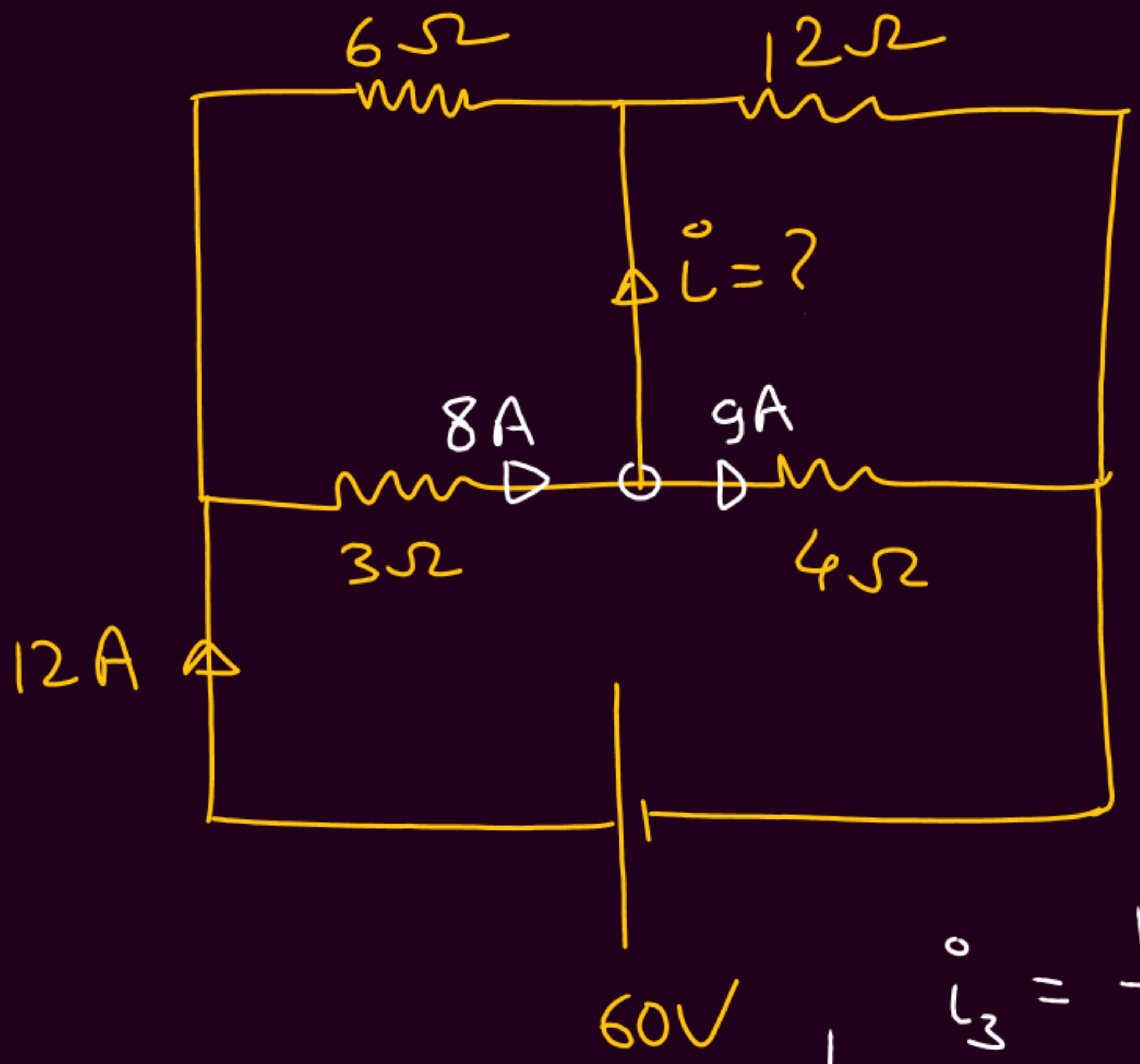
$$V_{AB} = +(5)(2) - (5)(6)$$

$$= -20V$$



$$\frac{(12) \times 4}{12+4} = 3A$$

$$V_{AB} = (3)(6) - (9)(1) = \underline{\underline{9V}}$$



$$8 = 9 + i$$

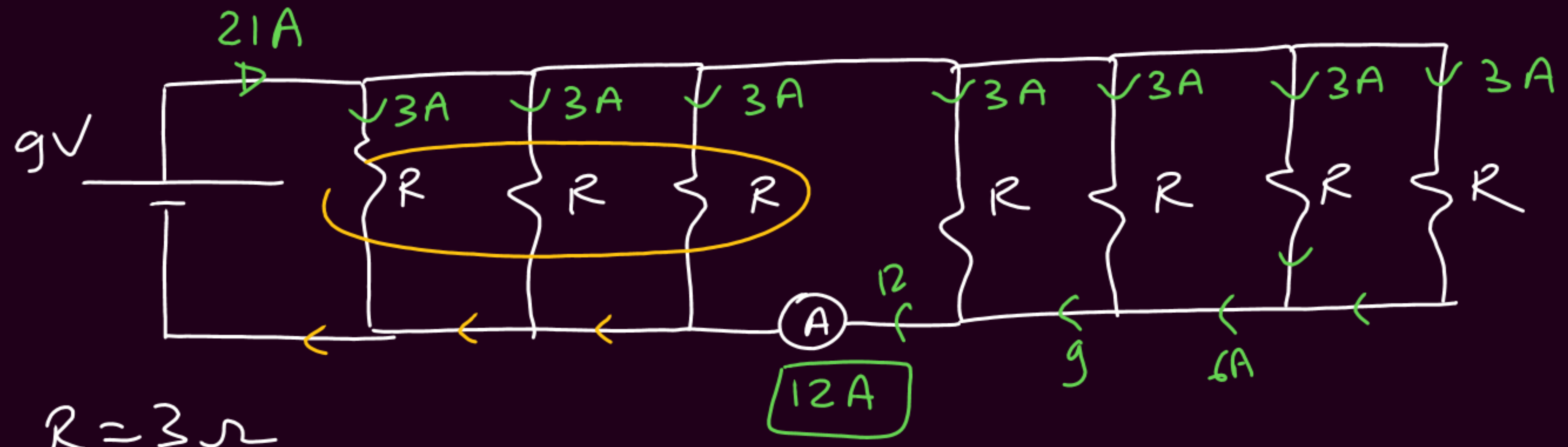
$$\boxed{i = -1A}$$

$$i_3 = \frac{12 \times 6}{3+6} = 8A$$

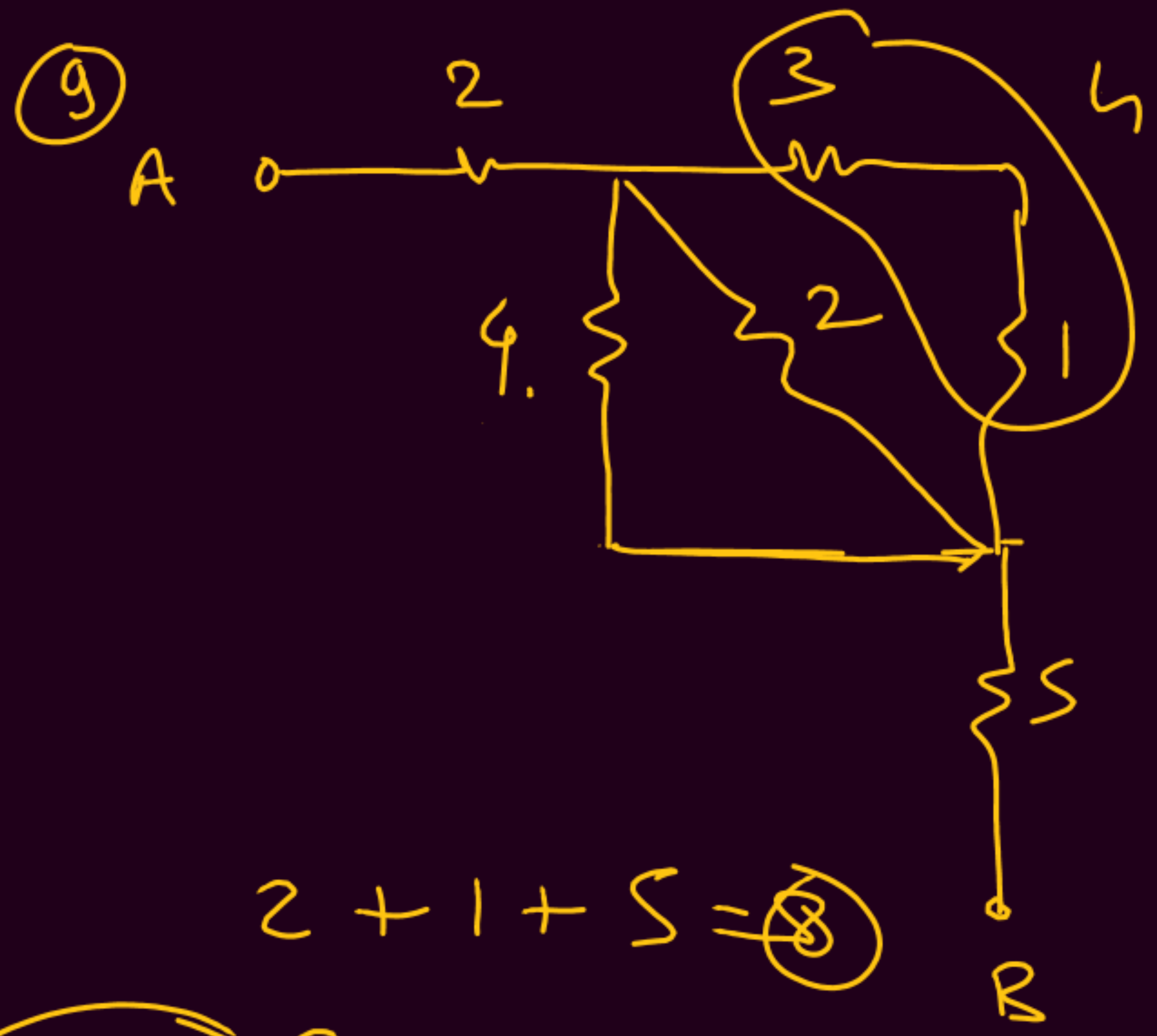
$$i_4 = \frac{12 \times 12}{4+12} = 9A$$

