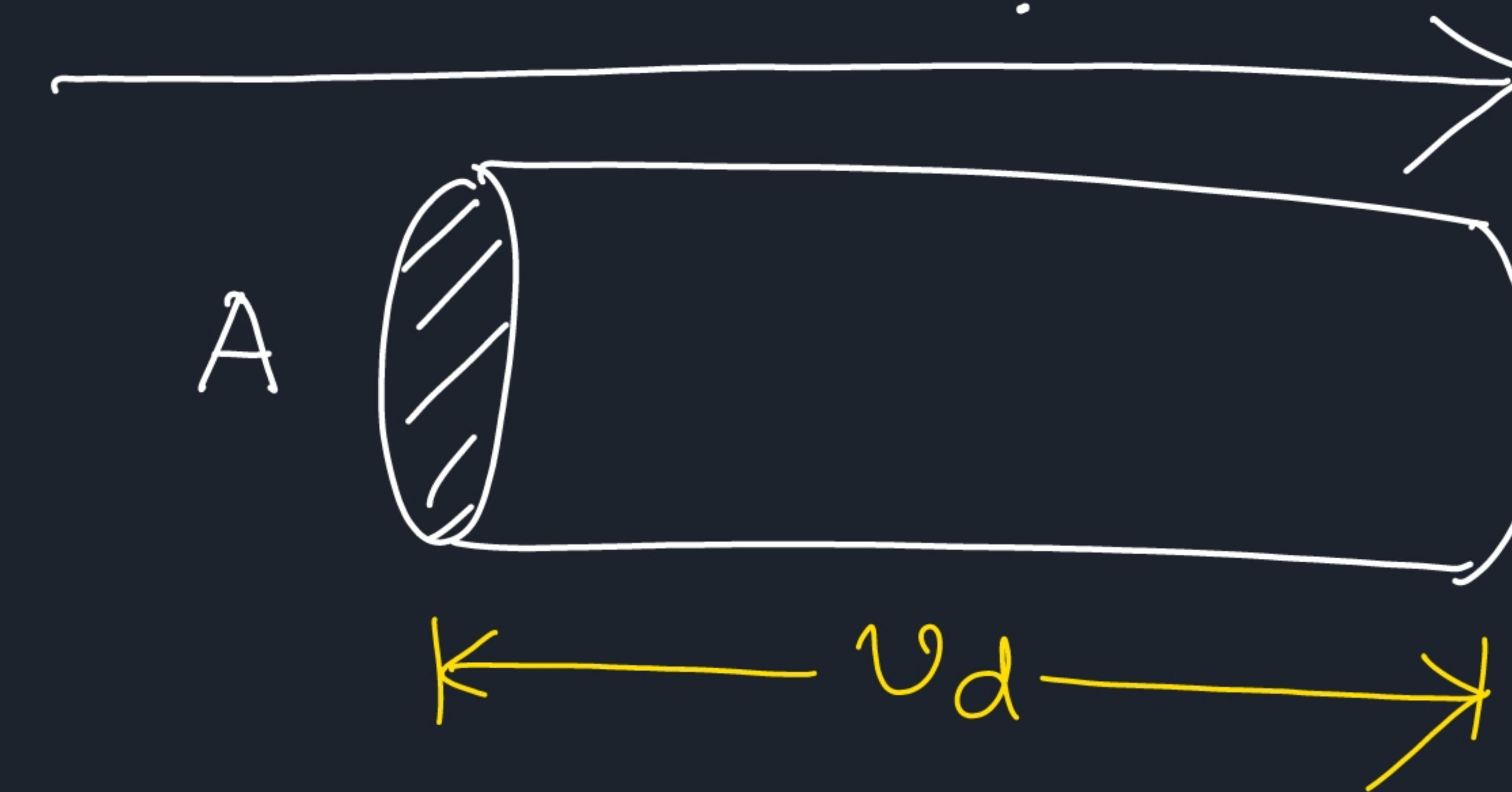




$$v_d = \frac{eE}{m_e} \tau$$

Relaxation Time



Random Motion + Organized Motion.

N_e

$\vec{J} = 6 \vec{E}$

\Rightarrow OHM'S law.

$$E = -\frac{dV}{dx}$$

$$\frac{I}{A} = 6 \frac{V}{l}$$

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

$$|E| = \left| \frac{V}{l} \right|$$

$$e N_e A v_d = Q = I$$

$$I = e N_e A \frac{e E}{m_e} \tau$$

$$\frac{I}{A} = \left\{ \frac{e^2 N_e \tau}{m_e} \right\} E = J$$

-

$$V = \frac{\int I}{A} \quad I = R V$$

$$V = R I$$

Problem:-

Cu wire

$$A = 4 \text{ mm}^2$$

$$\lambda = 4 \text{ m}$$

$$I = 10 \text{ A}$$

$$N_e = 8 \times 10^{28} \text{ m}^{-3}$$

$$V_d = ?$$

$$I = N_e e A V_d$$

$$V_d = \frac{I}{N_e e A}$$

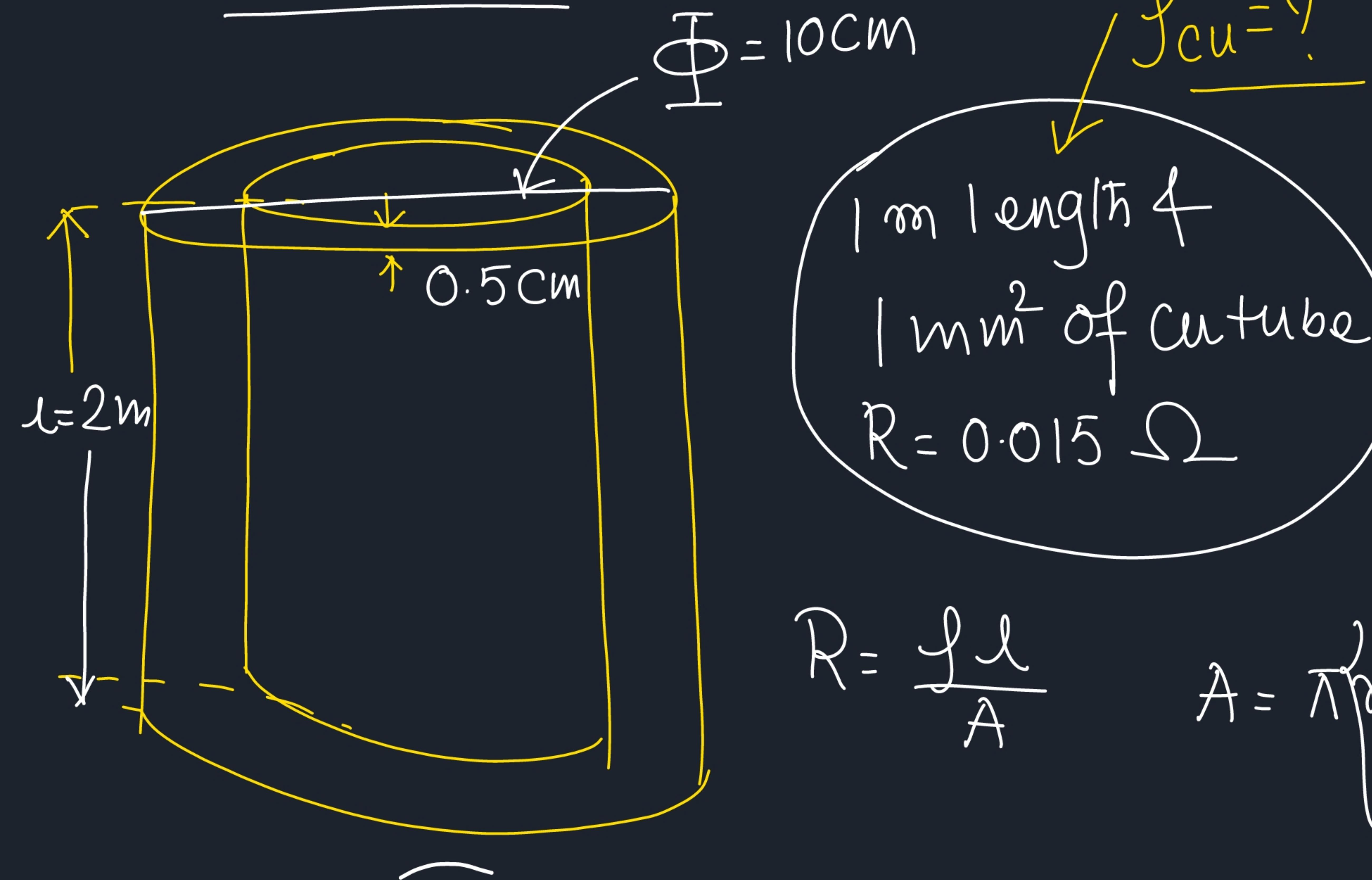
$$0.000195 \text{ V}$$

$$= \frac{10}{8 \times 10^{28} \times 1.602 \times 10^{-19} \times 4 \times 10^{-6}} \text{ m/sec.}$$
$$= 1.95 \times 10^{-4} \text{ m/sec.}$$

)