$$R_{eq} = 5\Omega$$

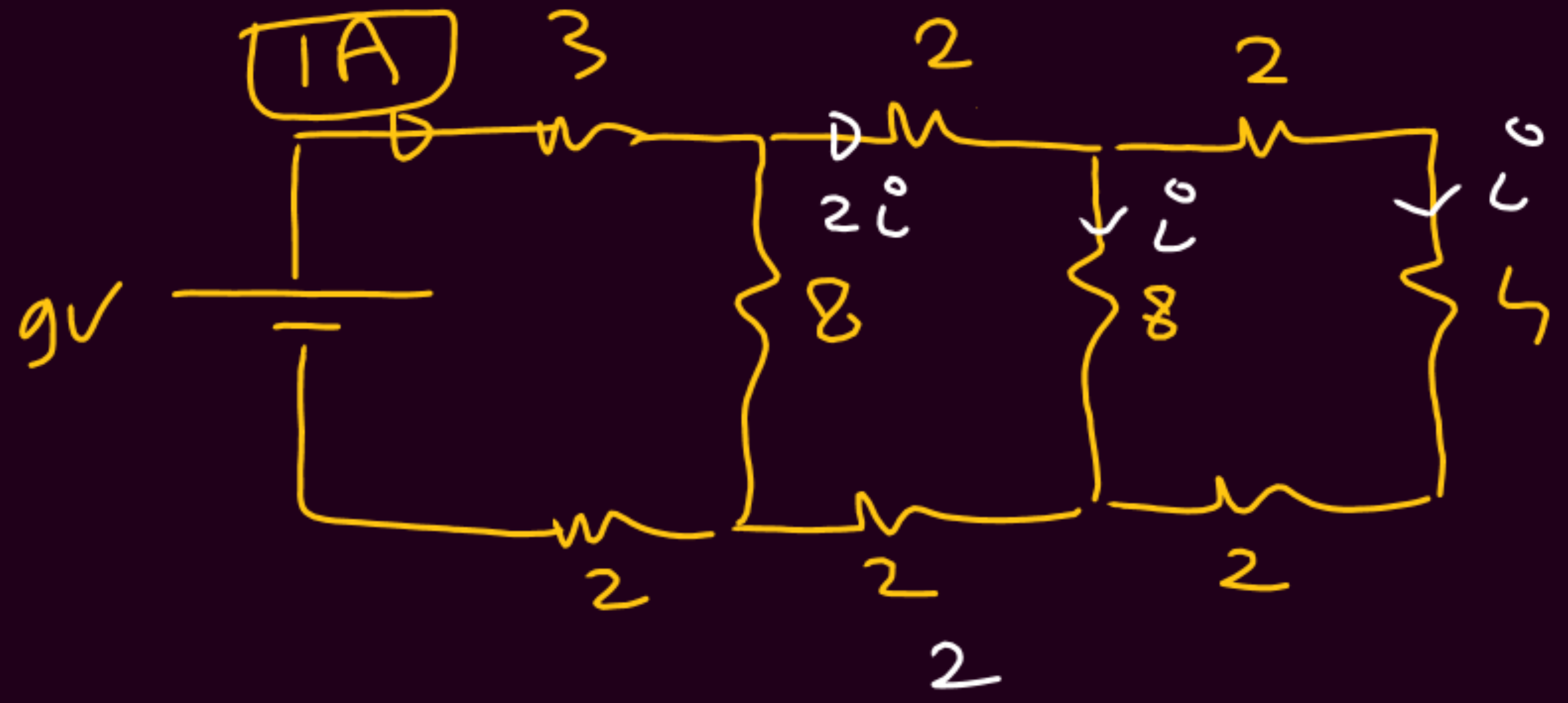
$$i = \frac{60}{5} = 12A$$

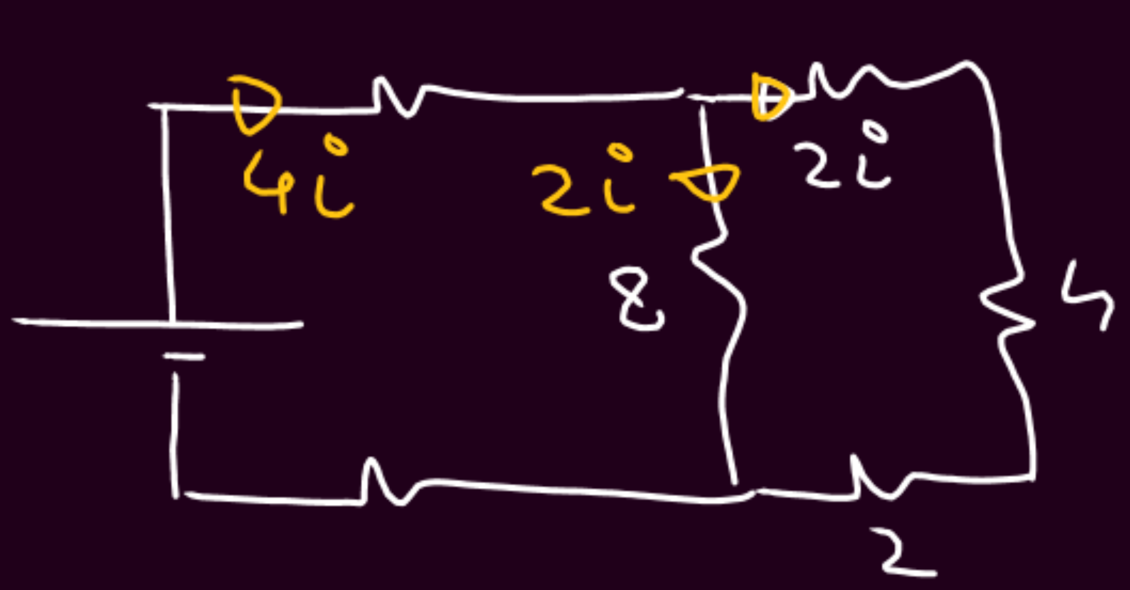


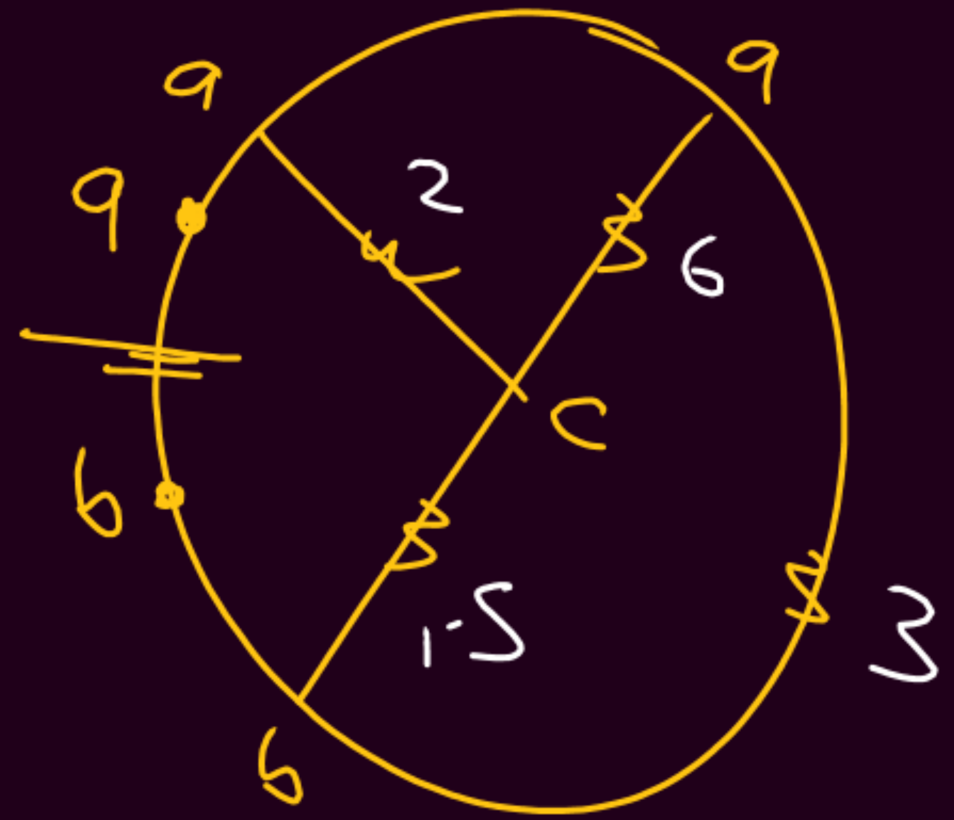
$R = 3\Omega$



$2 + 1 + 5 = 8$







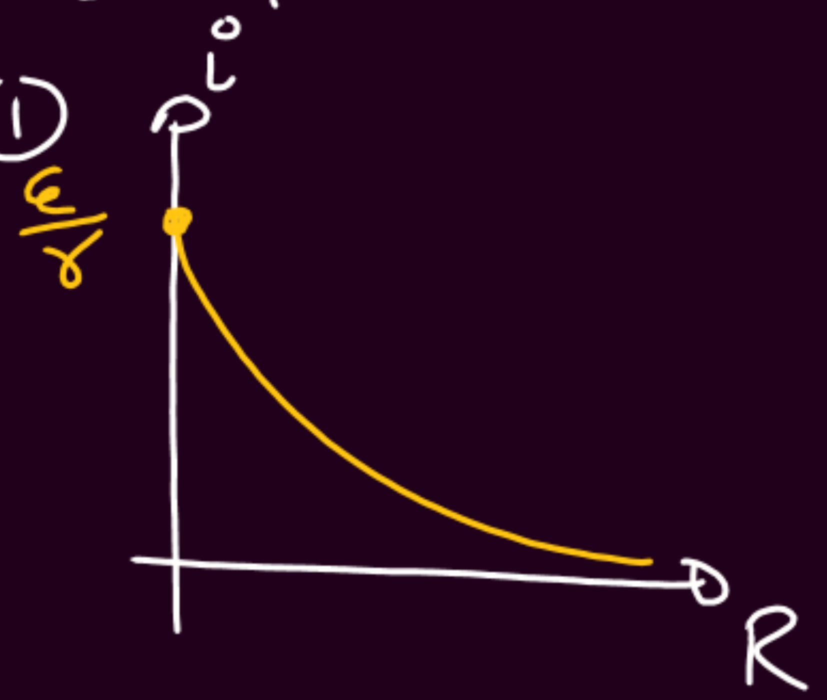
$\frac{6}{1.5}$

$4i = 1$

$i = 0.25A$

Graphs

(1)

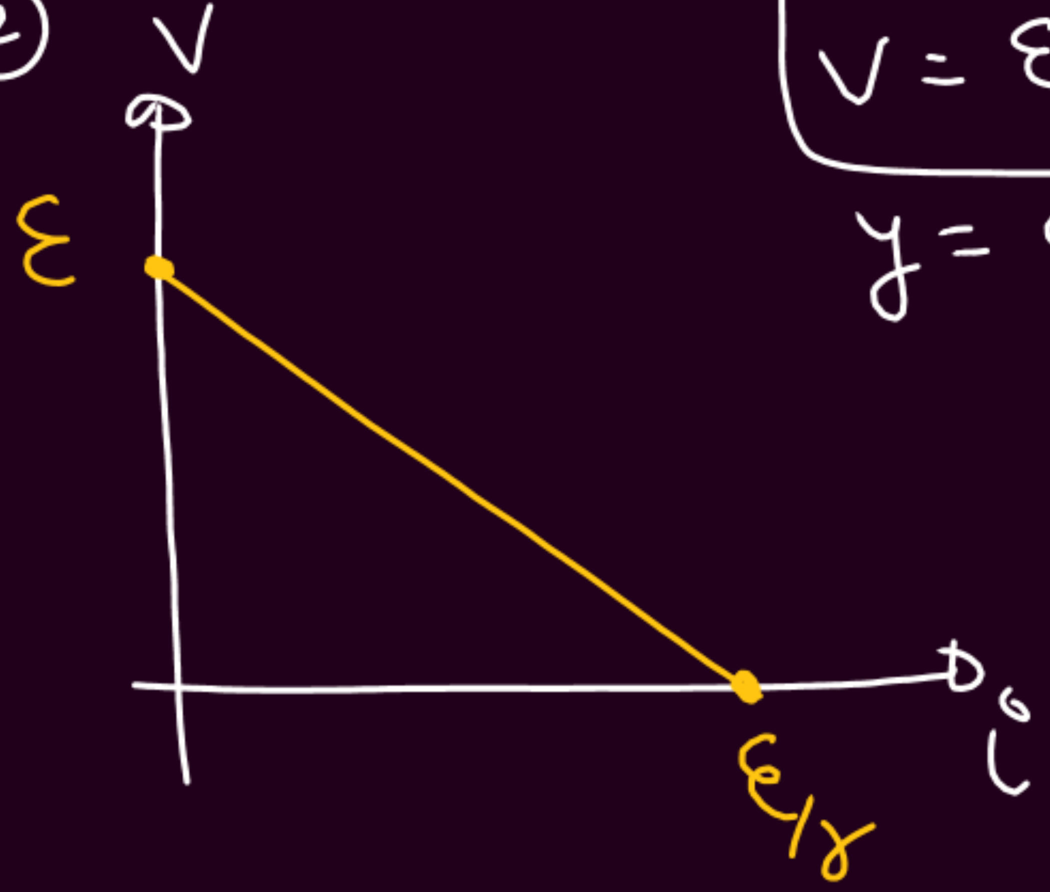


$R = 0 \quad i = \frac{\varepsilon}{r}$

$R \to \infty \quad i \to 0$

$$\boxed{i = \frac{\varepsilon}{R + r}}$$

(2)



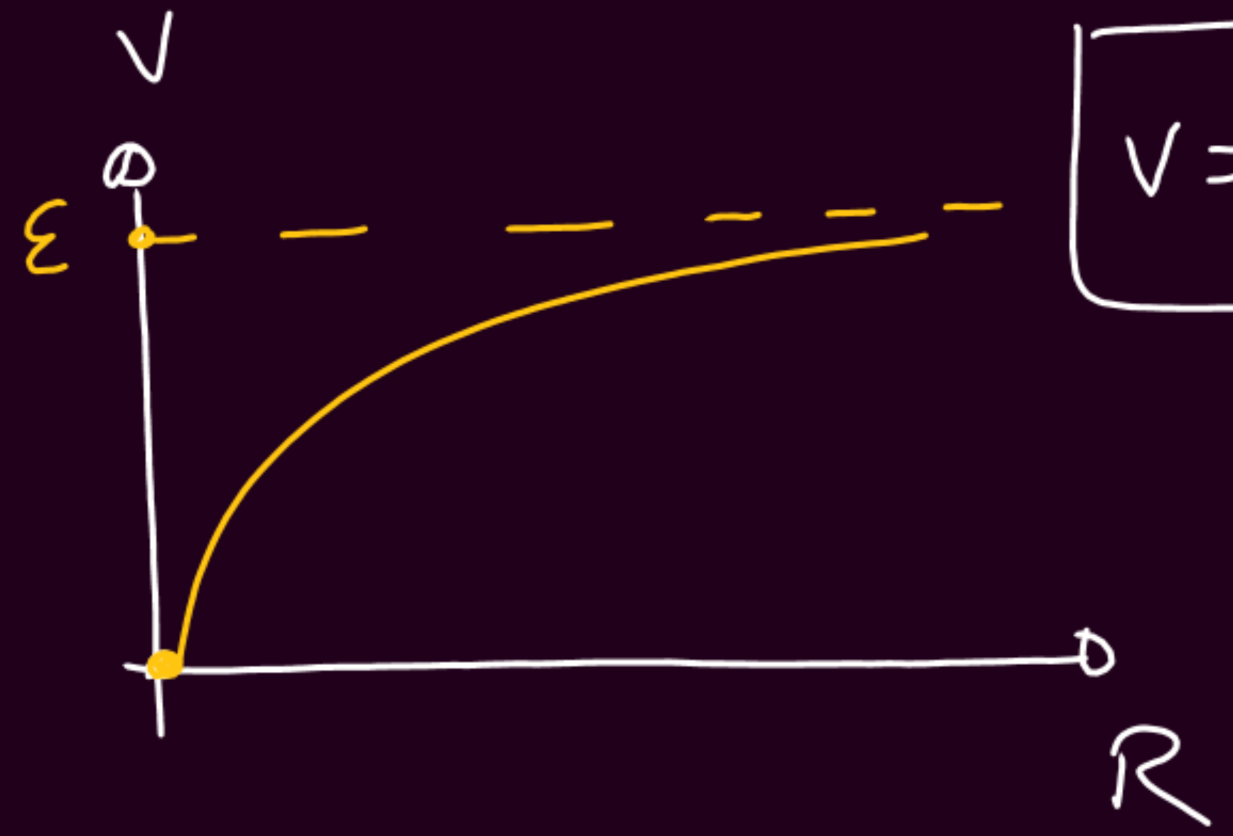
$$\boxed{V = \varepsilon - i r}$$

$y = c + x m$

$i = 0 \quad V = \varepsilon$

$i = \varepsilon/r \quad V = 0$

slope $= -r$



$$\boxed{V = \frac{\varepsilon R}{R + r}}$$

$R = 0 \, , \; V = 0$

$R \to \infty \, , \; V = \varepsilon$

Q. $(10V, 2\Omega)$

$R = 3\Omega$

① $i = \frac{\mathcal{E}}{R+r} = \frac{10}{3+2} = 2A$

② $V_{cell} = \mathcal{E} - ir = 10 - 2\times 2 = 6V$

$= iR = 2\times 3 = 6V$

Q. $1\Omega \Rightarrow 3A$

$3\Omega \Rightarrow 2A$

$5\Omega \Rightarrow i = ?$

$$i = \frac{\mathcal{E}}{R+r}$$

$$\left.\begin{aligned} 3 &= \frac{\mathcal{E}}{1+r} \\ 2 &= \frac{\mathcal{E}}{3+r} \end{aligned}\right\} \quad \mathcal{E} = 3 + 3r = 6 + 2r$$

$$\boxed{r = 3\Omega}$$

$$\mathcal{E} = 3 + 3(3) = 12V$$

$$i = \frac{\mathcal{E}}{5+r} = \frac{12}{5+3} = \frac{12}{8} = 1.5A$$

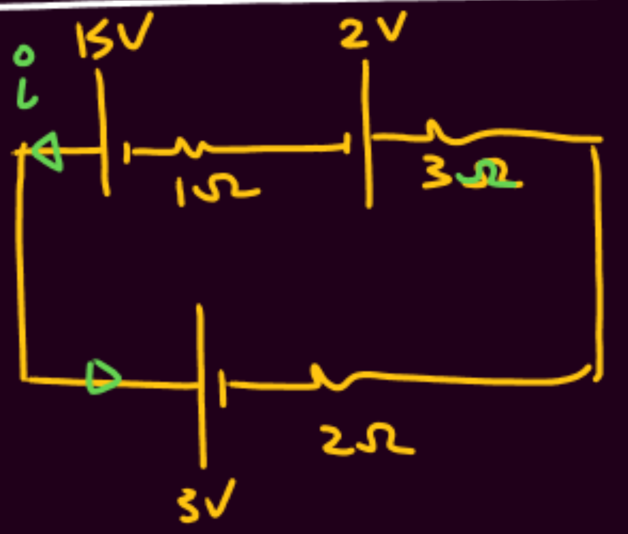
Q.

o.c. $V = \mathcal{E} = 10V$

$V = \mathcal{E} - ir = 8V$

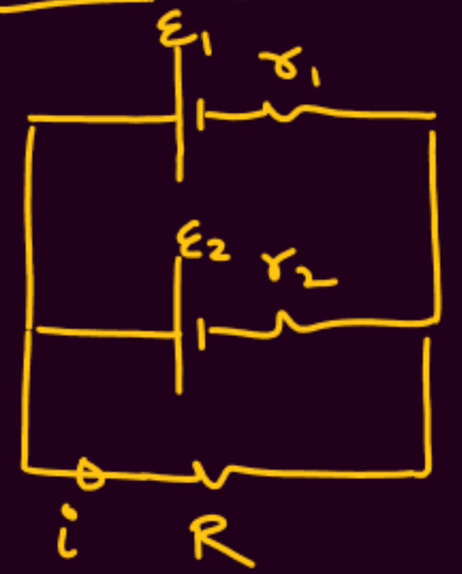
$$\boxed{r = R\left(\frac{\mathcal{E}}{V} - 1\right)} = 4\left(\frac{10}{8} - 1\right) = 1\Omega$$

$(2) + 4 - 10 + i(1) = 0$



$i = \frac{15-2-3}{1+3+2} = \frac{10}{6} = 5/3\ A$

Parallel combination (Extra)



$$\varepsilon_{eq} = \frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 + r_2}$$

$$r_{eq} = \frac{r_1 r_2}{r_1 + r_2}$$

n-identical cells in parallel

① $\varepsilon_{eq} = \varepsilon$

② $r_{eq} = \frac{r}{n}$

Series

$\varepsilon_{eq} = n\varepsilon$

$r_{eq} = nr$

Mixed Grouping (Extra)

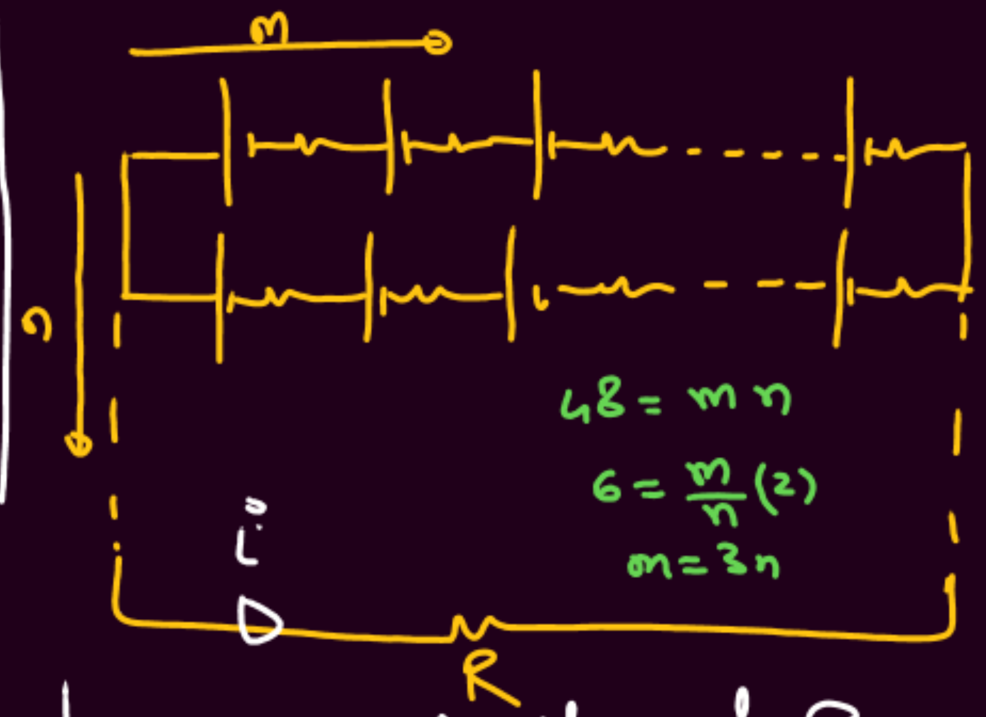
① $\boxed{N = mn}$ 1

② m cells in a row
n such rows

③ $\varepsilon_{eq} = m\varepsilon$

④ $r_{eq} = \frac{mr}{n}$

⑤ $i = \frac{m\varepsilon}{R + \frac{mr}{n}}$



$48 = mn$

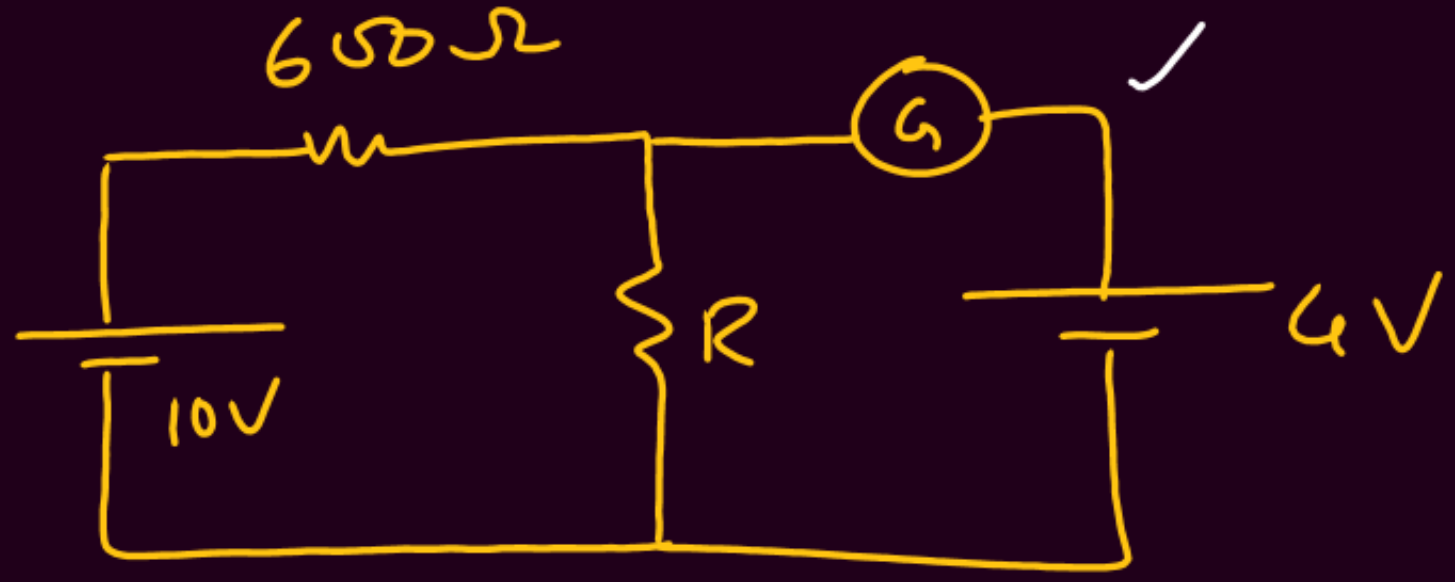
$6 = \frac{m}{n}(2)$

$m = 3n$

For max i through R

2 when $\boxed{R = \frac{mr}{n}}$

A



If $i_g = 0$

then find R

PYQ

$$\Downarrow$$

$$\varepsilon_{eq} = 4$$

$$\frac{10R + 0}{R + 600} = 4$$

$$10R = 4R + 2400$$

$$6R = 2400$$

$$\boxed{R = 400\Omega}$$

Power

$$\frac{dw}{dt} = V\left(\frac{dq}{dt}\right)$$

$$\boxed{P = Vi = \frac{V^2}{R} = i^2 R}$$

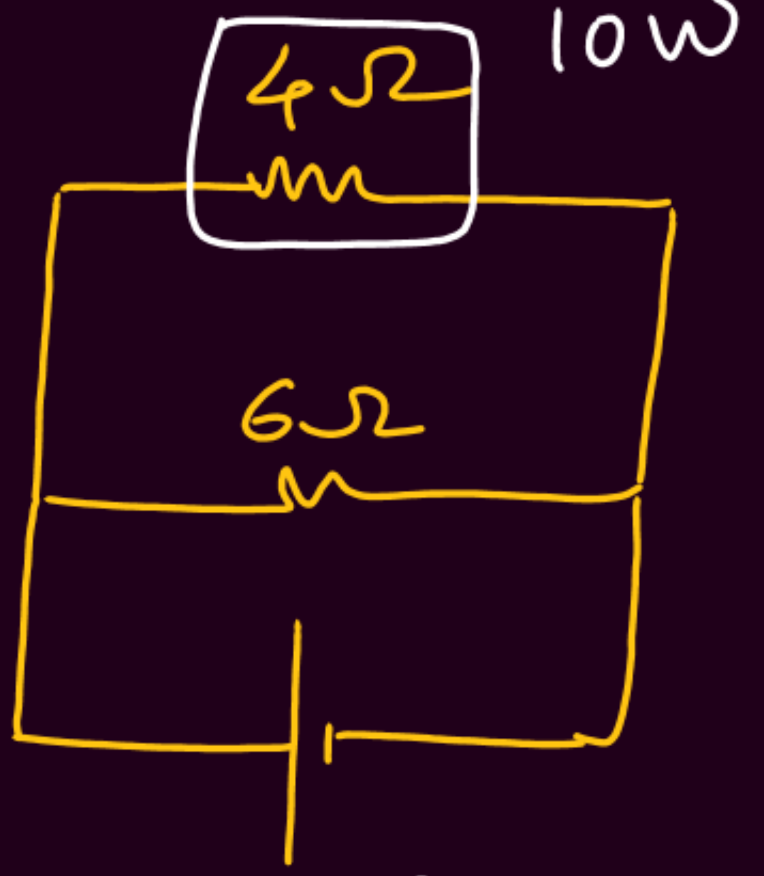
Power $\rightarrow$ W (watt)

$1\,\mathrm{kWhr} = 10^3(3600) = 3.6 \times 10^6\ \mathrm{J}$

[Commercial unit of energy]

Heat $= i^2 R t$

Q.

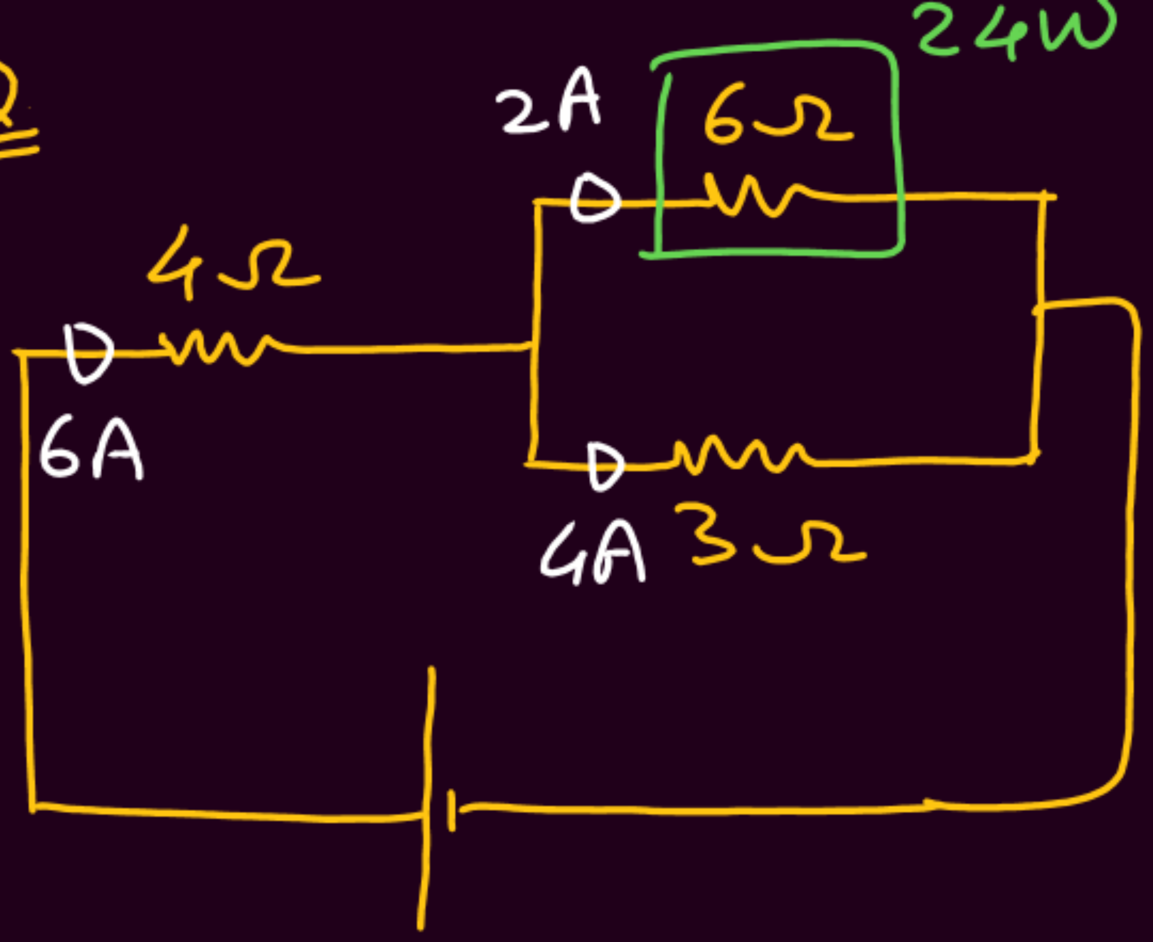


$$P = \frac{V^2}{R}$$

$$\frac{P}{10} = \frac{4}{6}$$

$$P = \frac{40}{6} = \frac{20}{3}\,W$$

Q.



① $24 = i^2(6)$

$i = 2\,A$

② $2(6) = i(3)$

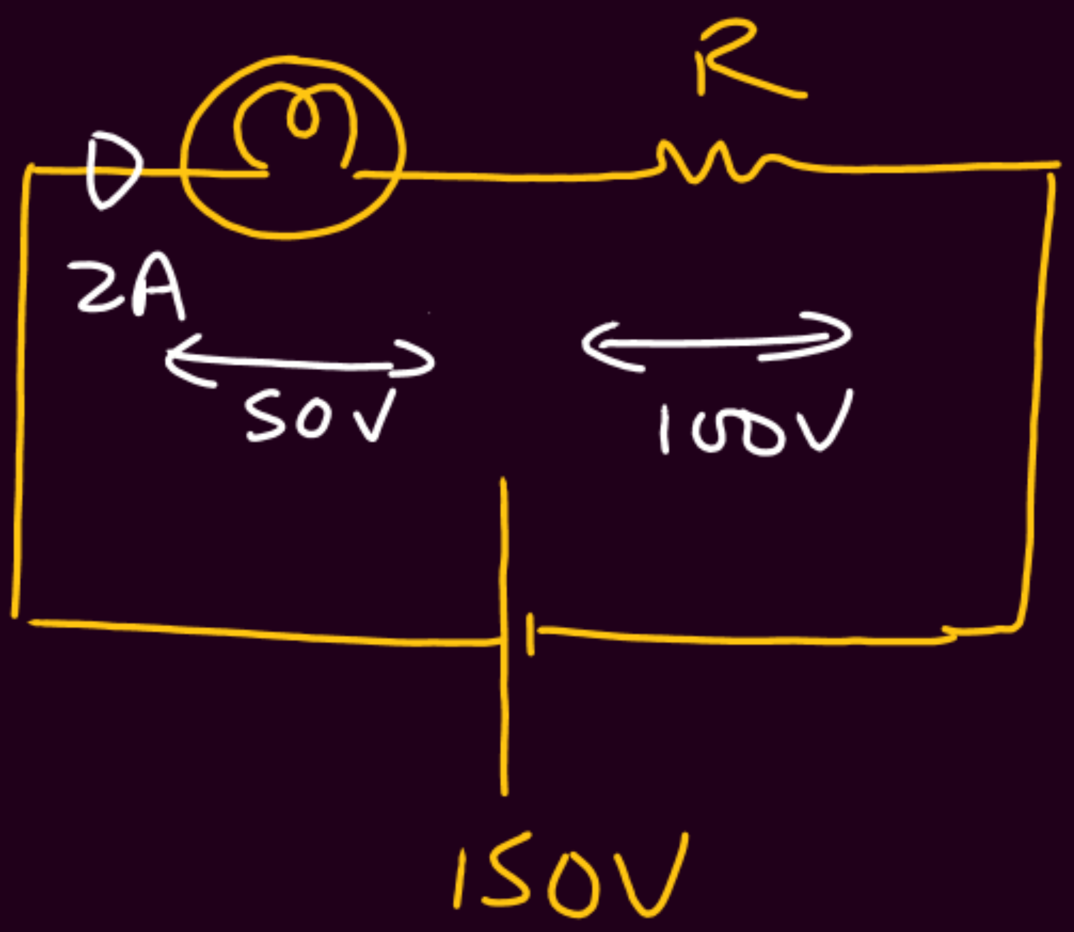
$i = 4A$

$$V = 6\,R_{eq}$$

$$= 6(6)$$

$$= \underline{\underline{36V}}$$

[100W, 50V]