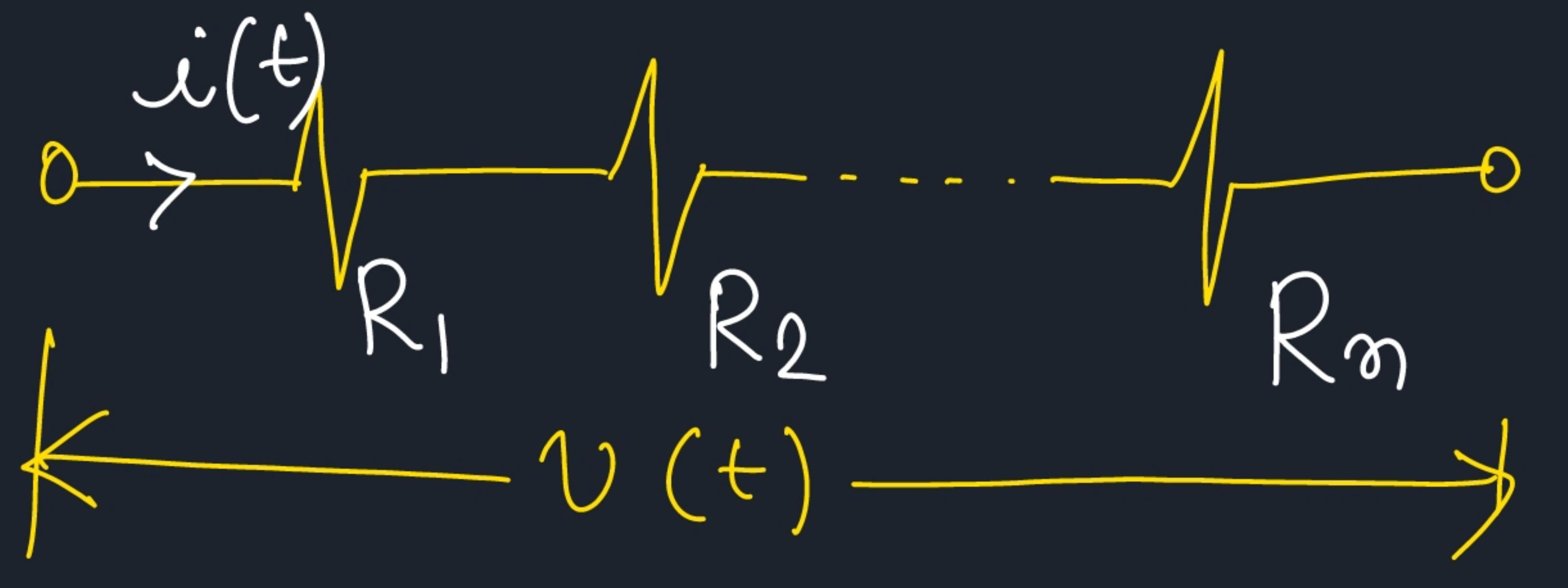


Problem:-



$$R = \frac{\rho l}{A}$$
$$\rho = \frac{RA}{l}$$
$$= \frac{0.015 \times 1 \times 10^{-6}}{1}$$

$$R = \frac{\rho l}{A}$$
$$A = \pi \left(R_{ext}^2 - R_{int}^2 \right) = ?$$
$$= 20.1038 \times 10^{-6} \Omega$$



$$\begin{aligned}
 V(t) &= V_1(t) + V_2(t) + \dots + V_n(t) \\
 &= i(t) R_1 + i(t) R_2 + \dots + i(t) R_n \\
 &= \left(\sum_{j=1}^n R_j \right) i(t)
 \end{aligned}$$

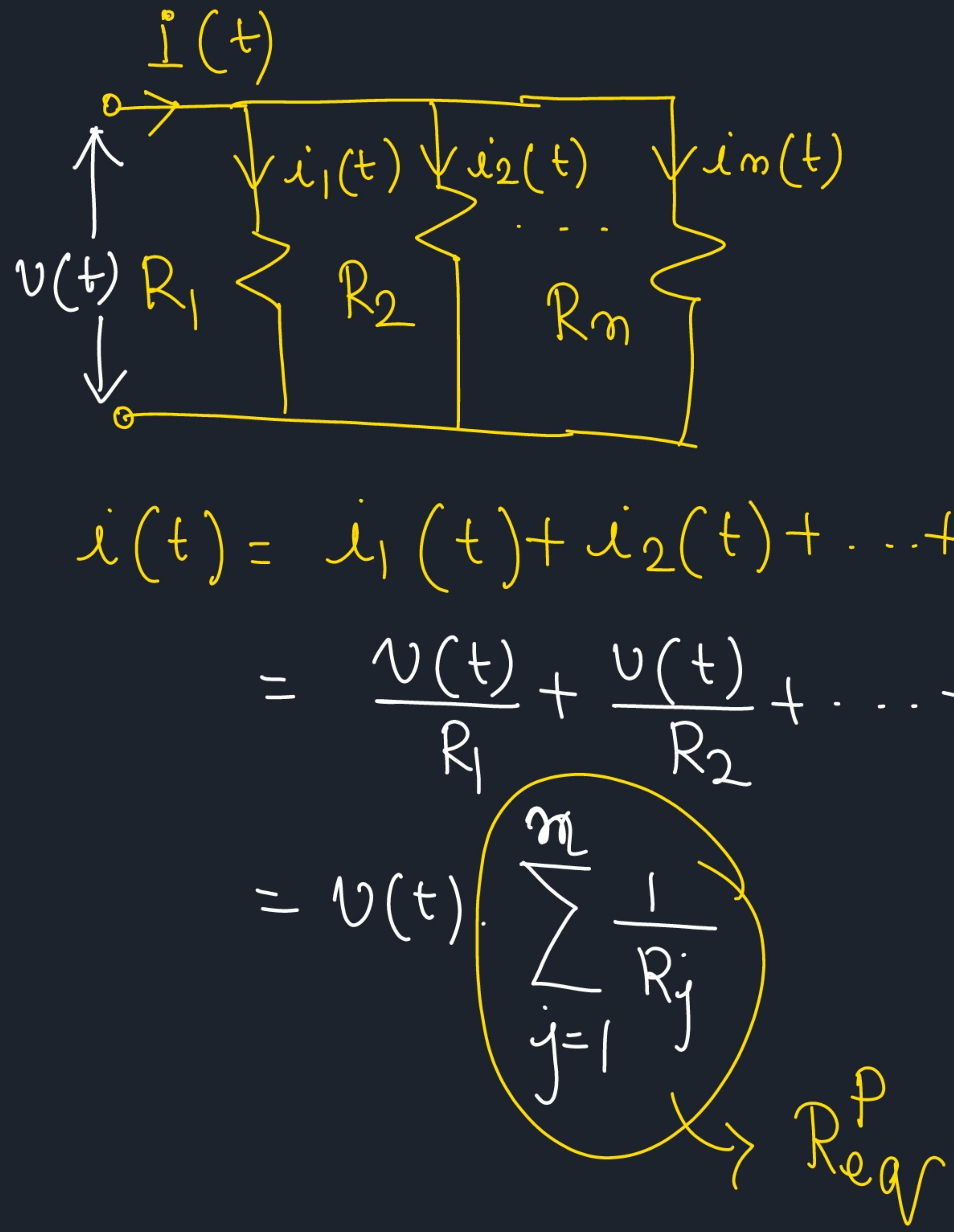
$\Rightarrow R_{\text{Req}}$

$$\begin{aligned}
 V_1(t) : V_2(t) : \dots : V_n(t) \\
 = R_1 : R_2 : \dots : R_n
 \end{aligned}$$

$$V_m(t) = \frac{R_m}{\sum_{j=1}^n R_j} V(t) \quad \checkmark$$

$$\begin{aligned}
 P_1(t) : P_2(t) : \dots : P_n(t) \\
 = R_1 : R_2 : \dots : R_n
 \end{aligned}$$