$R = ?$

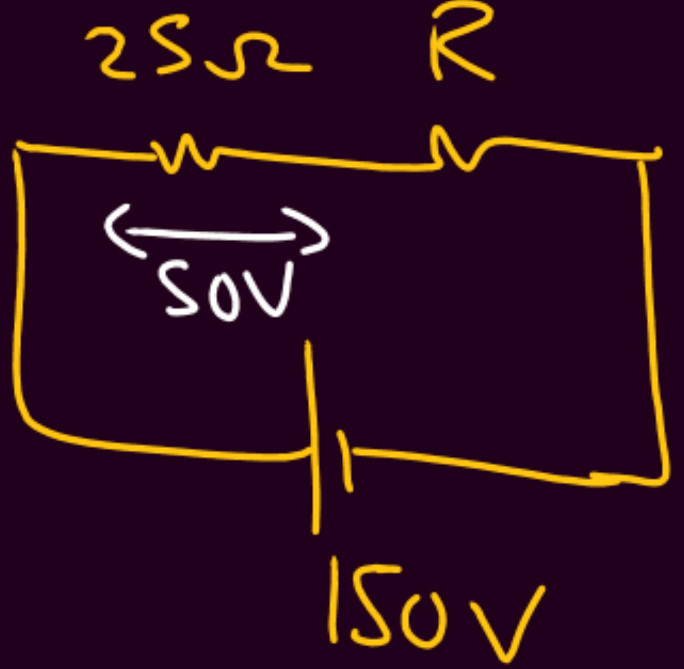
$100 = i(50)$

$\boxed{i = 2\,A}$

1. $100 = 2R$

$\boxed{R = 50\,\Omega}$

2. $R = \frac{(50)^2}{100} = 25\,\Omega$



I. $i = 2A = \frac{150}{25+R}$

II. $50 = i(25)$

$i = 2 = \frac{150}{25+R}$

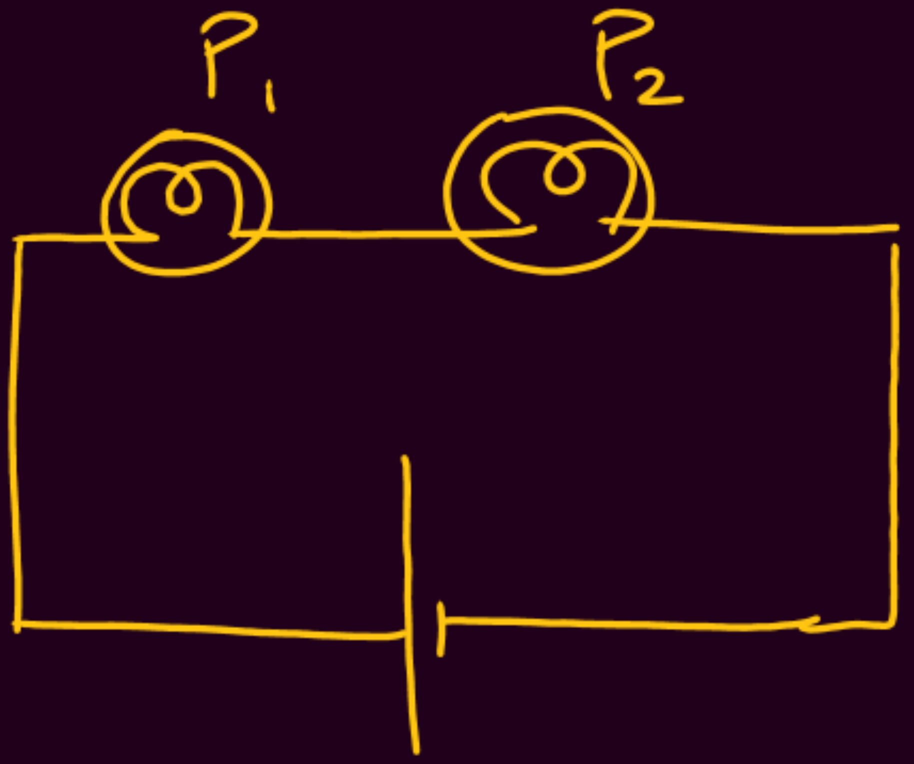
→ Bulbs have same rated voltage

→ Combination → Rated Supply

① Parallel

$$\boxed{P_{Total} = P_1 + P_2}$$

② Series

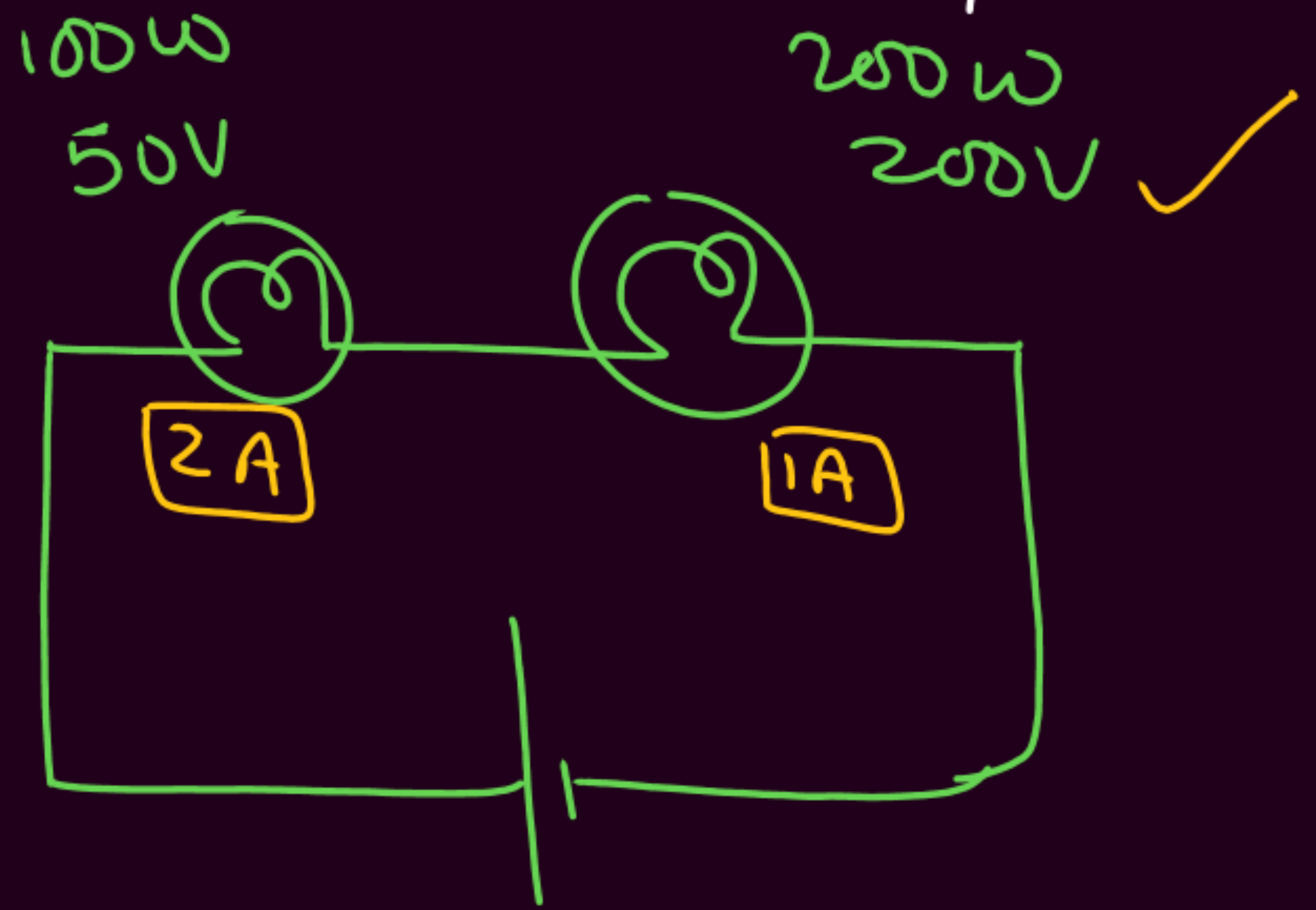


$$\boxed{P_{Total} = \frac{P_1 P_2}{P_1 + P_2}}$$

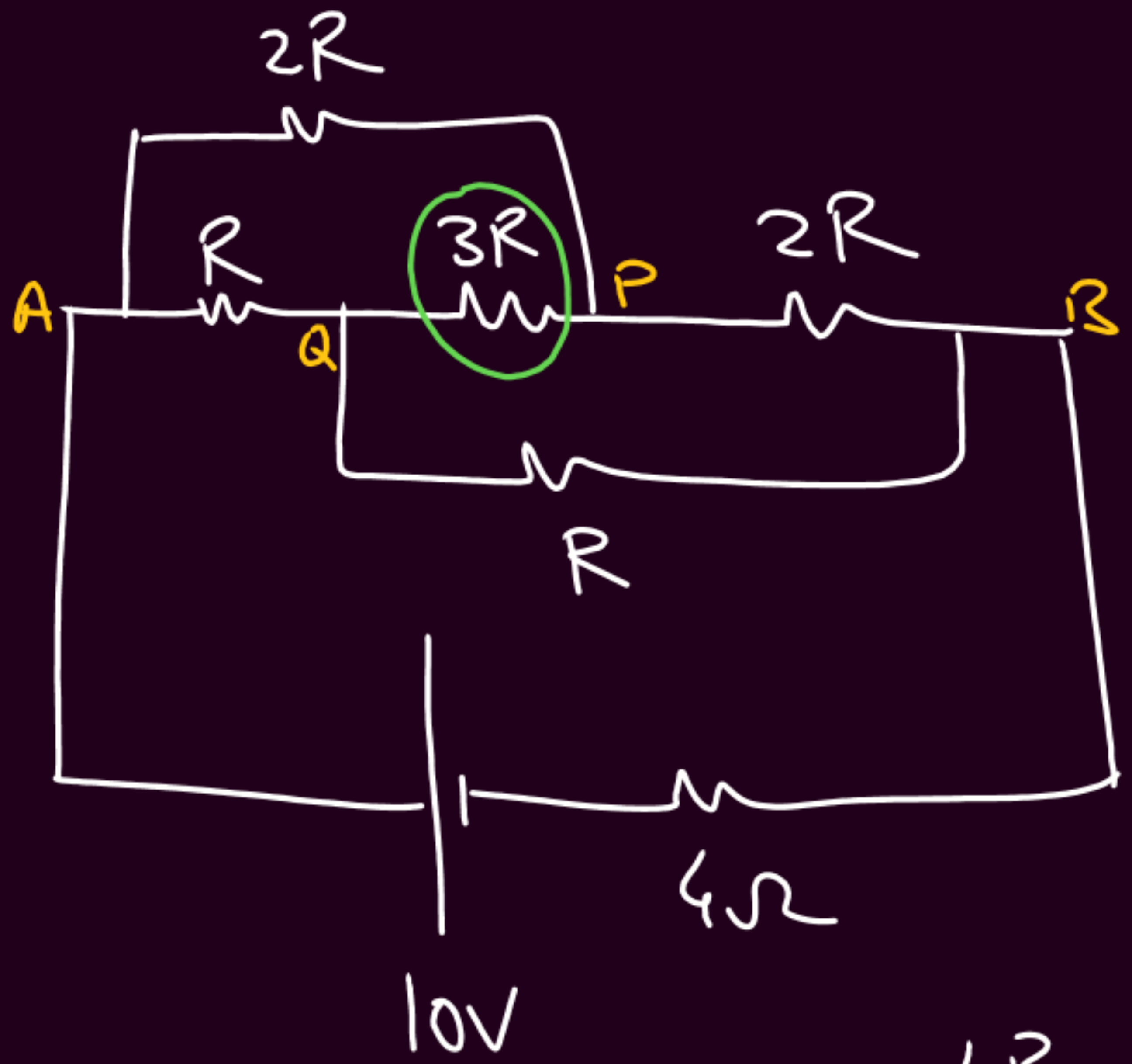
Q. 100 W 300 W

① Parallel $P = 100 + 300$
$= 400\,W$

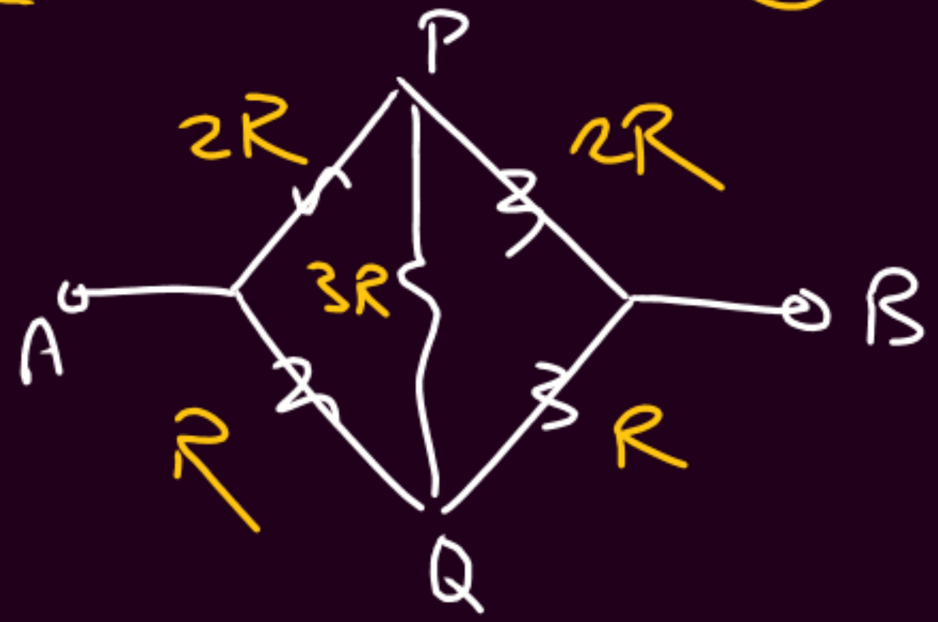
② Series $P = \frac{300}{4} = 75\,W$

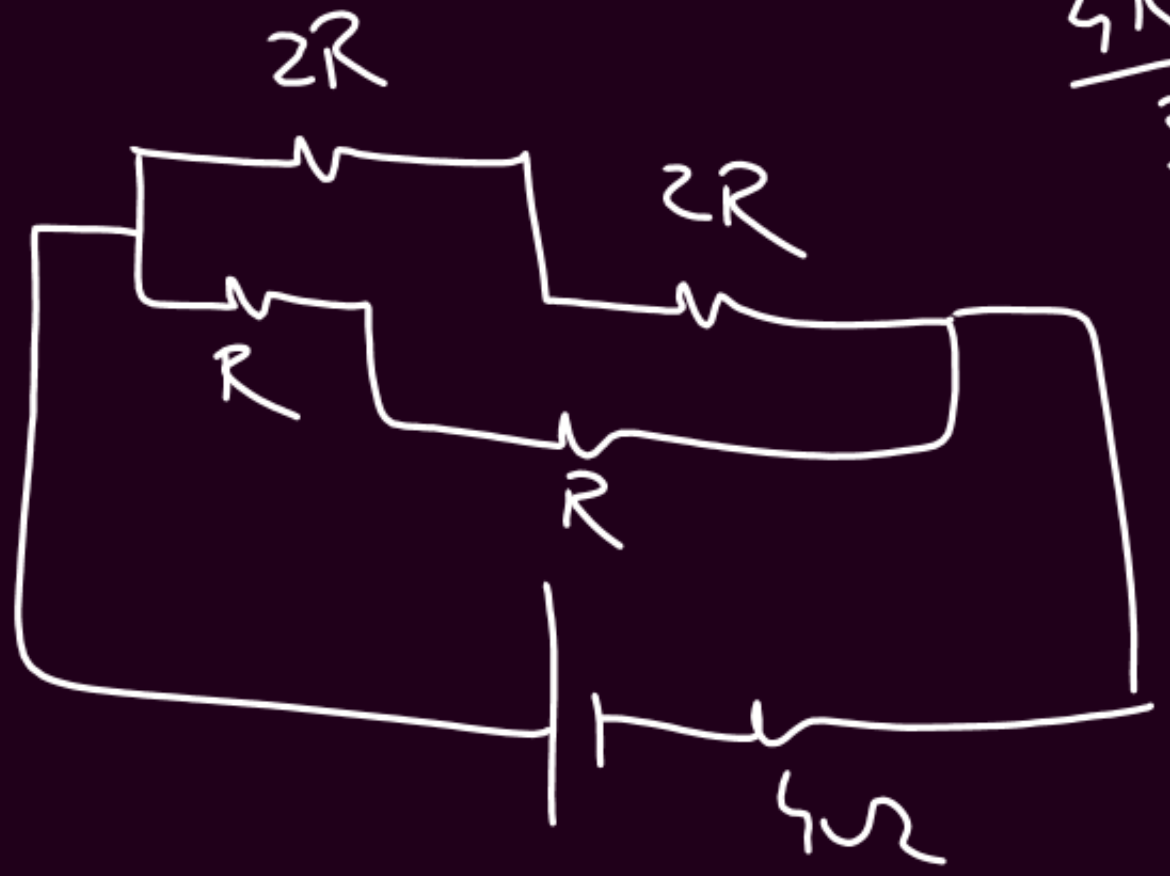


2) 15 W   4) 25 W



Find $R = ?$

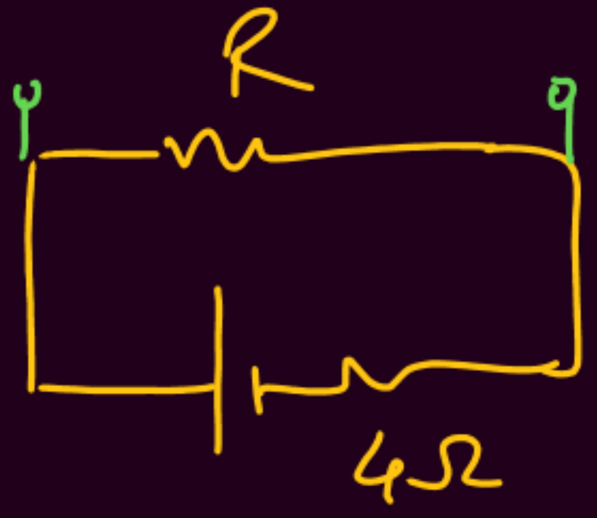




$$\frac{4R}{3} = 4$$

$$\boxed{R = 3\,\Omega}$$

Extra

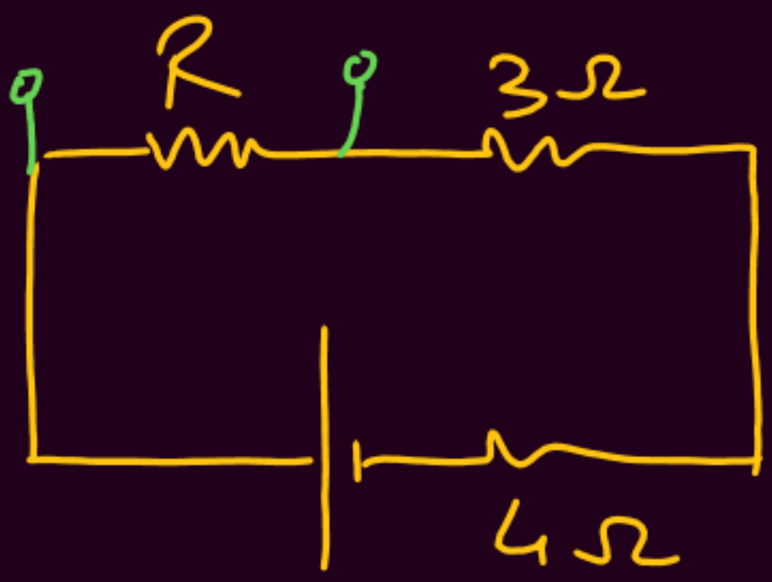


$R = ?$

To draw max Power through cell / R

$$\boxed{R = 4\Omega}$$

$$P = i^2 R$$

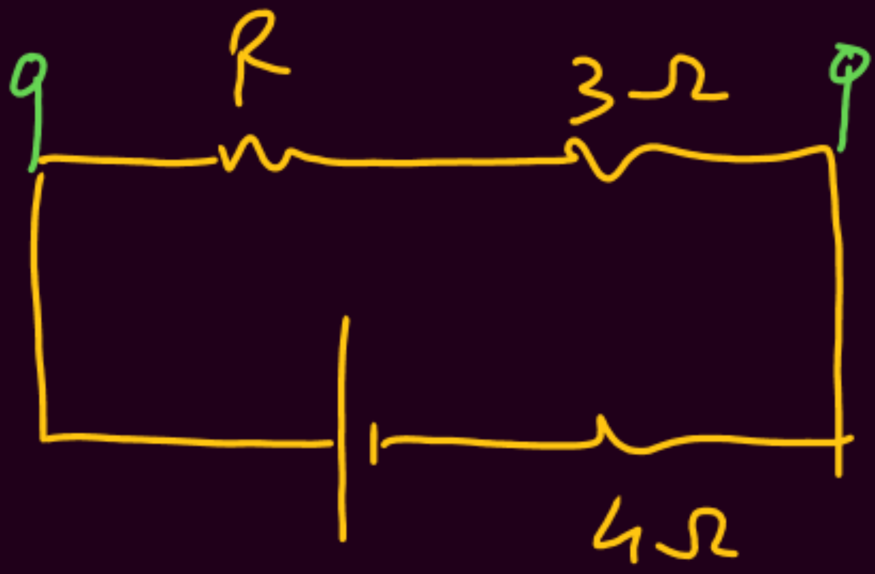


$R = ?$

To draw max Power through R

$$\boxed{R = 4 + 3 = 7\Omega}$$

$$P = i^2 R$$



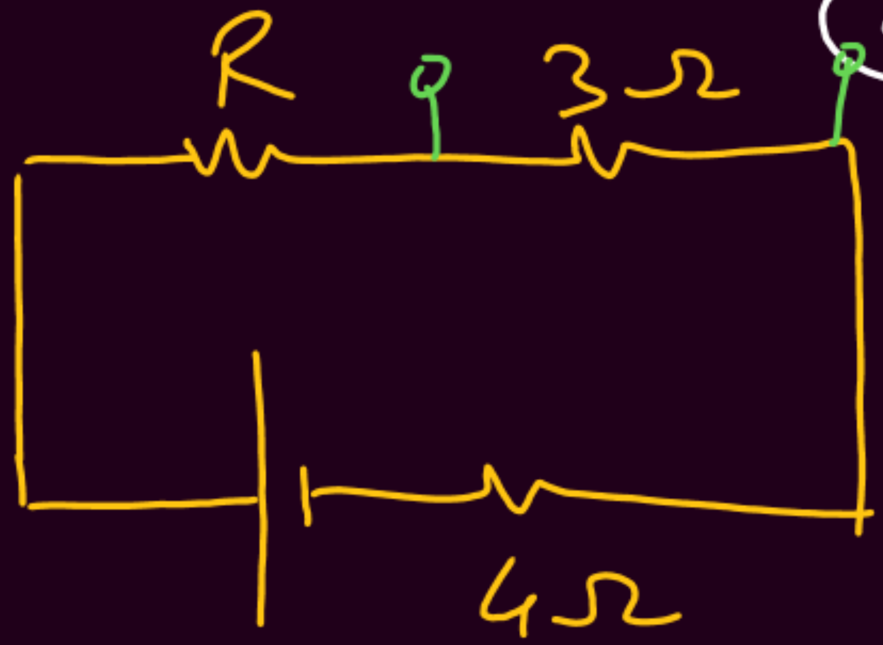
$R = ?$

To draw max Power through cell

$$R + 3 = 4$$

$$\boxed{R = 1\Omega}$$

$$P = i^2 (R+3)$$



$R = ?$

To draw max Power through '3Ω'

$$\boxed{R = 0}$$

$$P = i^2 (3)$$

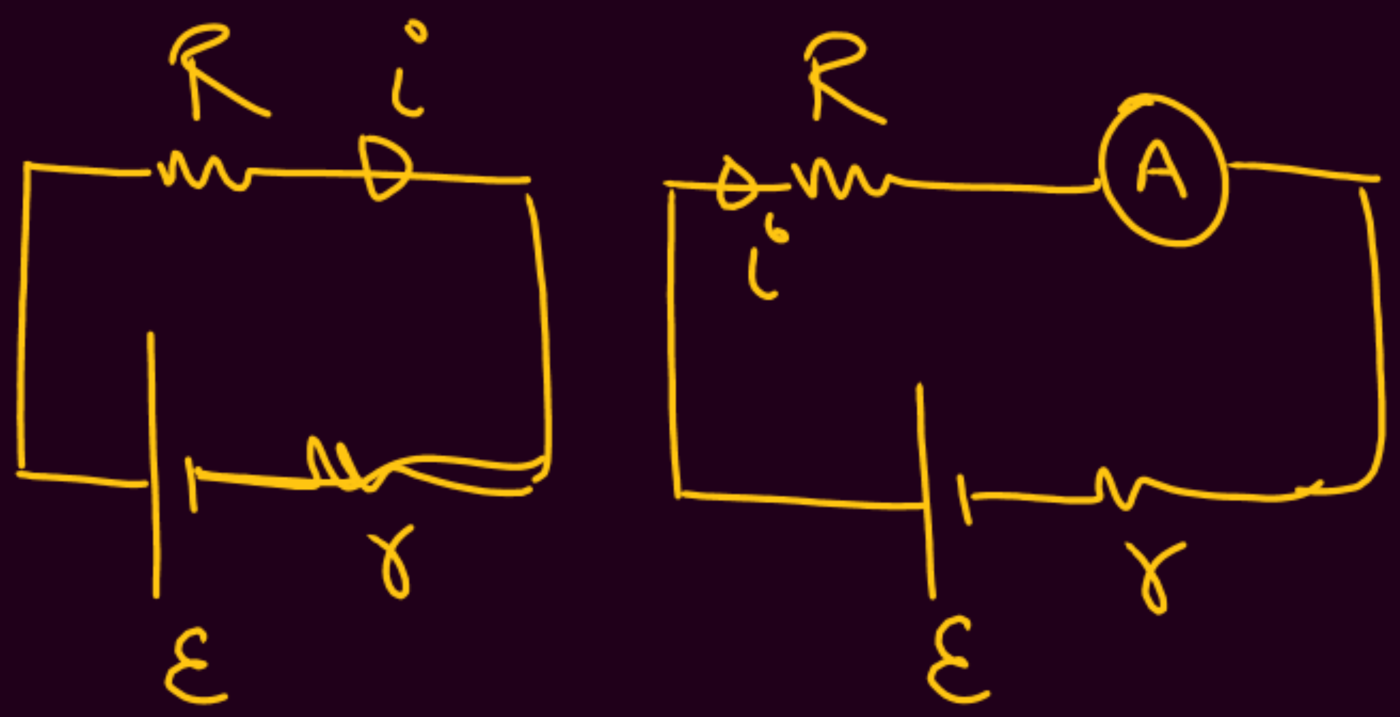
Measuring Devices

(A) Ammeter

→ it should be connected in Series

→ $i_{measured} < i_{true}$

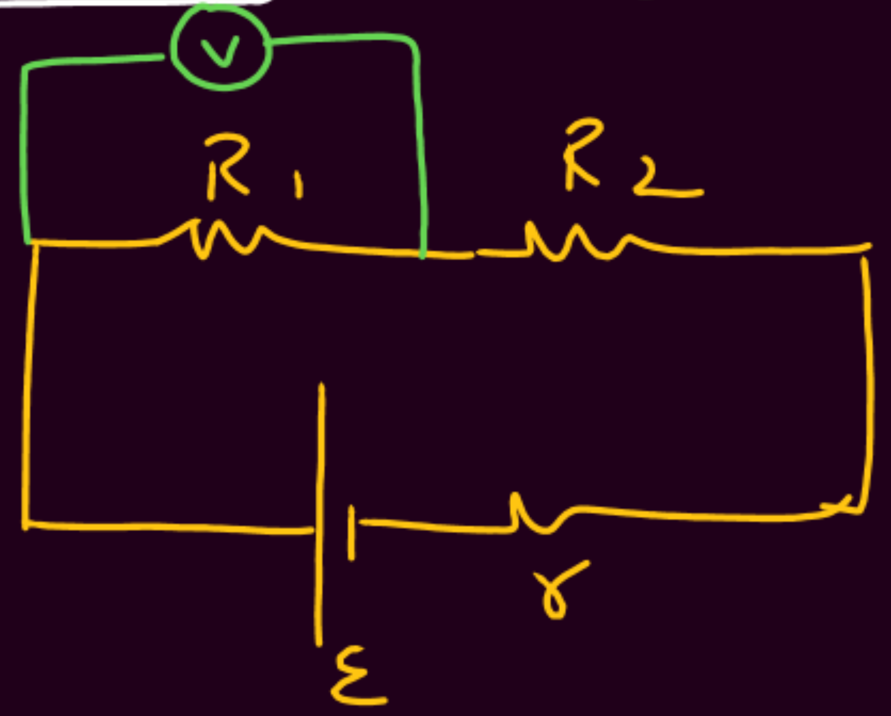
→ ideal $\boxed{R_A = 0}$



(V) Voltmeter

→ it should be conn. in parallel

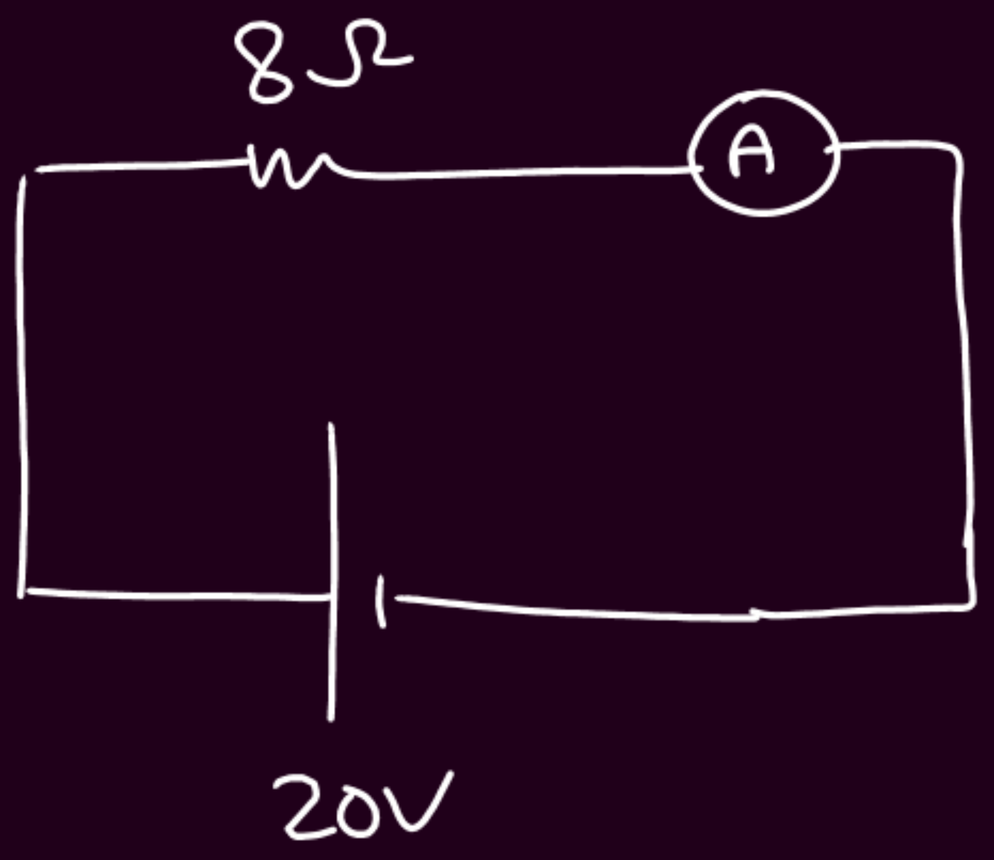
→ $V_{measured} < V_{true}$



→ ideal $\boxed{R_V \to \infty}$

↳ "Potentiometer"

Q

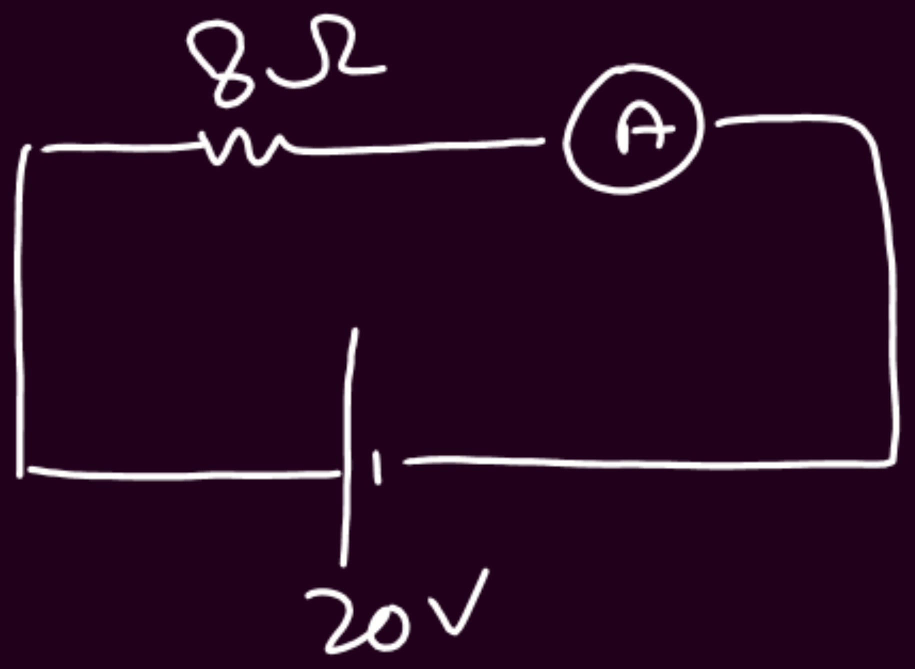


$(A) = ?$

Assume → ideal

$$(A) = \frac{20}{8} = 2.5\,A$$

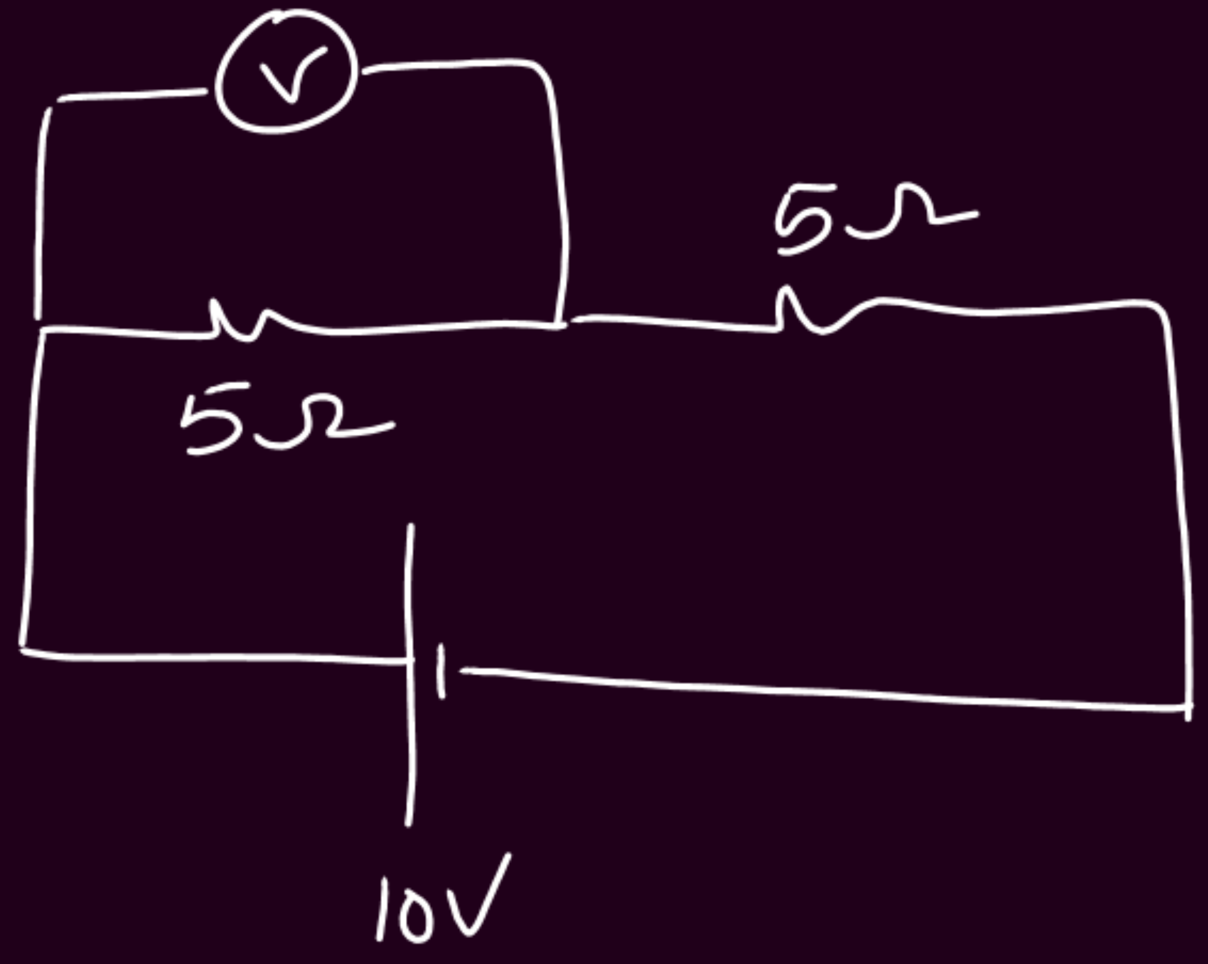
Q.