$$P_m(t) = \frac{R_m}{\sum_{j=1}^n R_j} P(t)$$

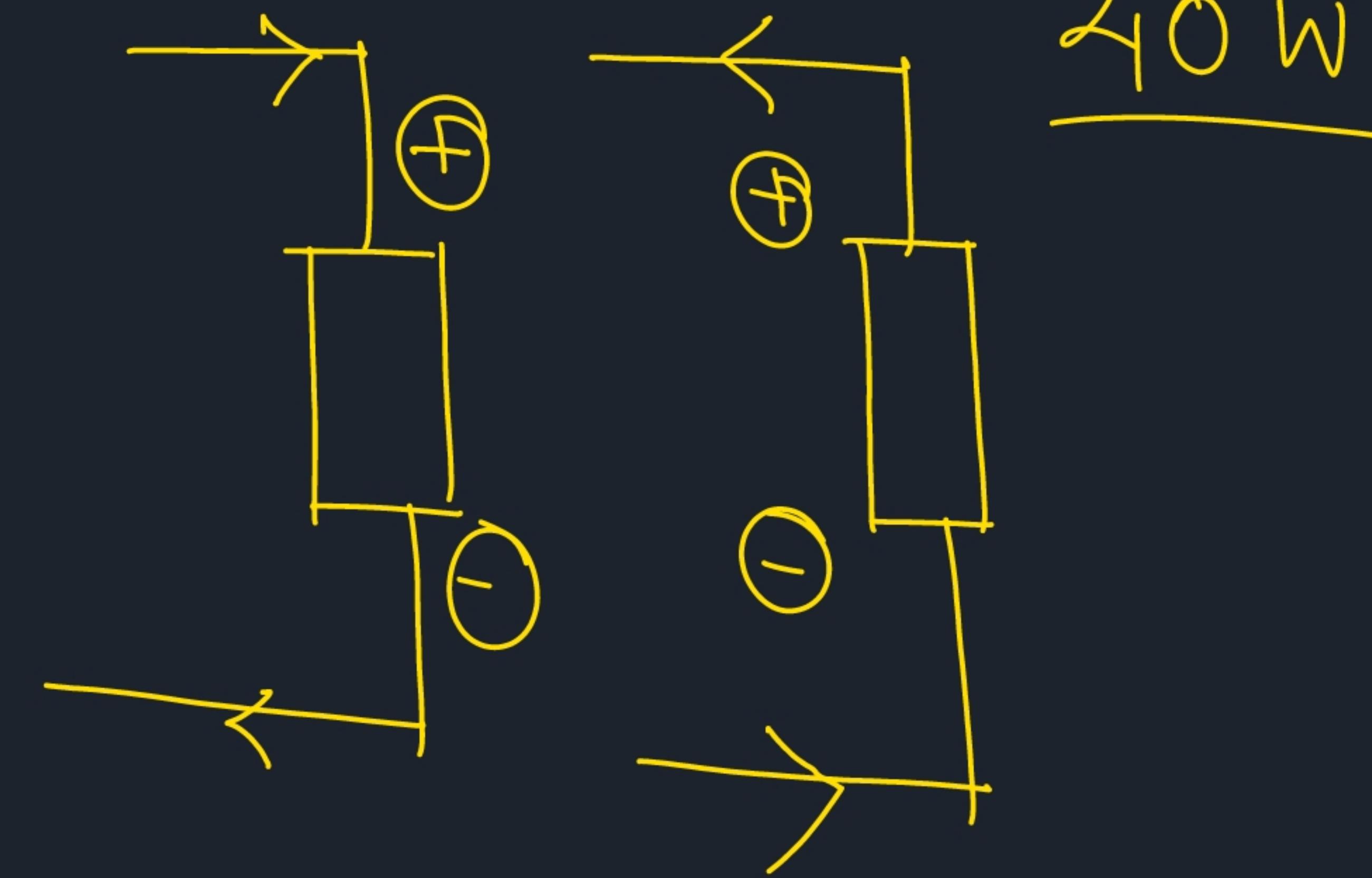
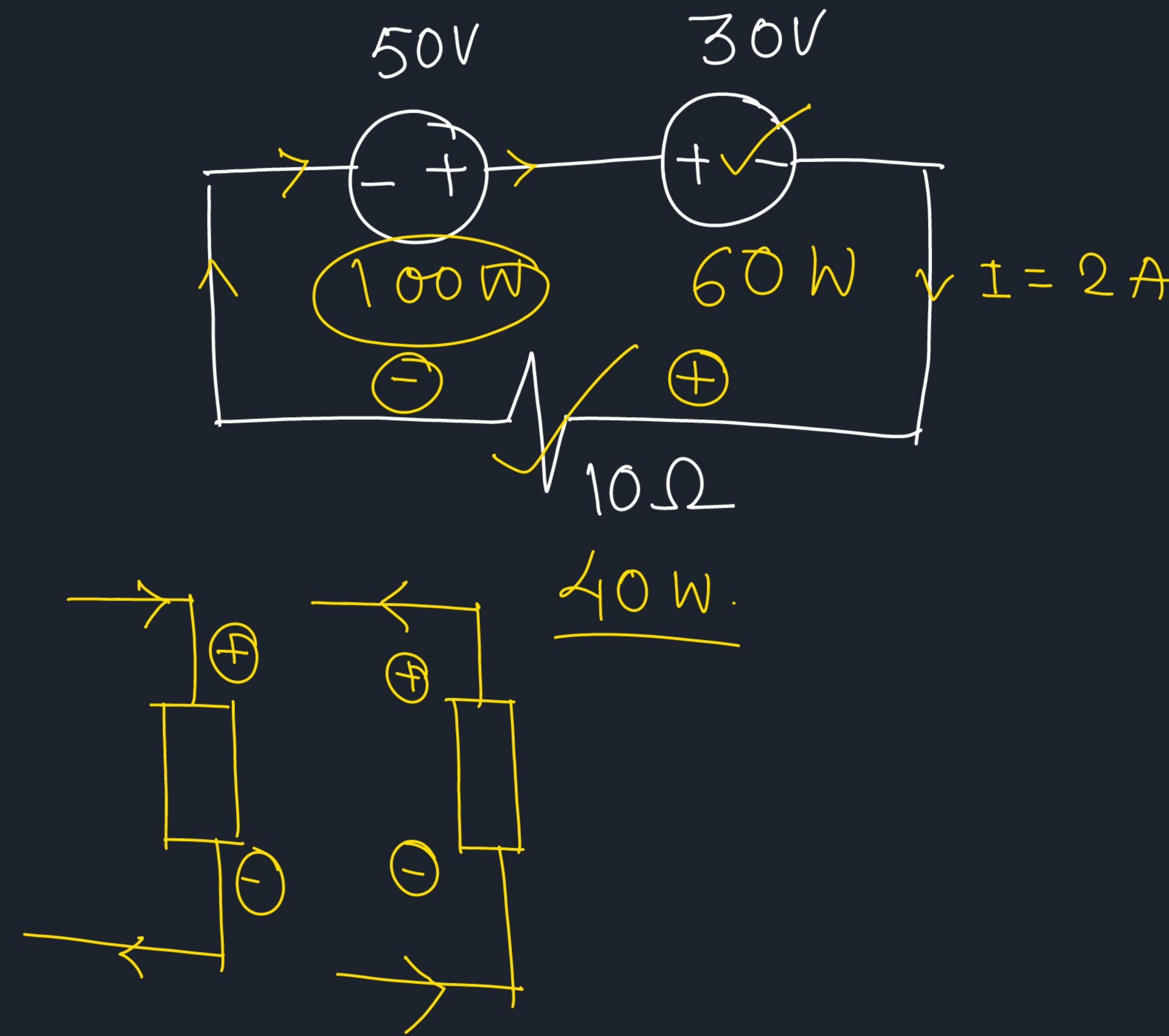
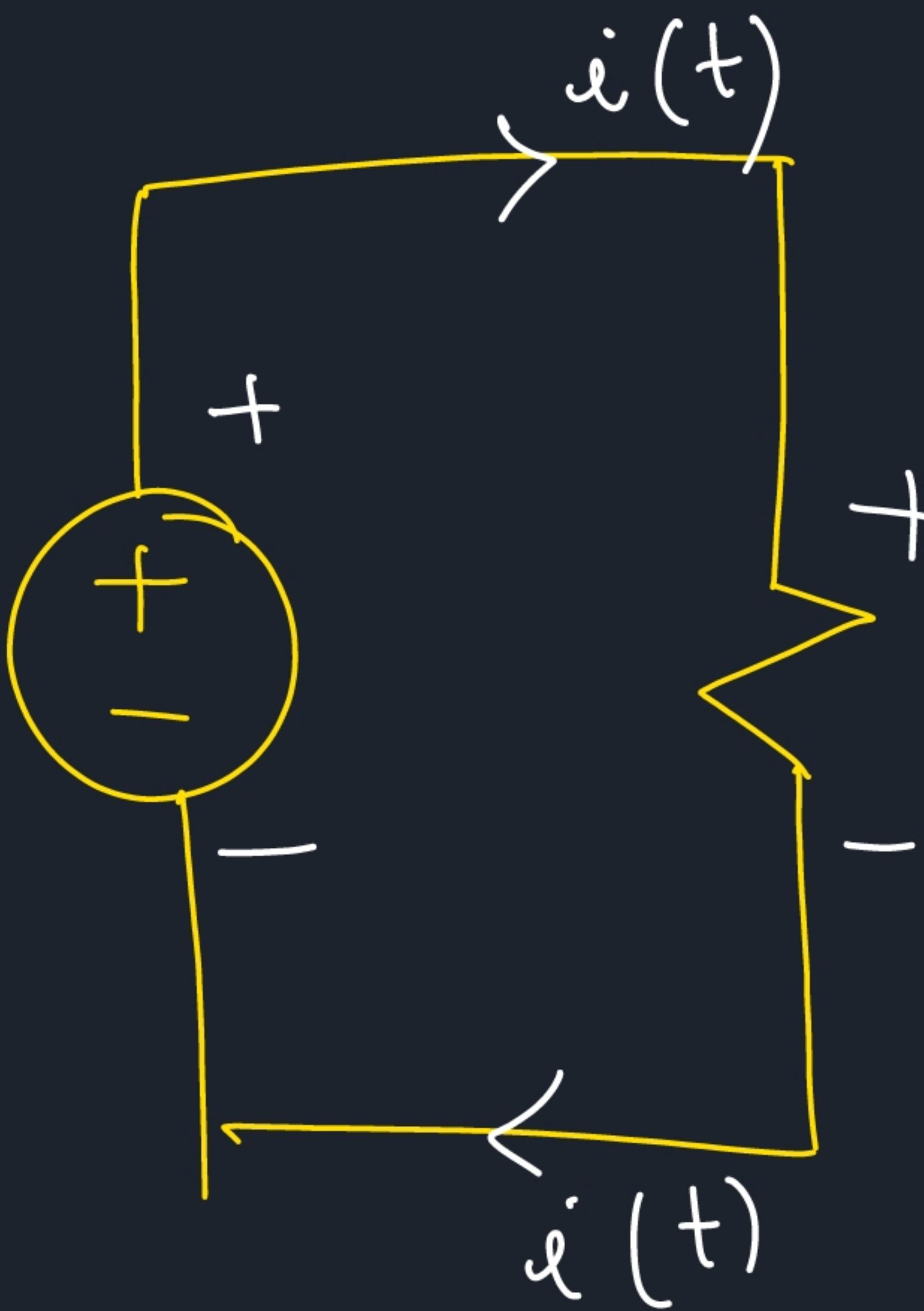
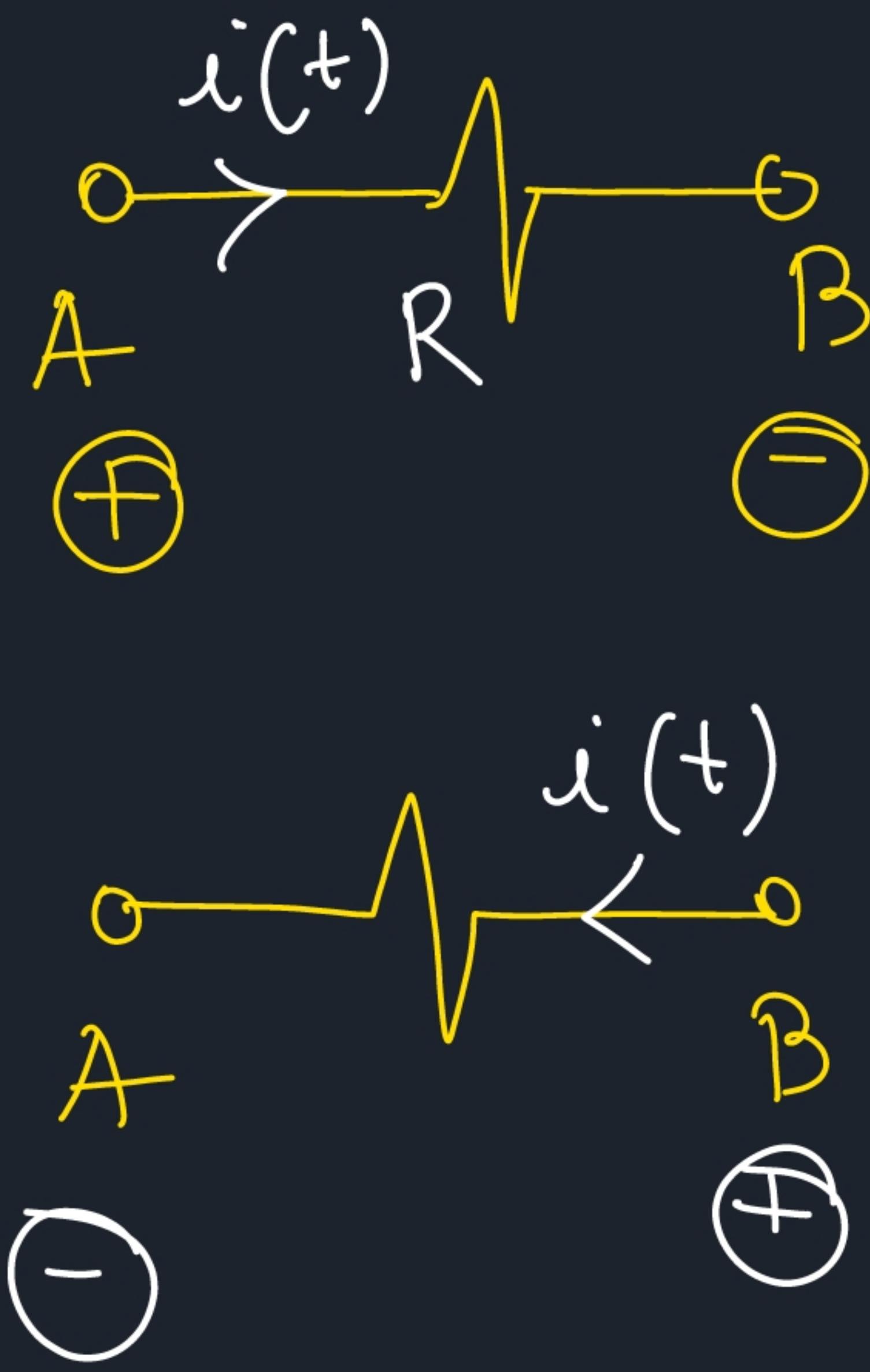


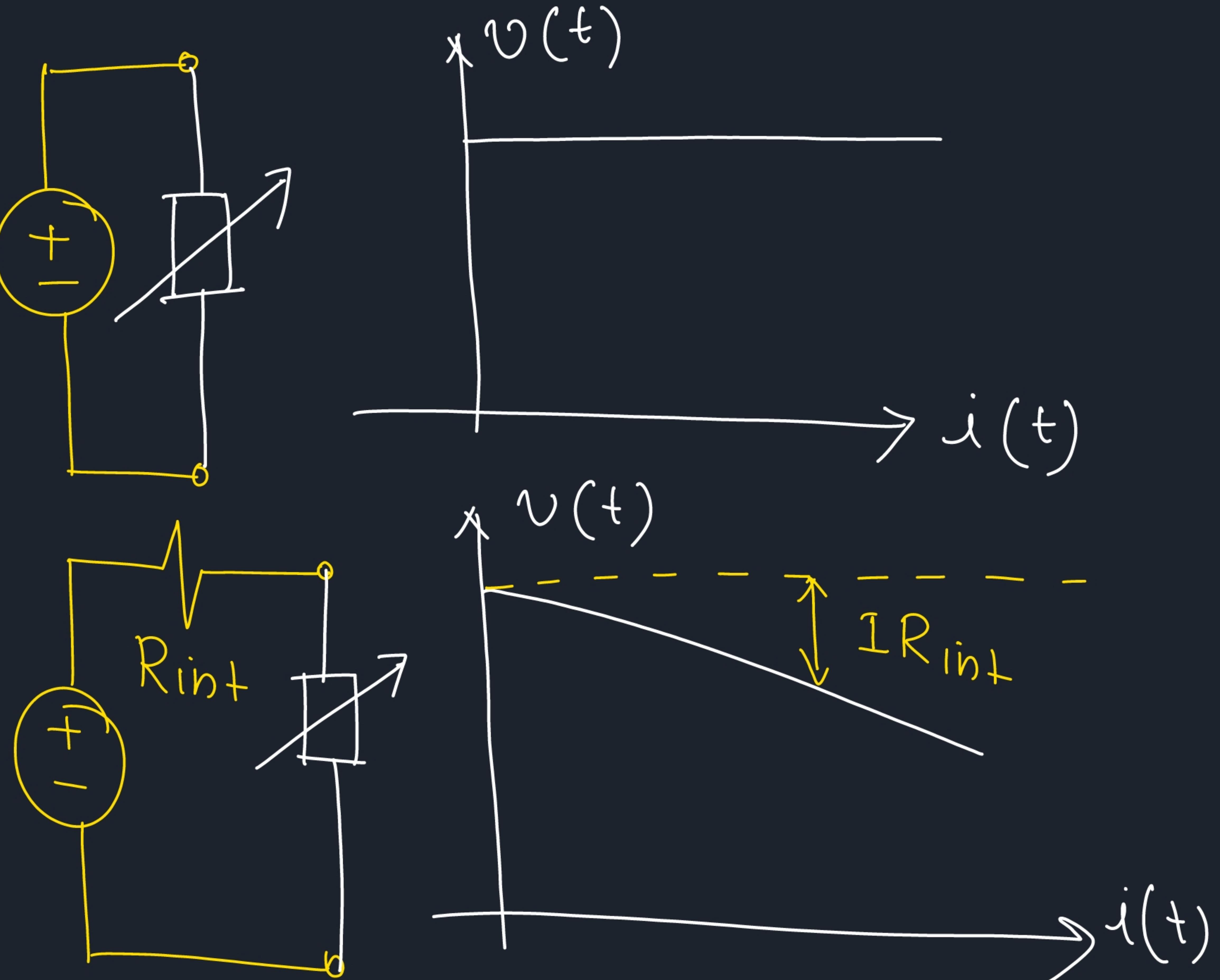
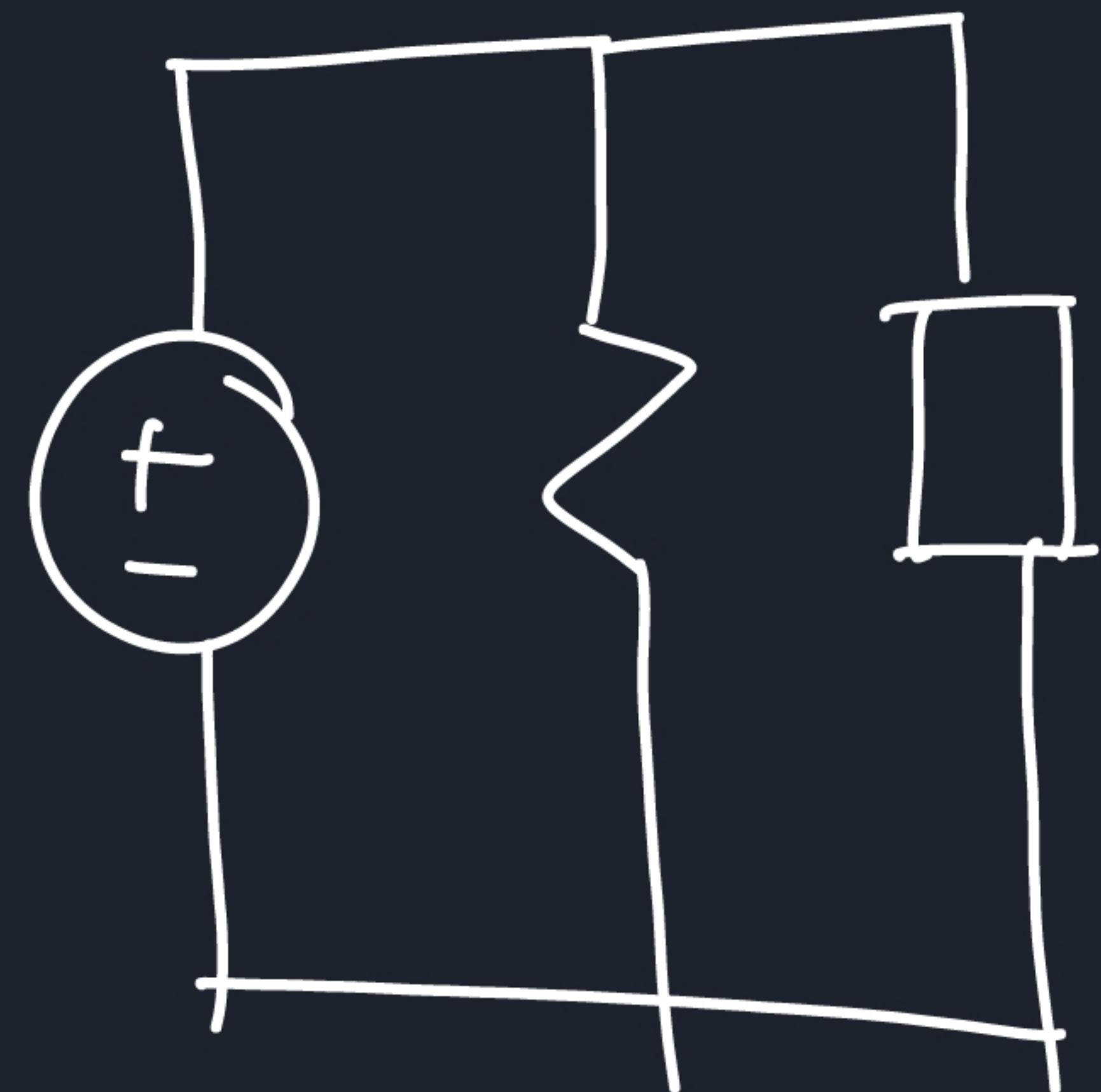
$$i_1(t) : i_2(t) \dots : i_n(t) = G_1 : G_2 \dots : G_n$$