if $(A) = 1A = \dfrac{20}{8 + R_A}$

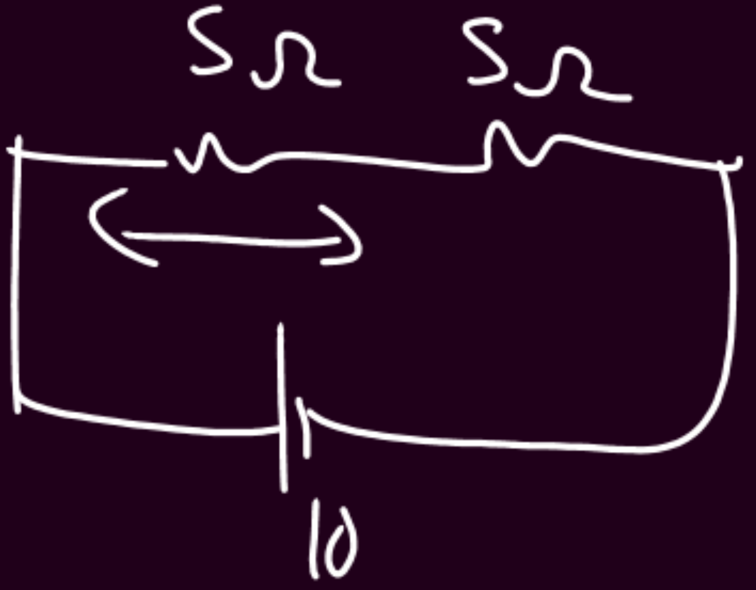
then $R_A = ?$ $\quad R_A = 12\,\Omega$

Q.



$V = ?$

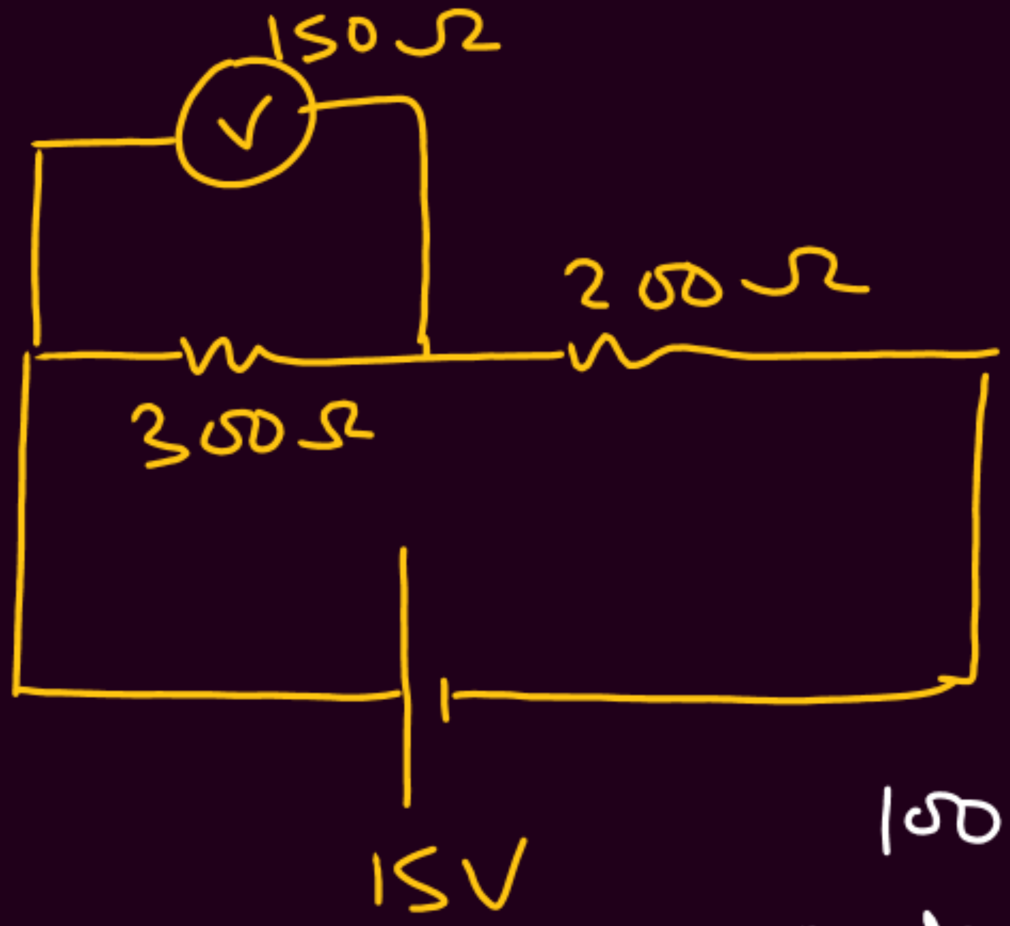
Assume - ideal



$i = 1A$

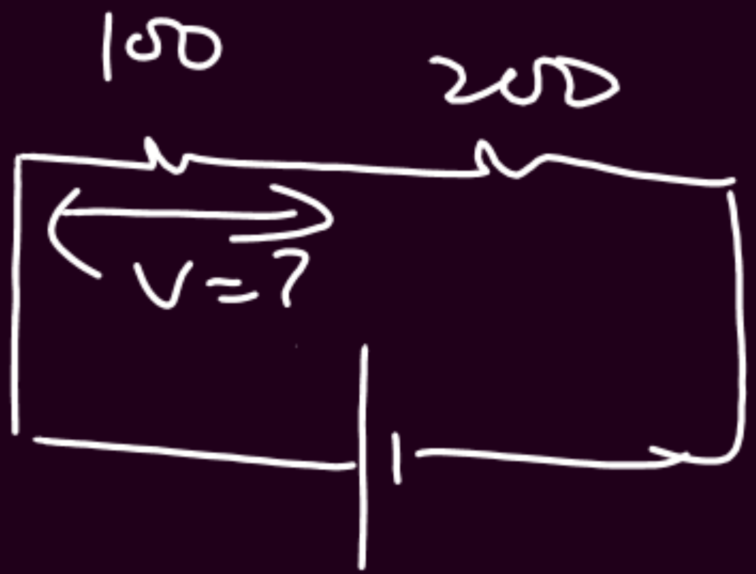
$V = (1)(5) = 5V$

Q.