$$i_m(t) = \frac{G_m}{\sum_{j=1}^n G_j} i(t)$$

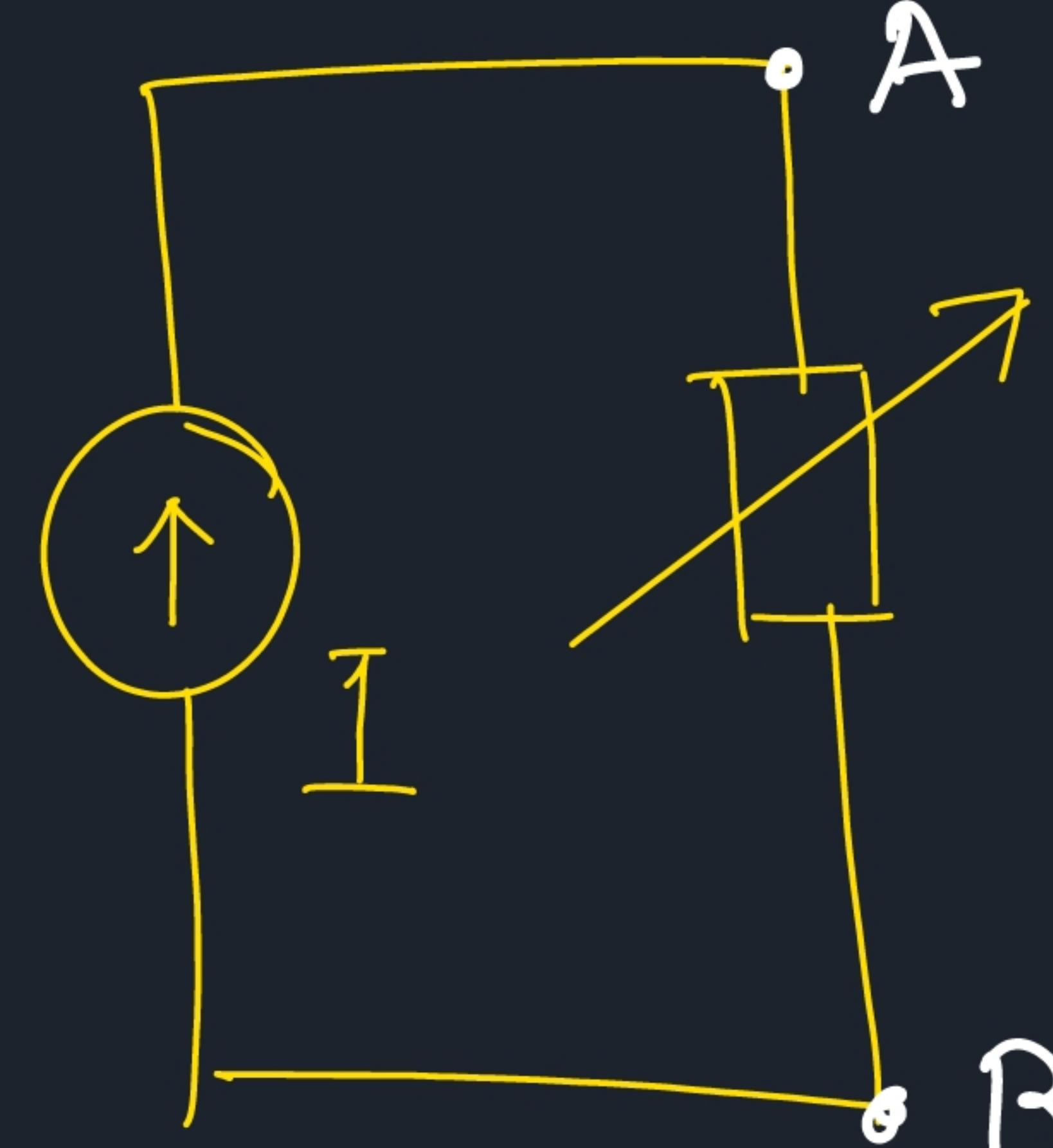
$$p_1(t) : p_2(t) \dots : p_n(t) = G_1 : G_2 \dots : G_n$$

$$p_m(t) = \frac{G_m}{\sum_{j=1}^n G_j} p(t)$$

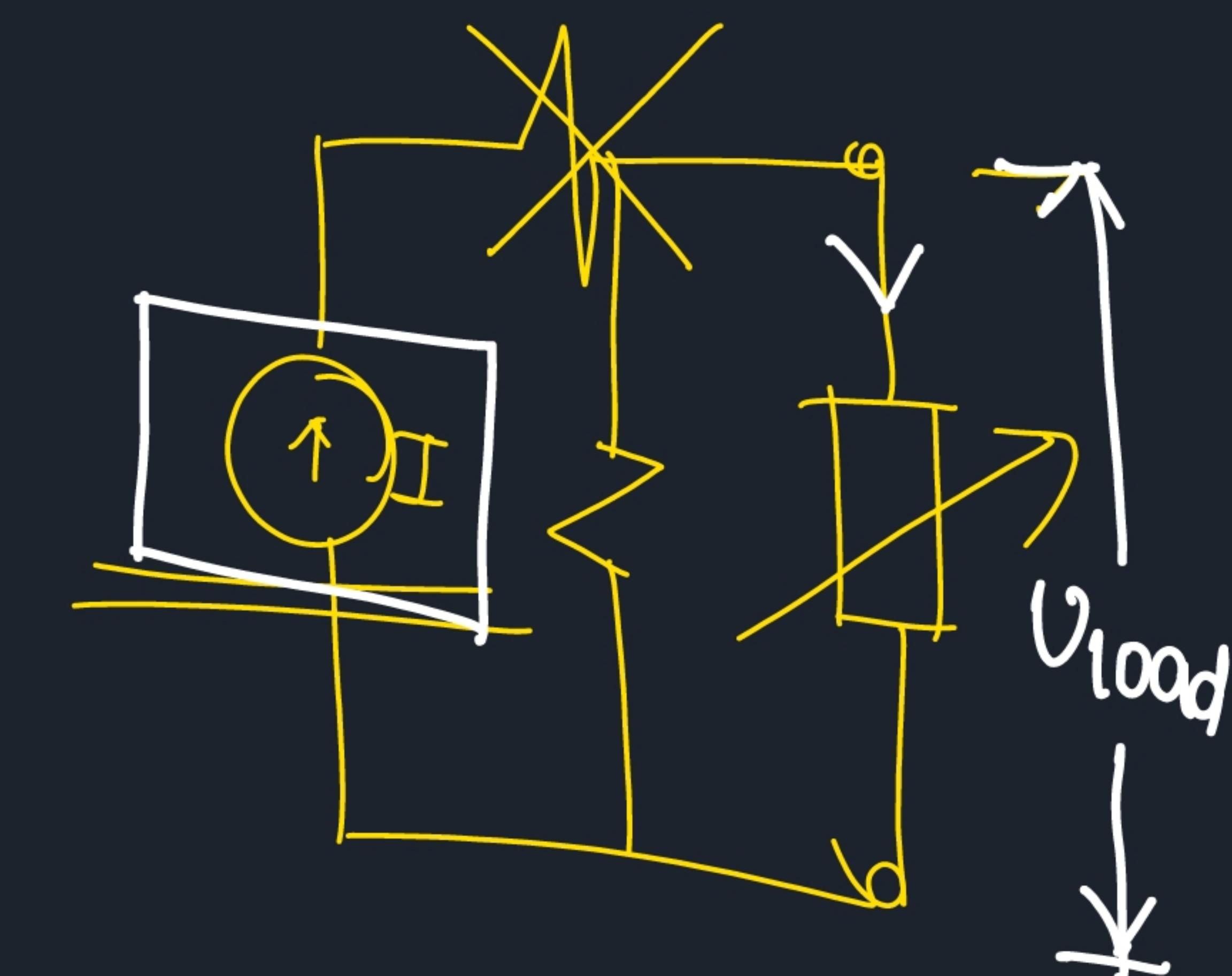
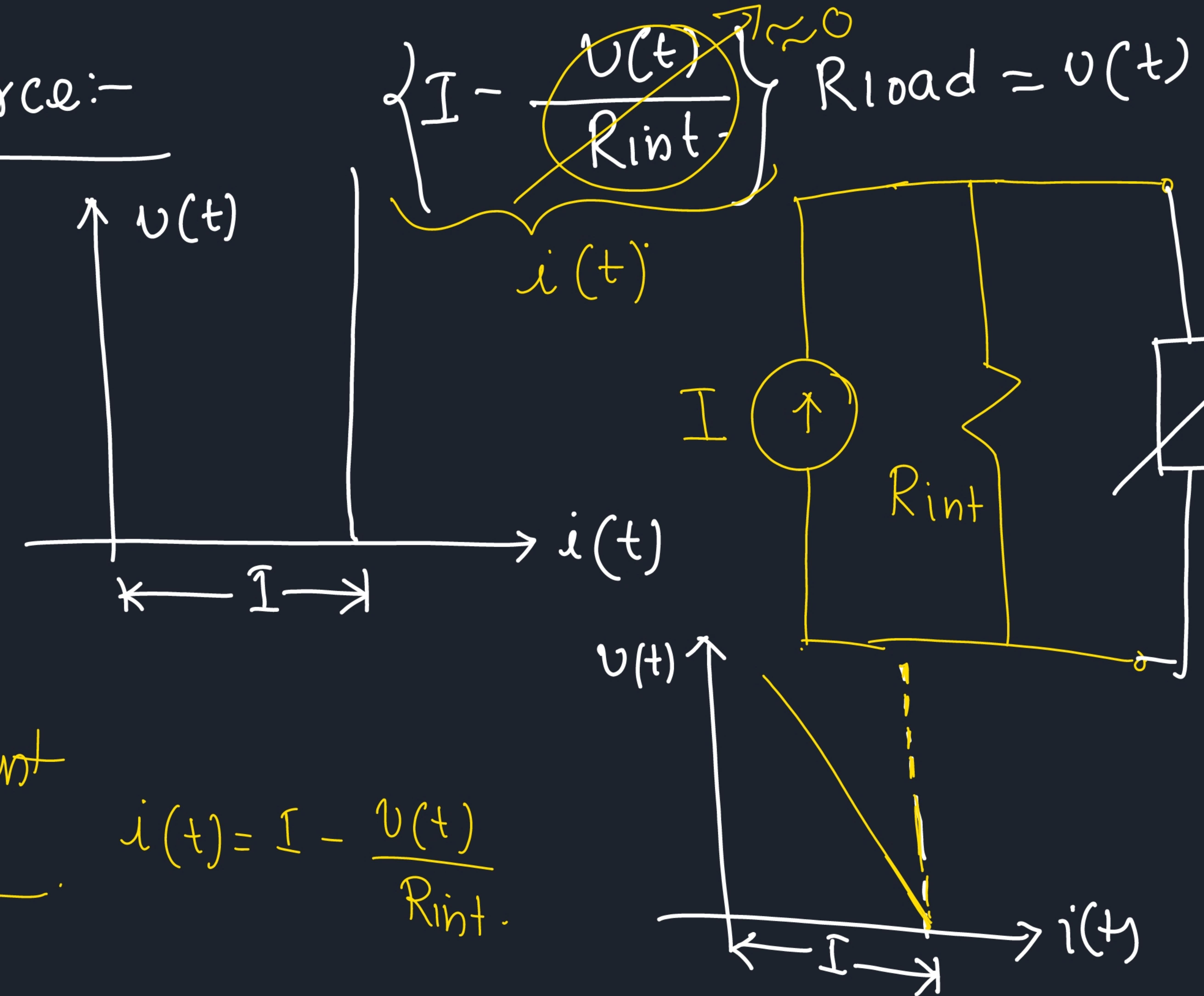


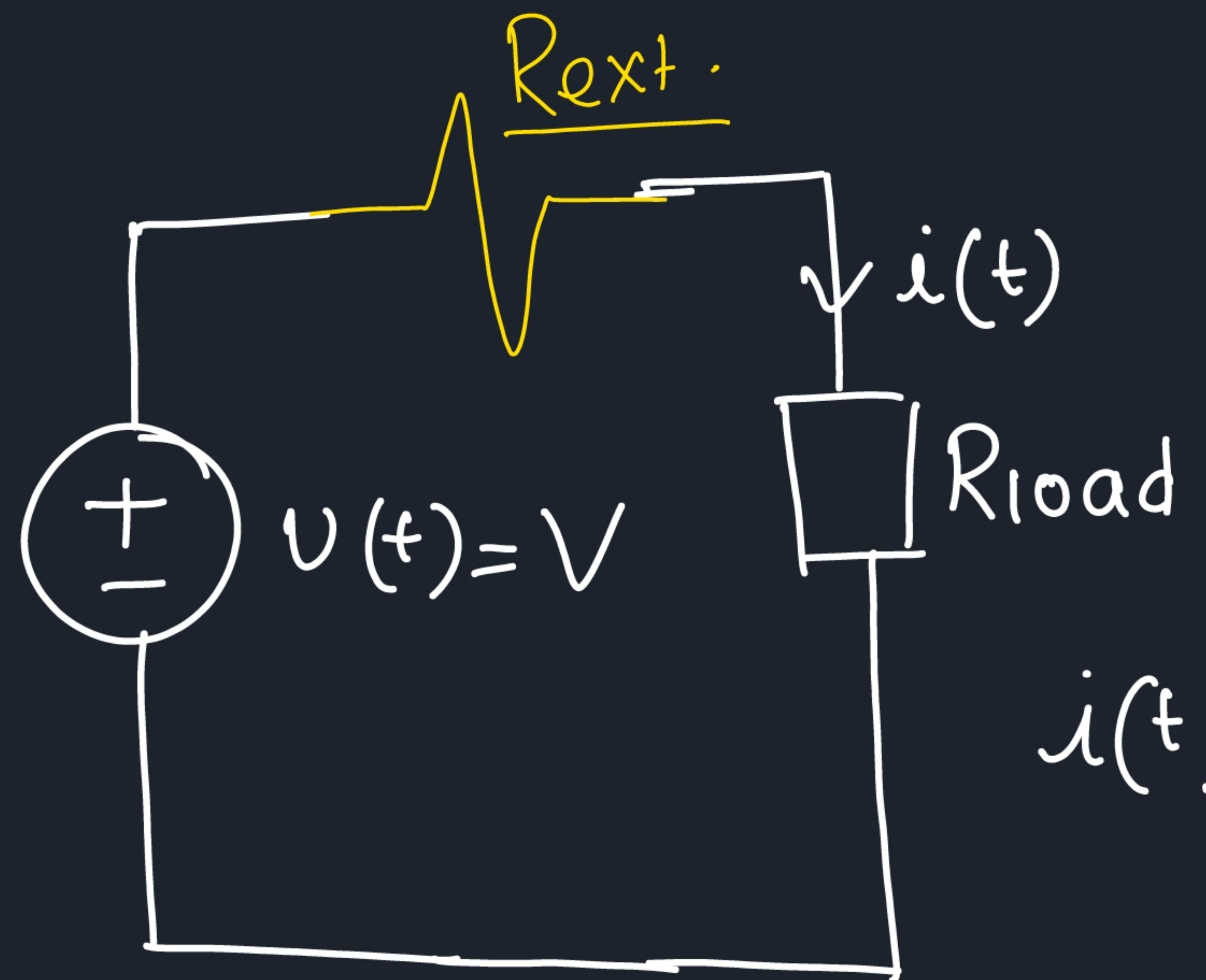


 Current Source:-



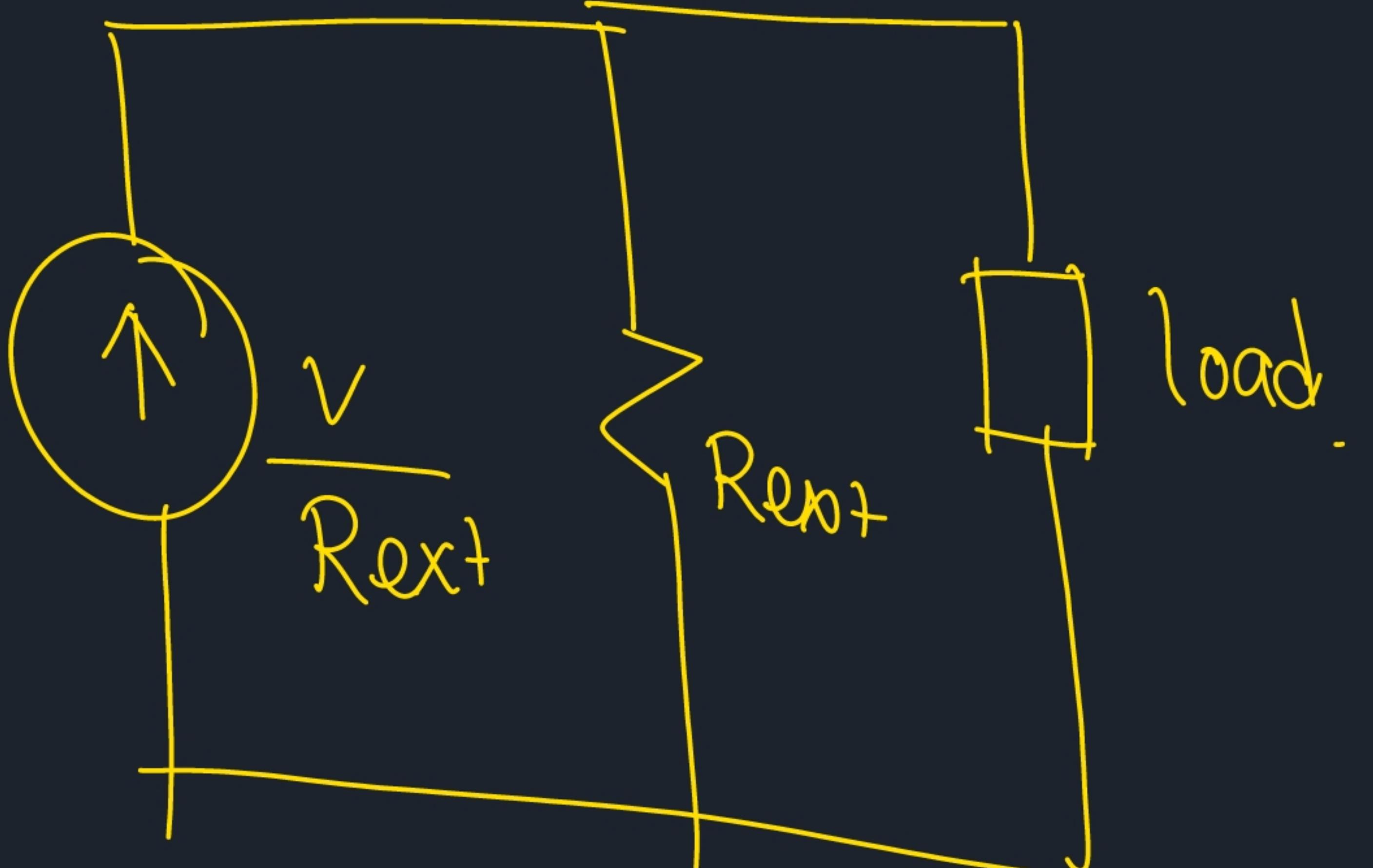
Ideal Current Source.