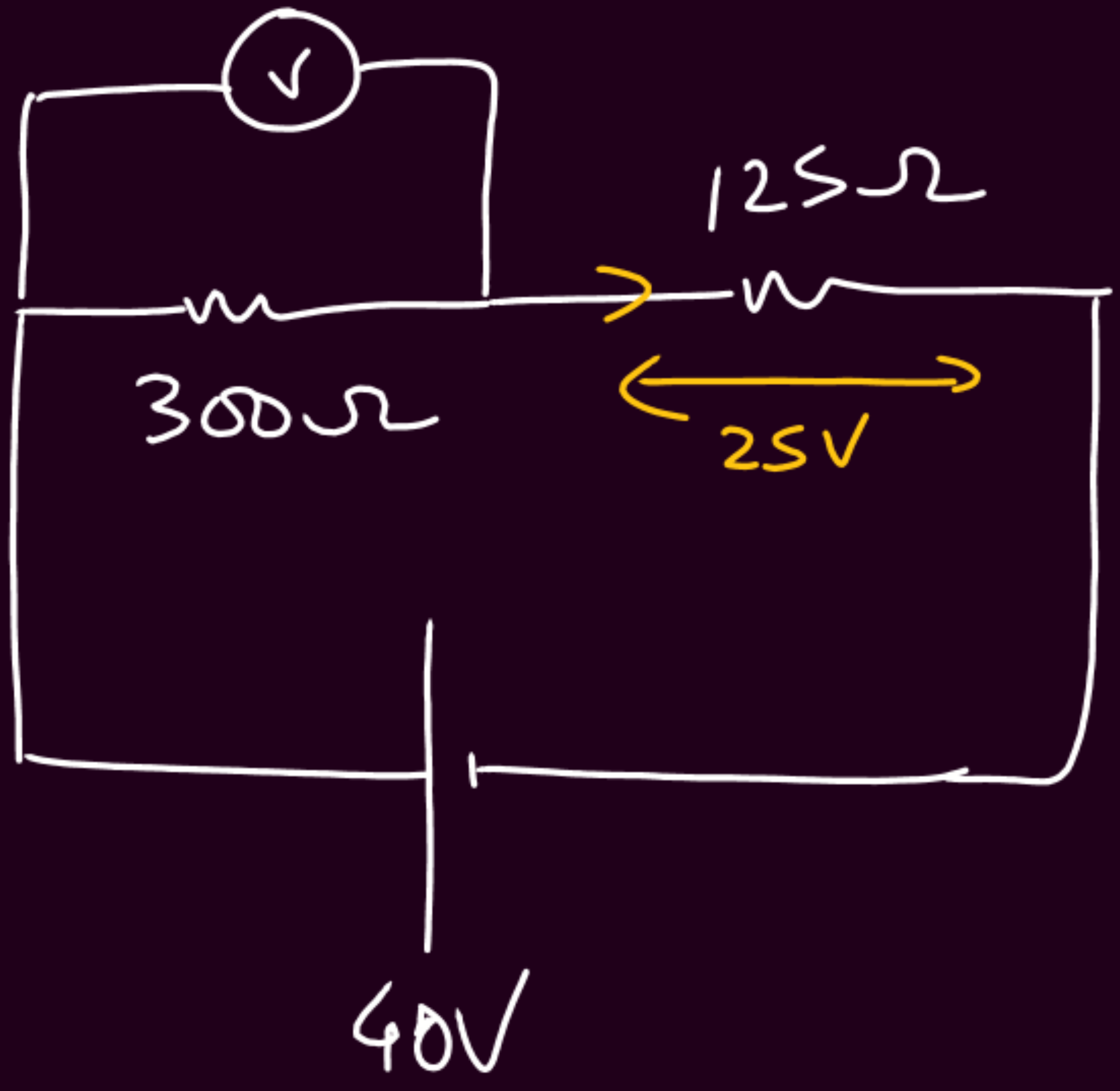


$R_{eq} = 300\ \Omega$

$i = \frac{15}{300}\ A$



$V = \left(\frac{15}{300}\right)100 = \underline{\underline{5V}}$



if $V = 15V$

$R_v = ?$

$$i = \frac{\cancel{25}}{\cancel{125}_{5}} A = \frac{40}{R_{eq}}$$

$$\boxed{R_{eq} = 200\Omega}$$

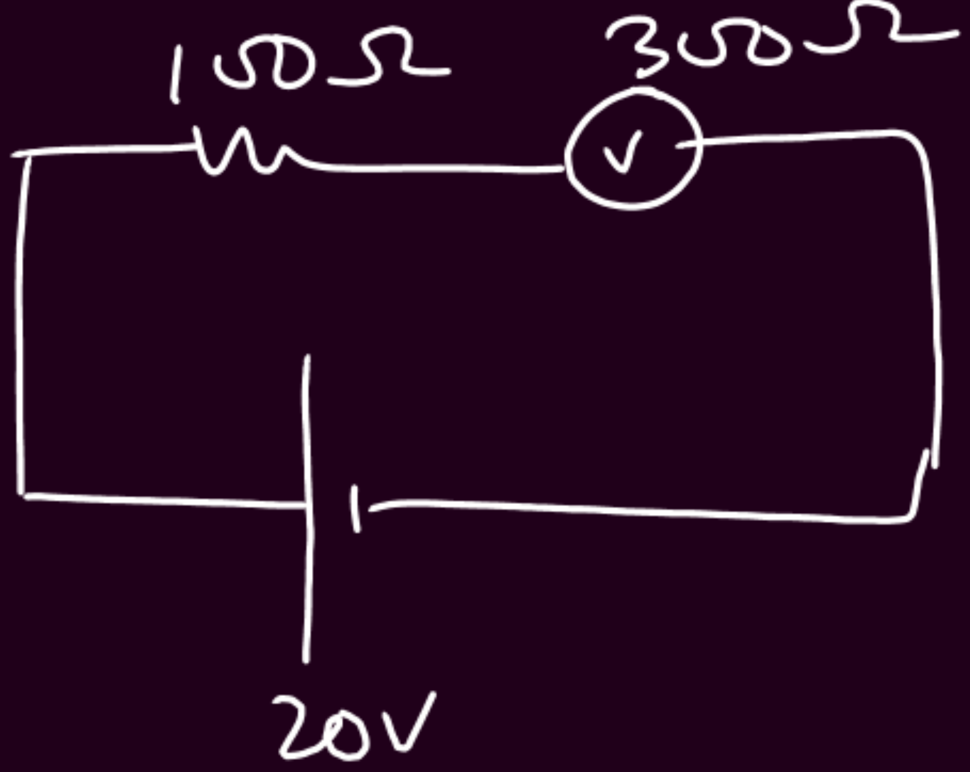
$$200 = 125 + \frac{300R}{300+R}$$

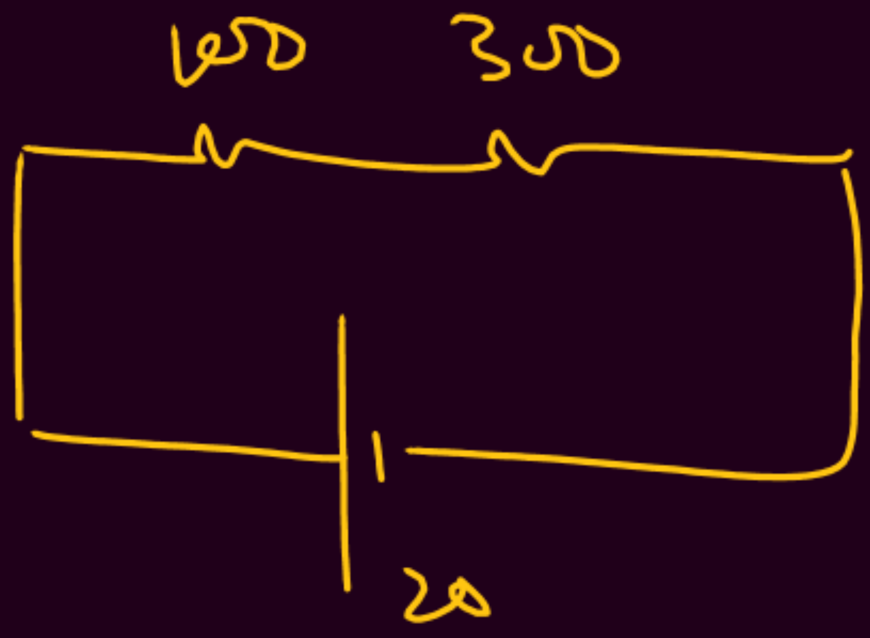
$$75 = \frac{300R}{300+R}$$

$$300 + R = 4R$$

$$300 = 3R$$

$$\boxed{R = 100\Omega}$$

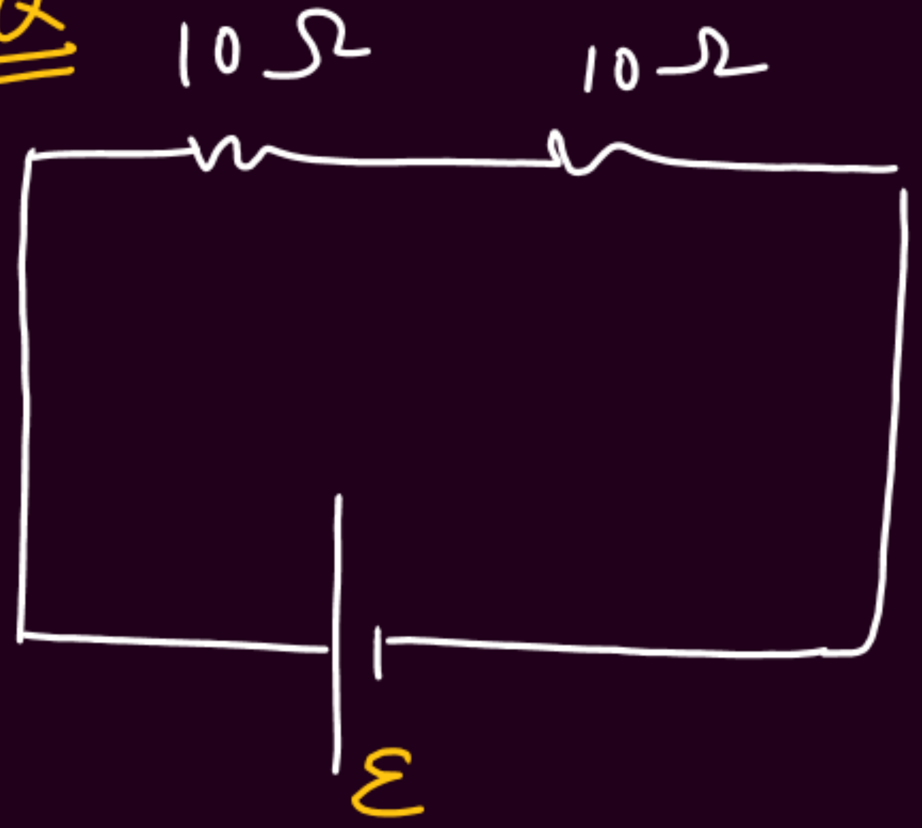


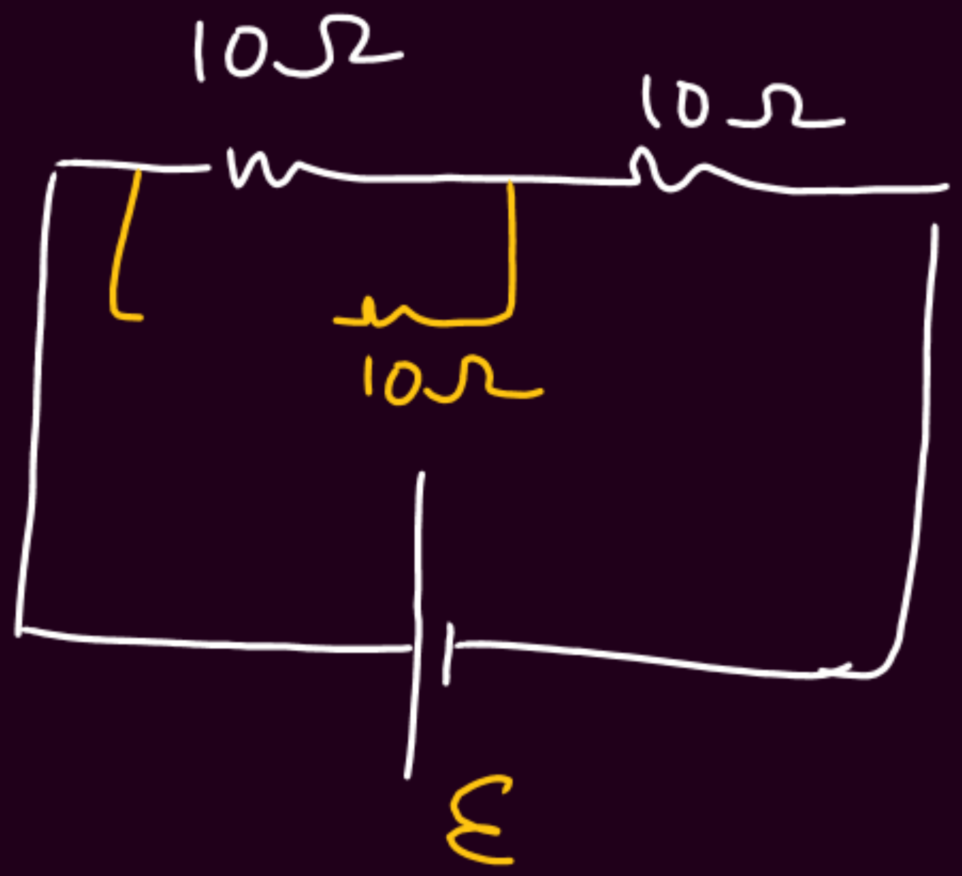


$$i = \frac{20}{400}$$

$$V = \frac{\overset{5}{\cancel{20}}}{\cancel{400}} \times 3\cancel{00} = 15V$$

PYQ





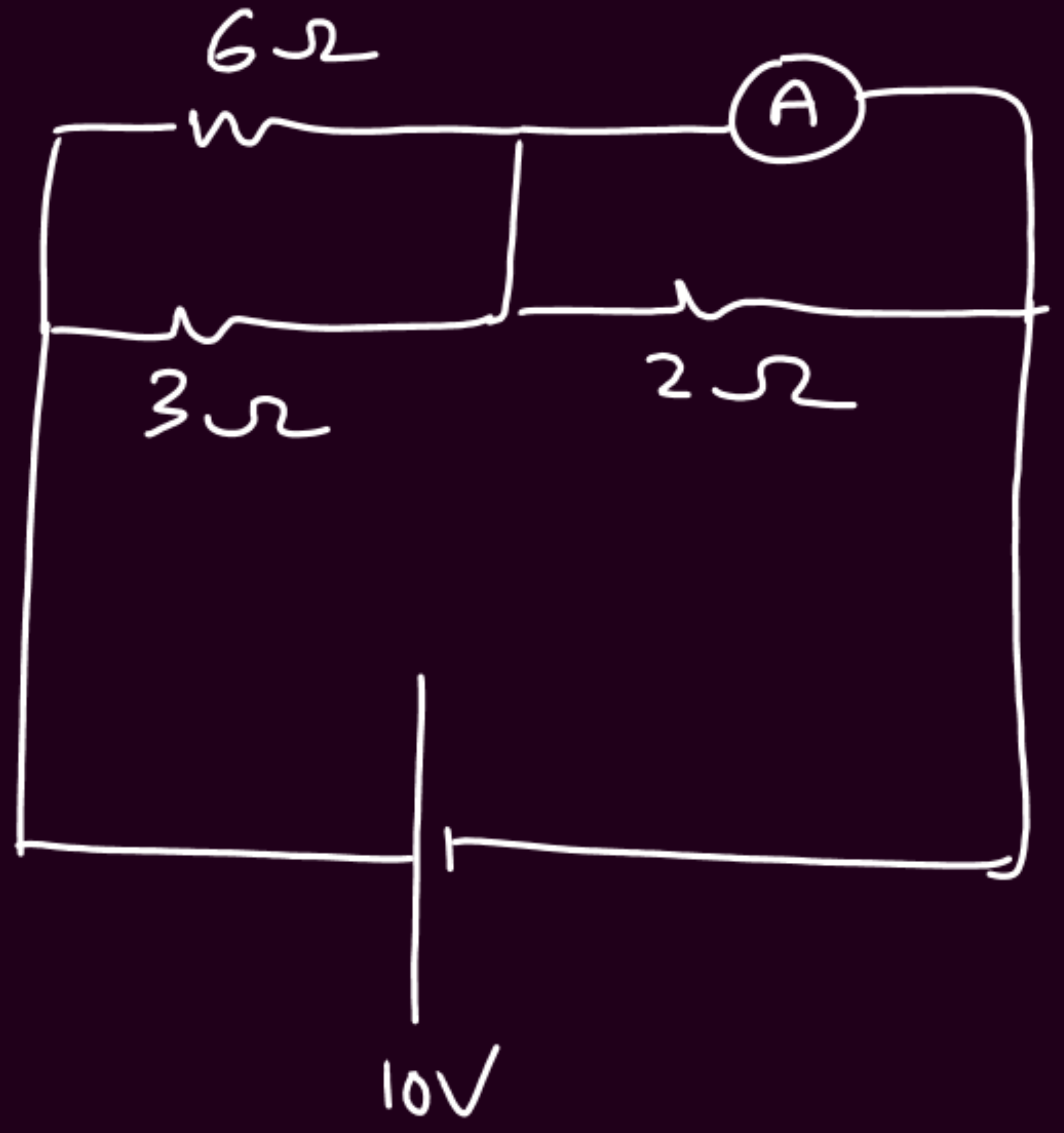
[given V_1 / V_2 are ideal]

1) $V_1 = V_2$

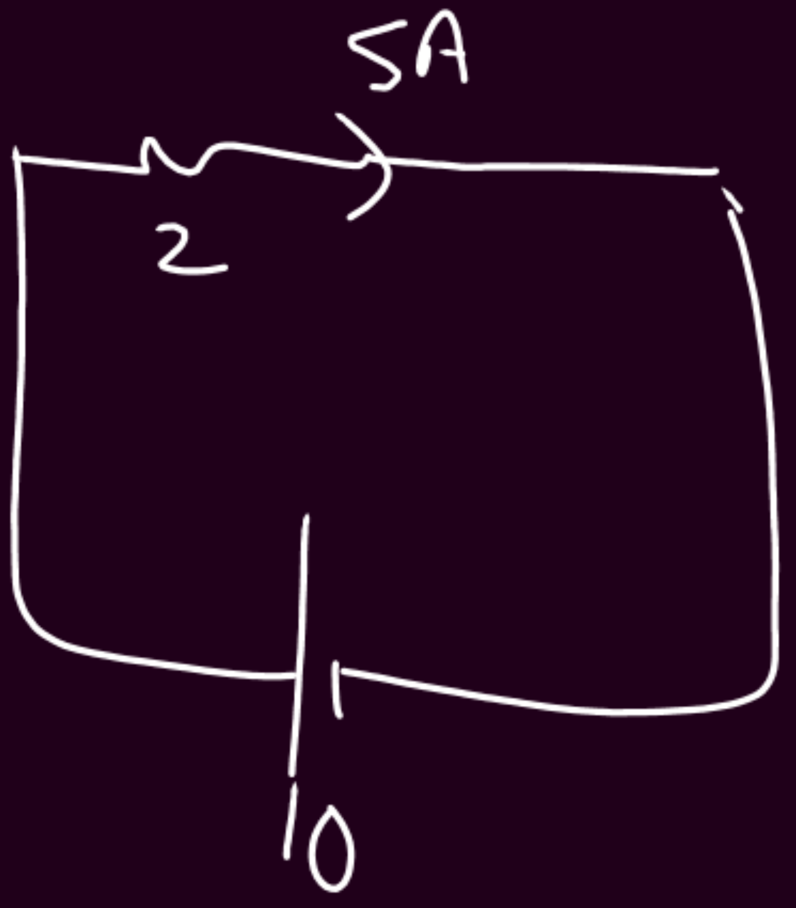
2) $V_1 < V_2$

3) $V_1 > V_2$

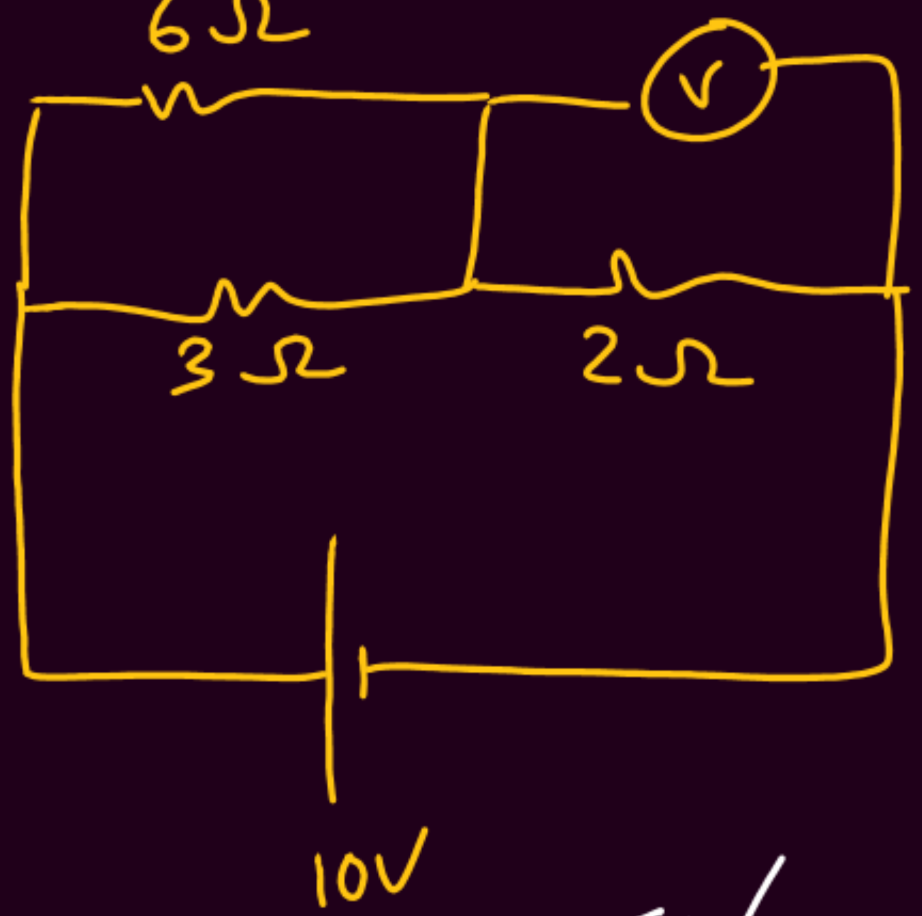
Q.



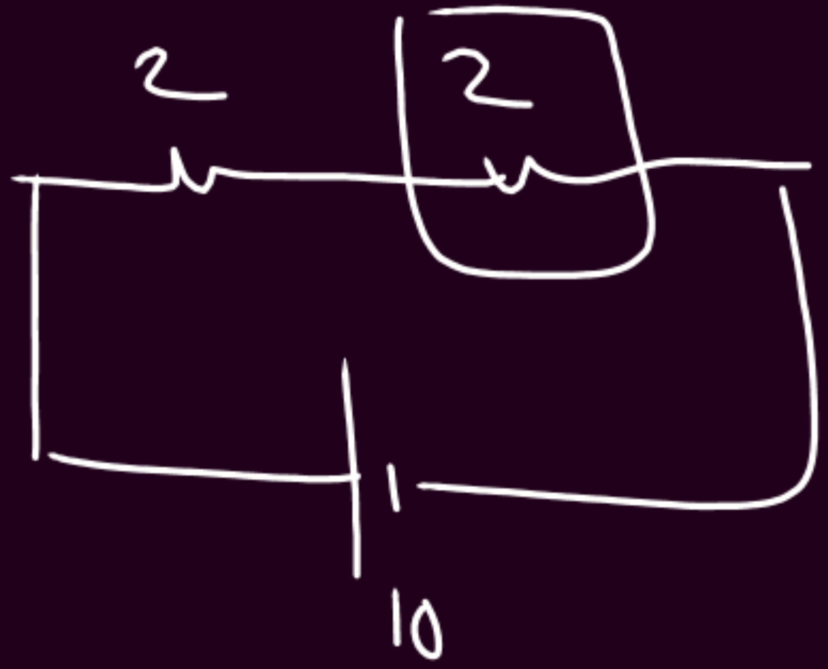
(A) = ?