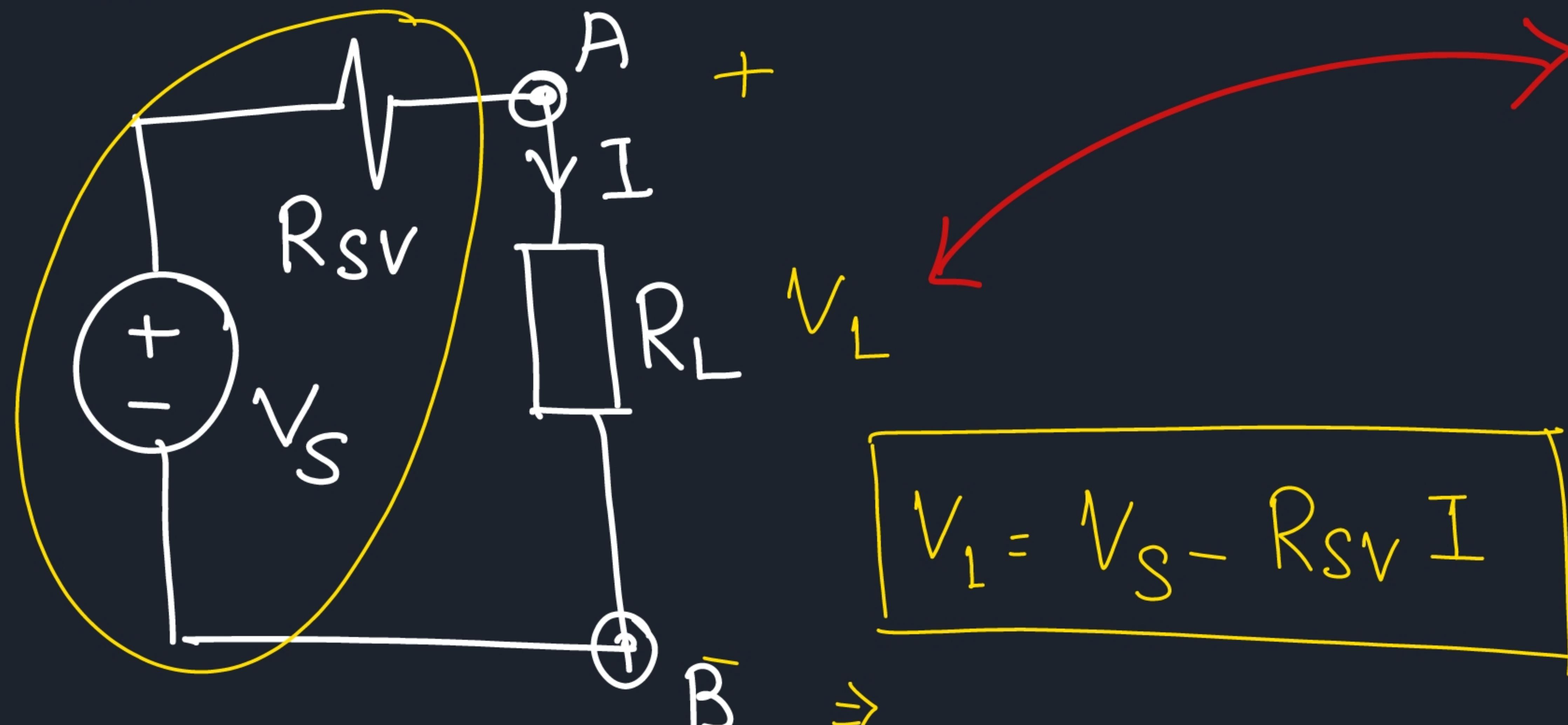
$$i(t) = \frac{V(t)}{R_{load} + R_{ext}}$$

$R_{ext} \gg R_{load}$

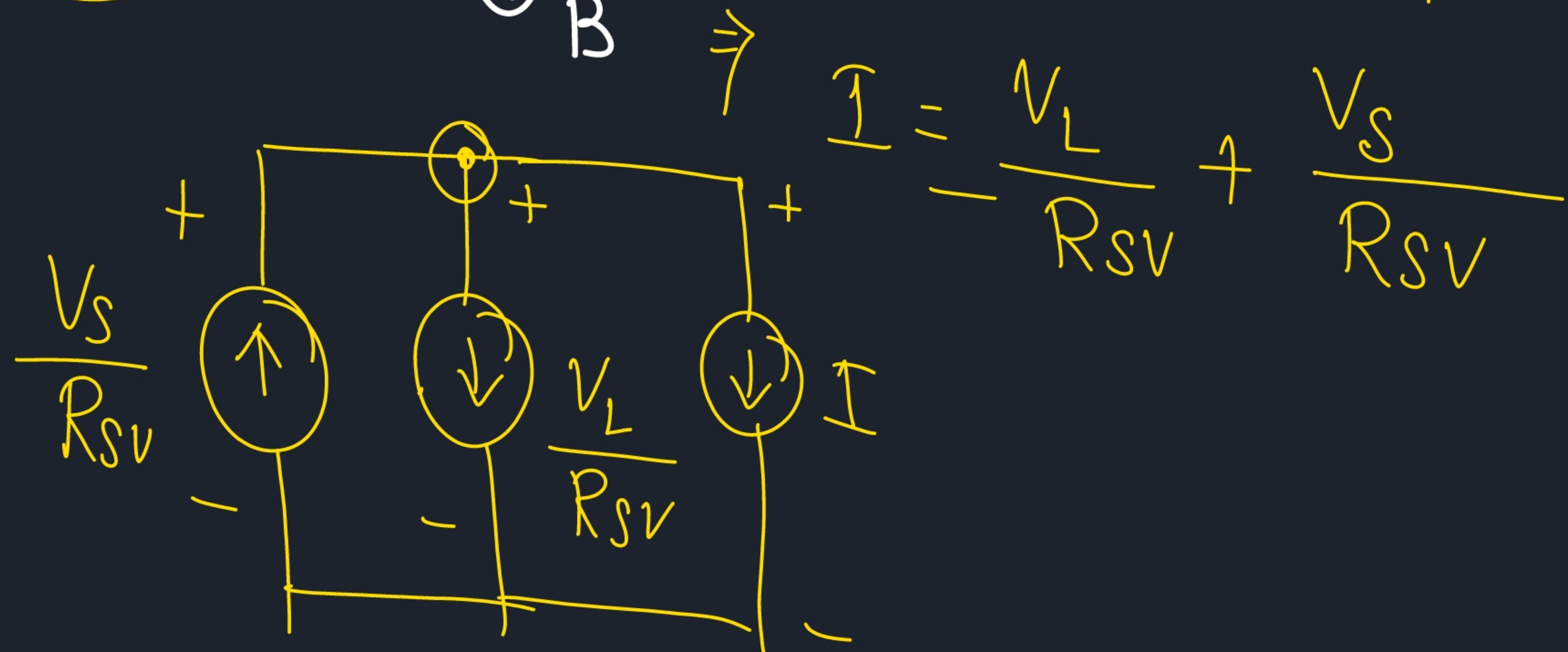
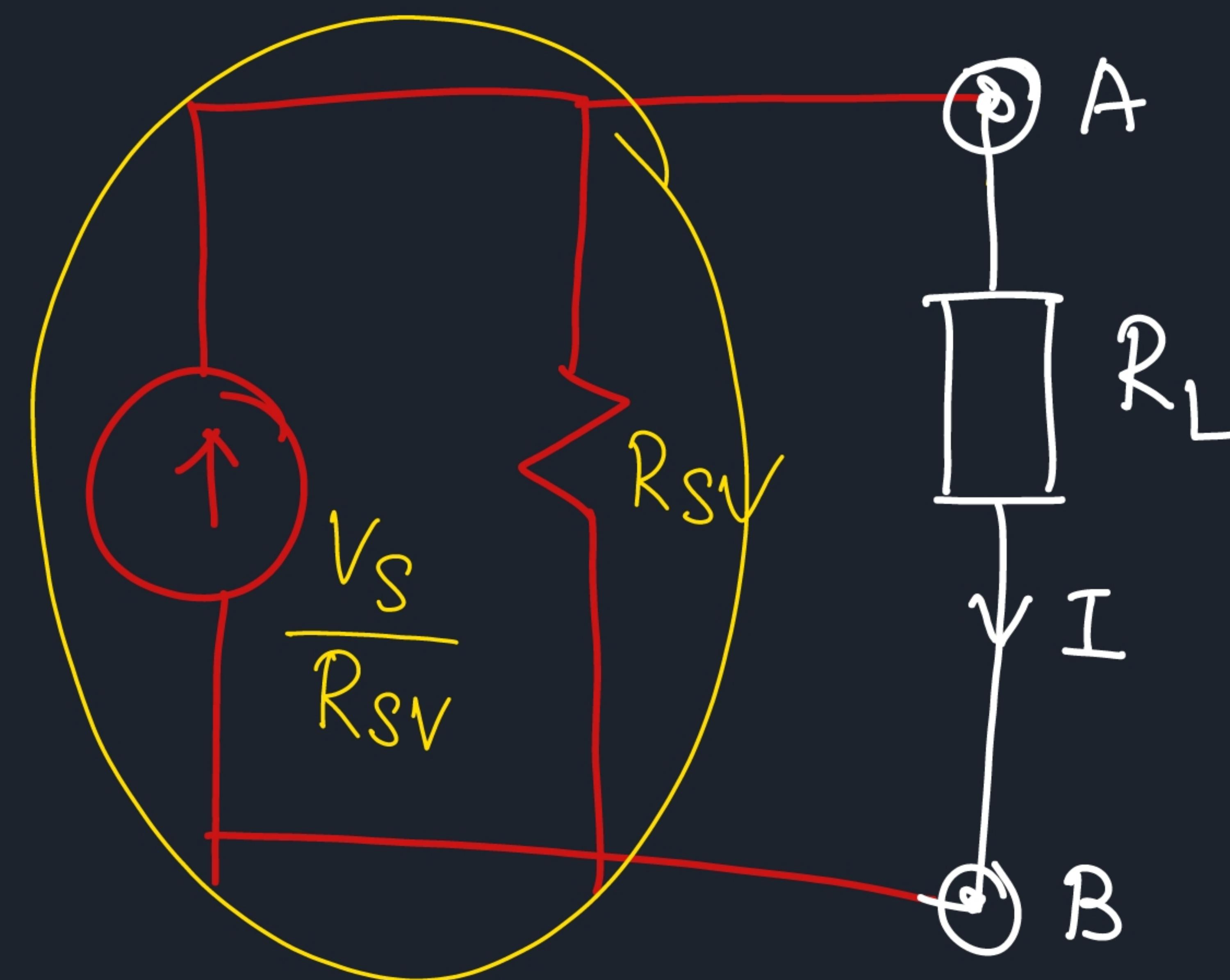