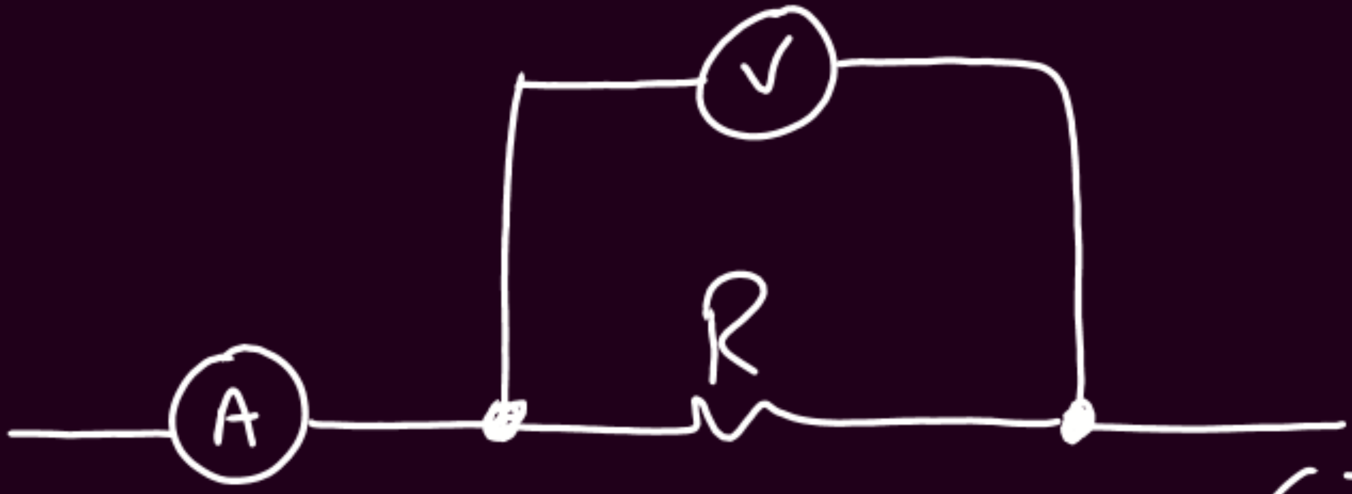


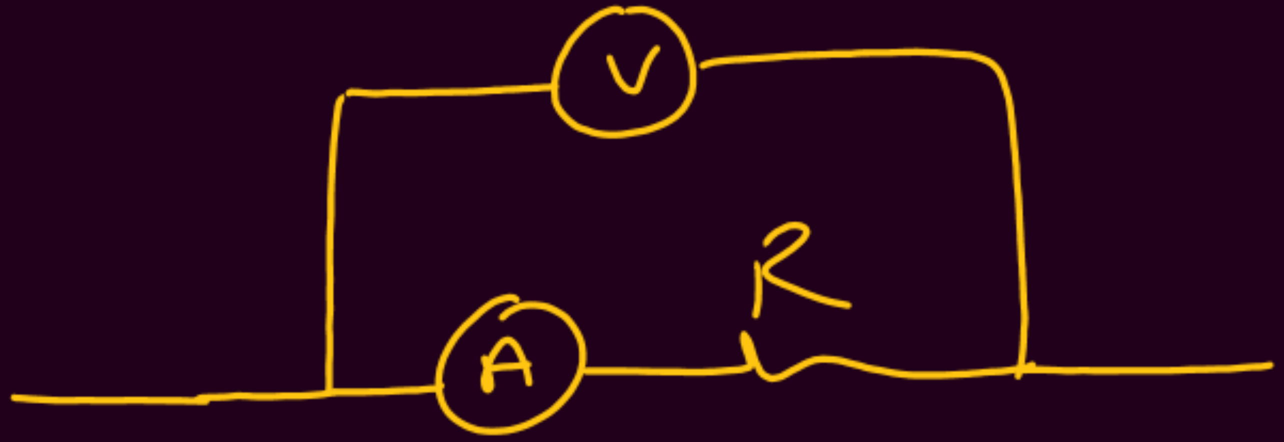
Q



5V ✓

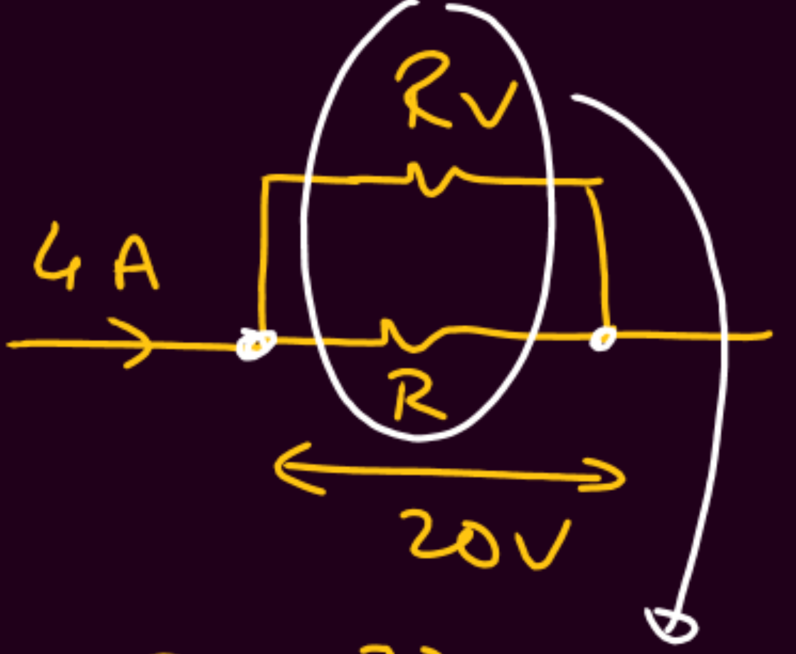






if $\text{V} = 20V$

$\text{A} = 4A$



$R_{eq} = \frac{20}{4} = 5\Omega$

Then

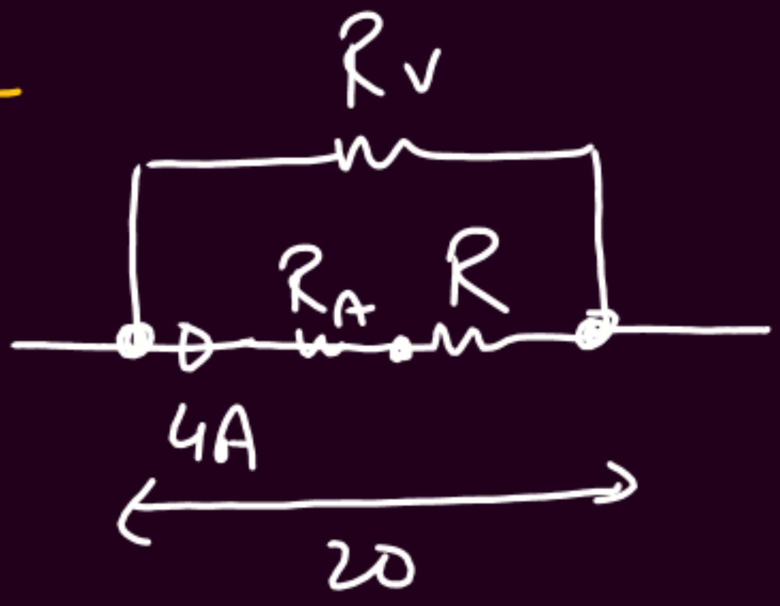
1) $R = 5\Omega$

2) $R > 5\Omega$

3) $R < 5\Omega$

if $\text{V} = 20V$

$\text{A} = 4A$



$\frac{20}{4} = 5 = R_A + R$

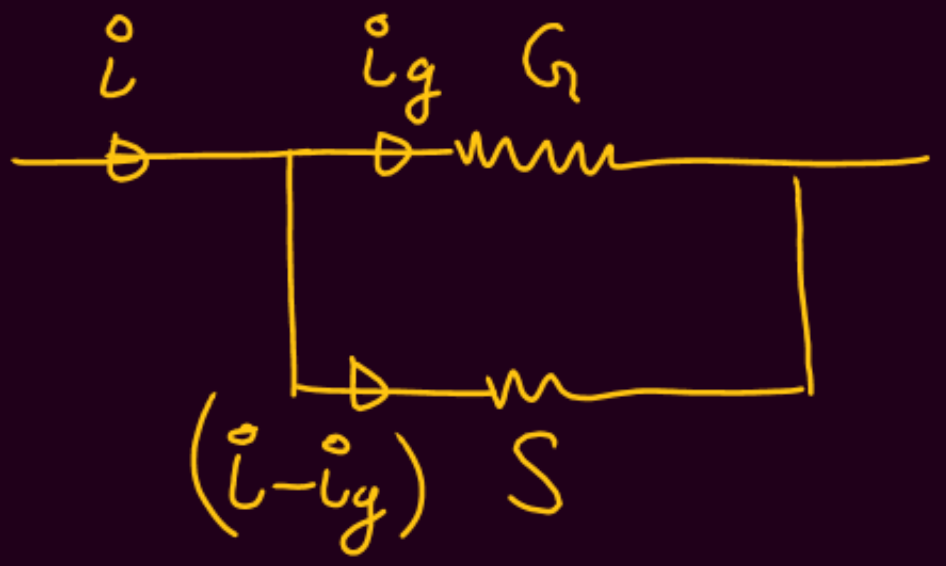
Then

1) $R = 5\Omega$

2) $R > 5\Omega$

3) $R < 5\Omega$

Conversion of G to A



Shunt = Resis in parallel

① Concept $\quad i_g G = (i - i_g) S$

② $n = \dfrac{\text{new rating}}{\text{old rating}} = \dfrac{i}{i_g}$

③ $\boxed{S = \dfrac{G}{n-1}}$

④ $R_A = \dfrac{GS}{G+S}$ $\quad \boxed{\approx S}$

Conversion of G into V

1. Concept $V_{new} = i_g (G + R_s)$

2. $n = \frac{\text{new rating}}{\text{old rating}} = \frac{V_{new}}{i_g G}$

3. $\boxed{R_s = (n-1)G}$

Q. G $(10\mu A, 200\,\Omega)$

A $1\,mA$

$S = ?$

$$n = \frac{1\times10^{-3}}{10\times10^{-6}} = 100$$

$$S = \frac{G}{n-1} = \frac{200}{100-1}$$

$$\boxed{S = \frac{200}{99}\,\Omega} \approx 2\,\Omega$$

Q. G $(1000\,\Omega, 10\,mA)$

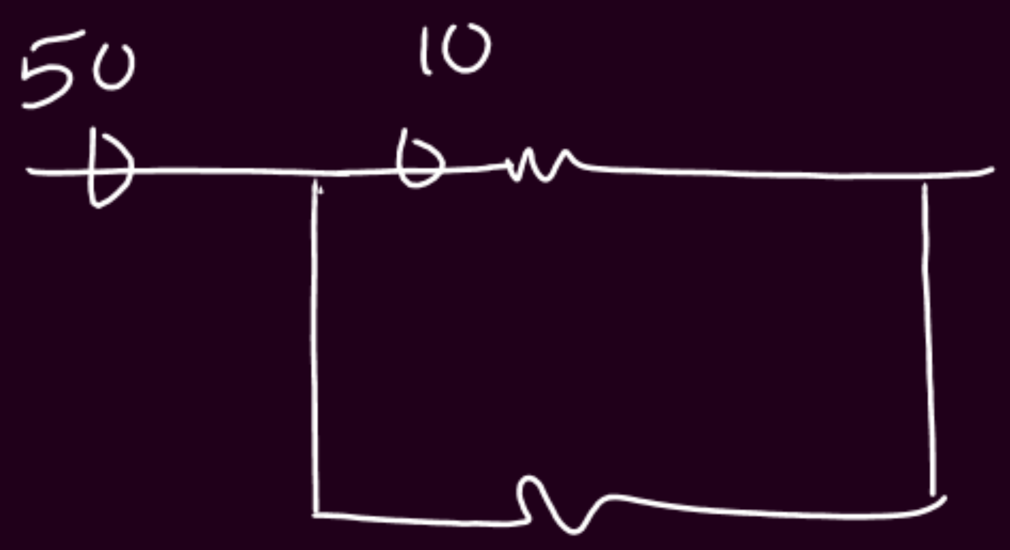
A $0.5\,A$

$$S = \frac{1000}{49} \approx 20\,\Omega$$

$$n = \frac{0.5}{10\times10^{-3}} = 50$$

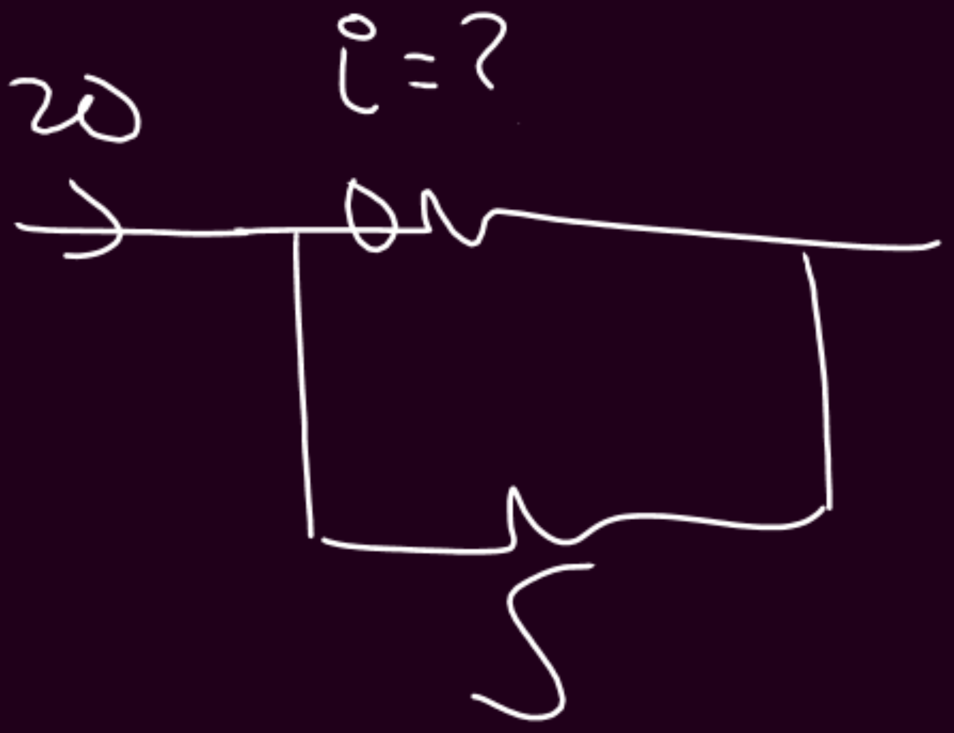
G $(200\,\Omega,\ 10\,mA)$

A $\underline{50\,mA}$



$$n = \frac{50}{10} = \frac{20}{i}$$

$$\boxed{i = 4\,mA}$$



$$i_s = 20 - 4 = \underline{16\,mA}$$

G $(200\,\Omega,\ 10\ \text{div/mA})$

A $(2\ \text{div/mA})$

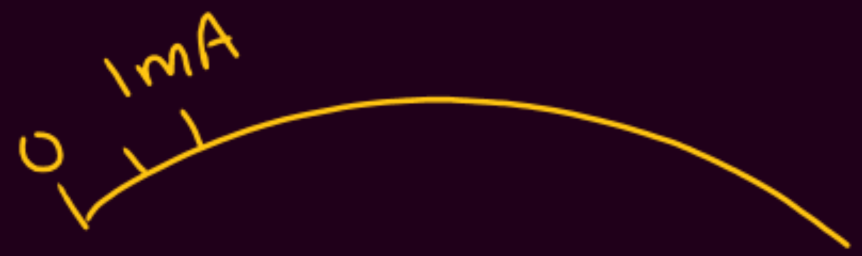
$$n = \frac{\left(\frac{1}{2}\right)}{\left(\frac{1}{10}\right)} = \frac{10}{2} = 5$$

$$\boxed{S = \frac{200}{5-1} = 50\,\Omega}$$

per div

$\frac{1}{10}$ mA/div

$\frac{1}{2}$ mA/div



Ⓖ $(200\,\Omega,\ 1\,mA)$

Ⓥ $2V$

$$n = \frac{2}{(10^{-3})(200)} = 10$$

$$R_s = (n-1)G$$

$$= (10-1)\,200$$

$$= \underline{\underline{1800\,\Omega}}$$

Ⓥ $(100\,k\Omega,\ 20V)$

Ⓐ $\boxed{1mA}$

$$n = \frac{10^{-3}}{\left(\frac{20}{100\times10^{3}}\right)} = 5$$

$$S = \frac{G}{n-1} = \frac{100k}{5-1}$$

$$\boxed{S = 25\,k\Omega}$$