∴

Source Transformation:-

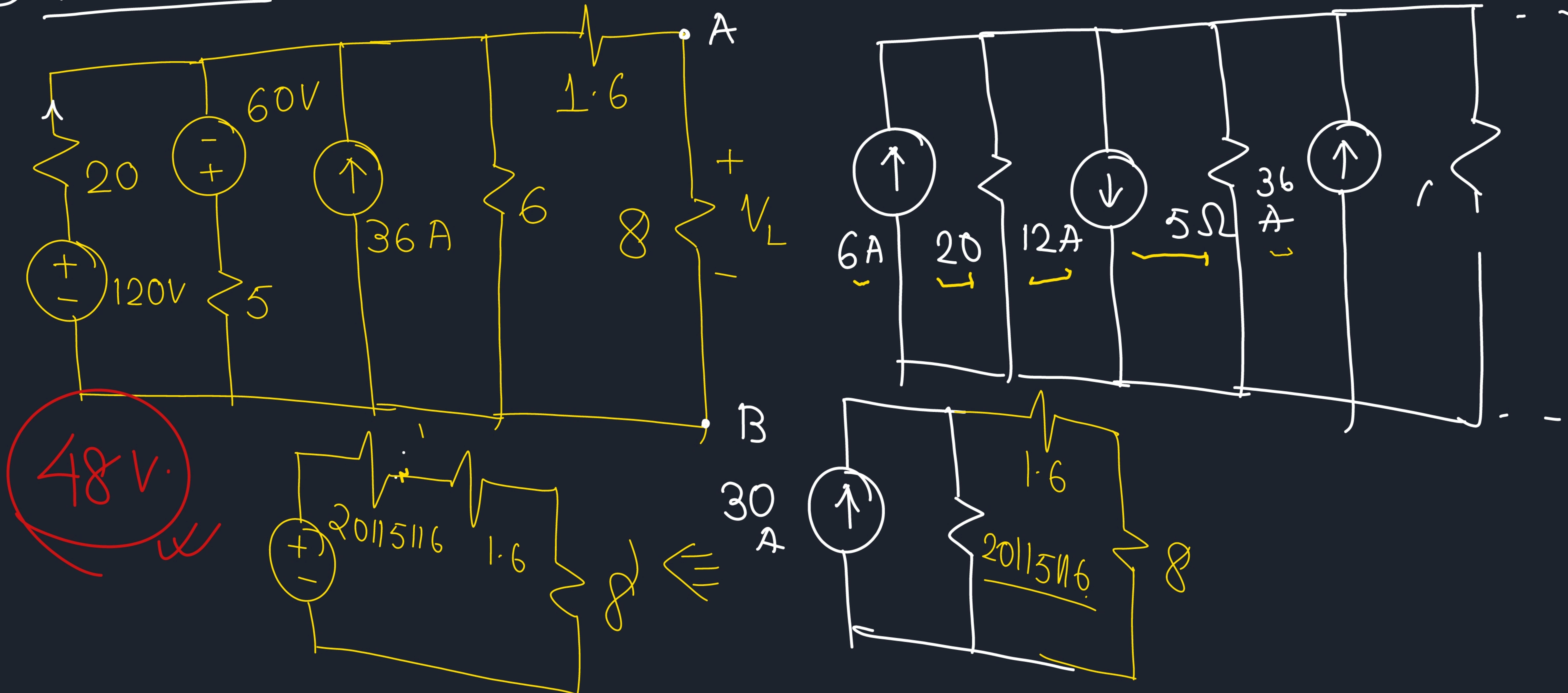


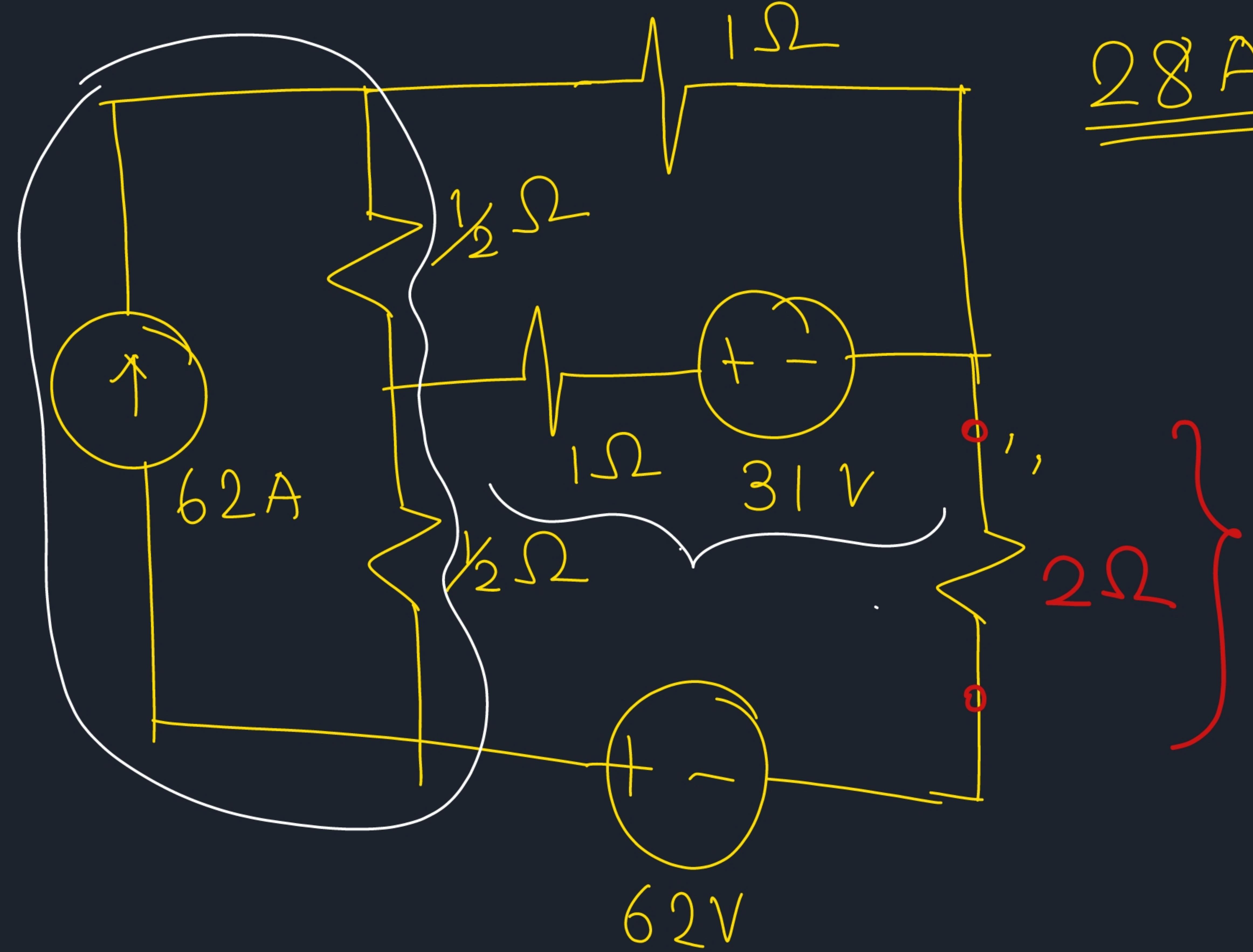
$$V_L = V_s - R_{SV} I$$



$$I = -\frac{V_L}{R_{SV}} + \frac{V_s}{R_{SV}}$$

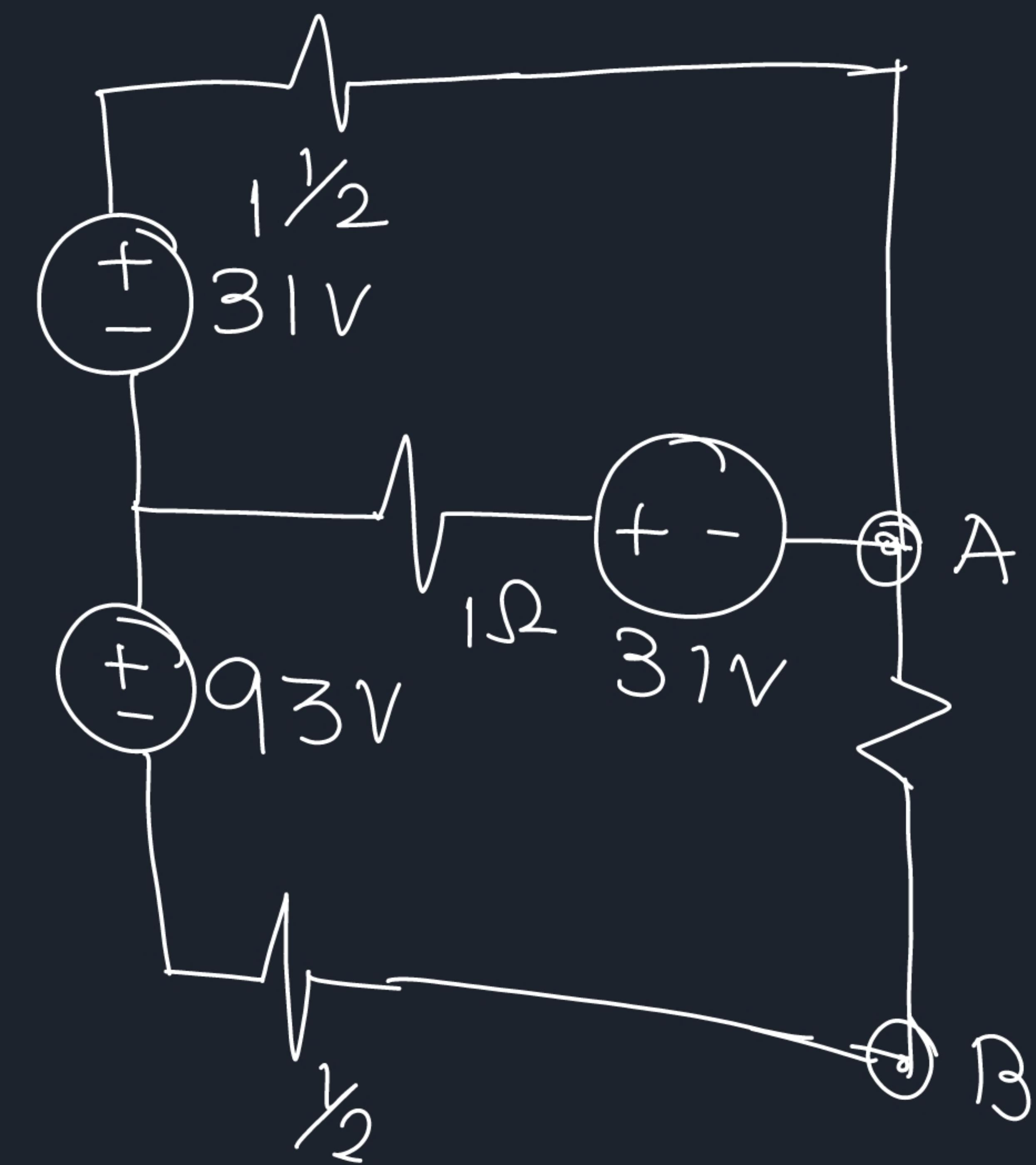
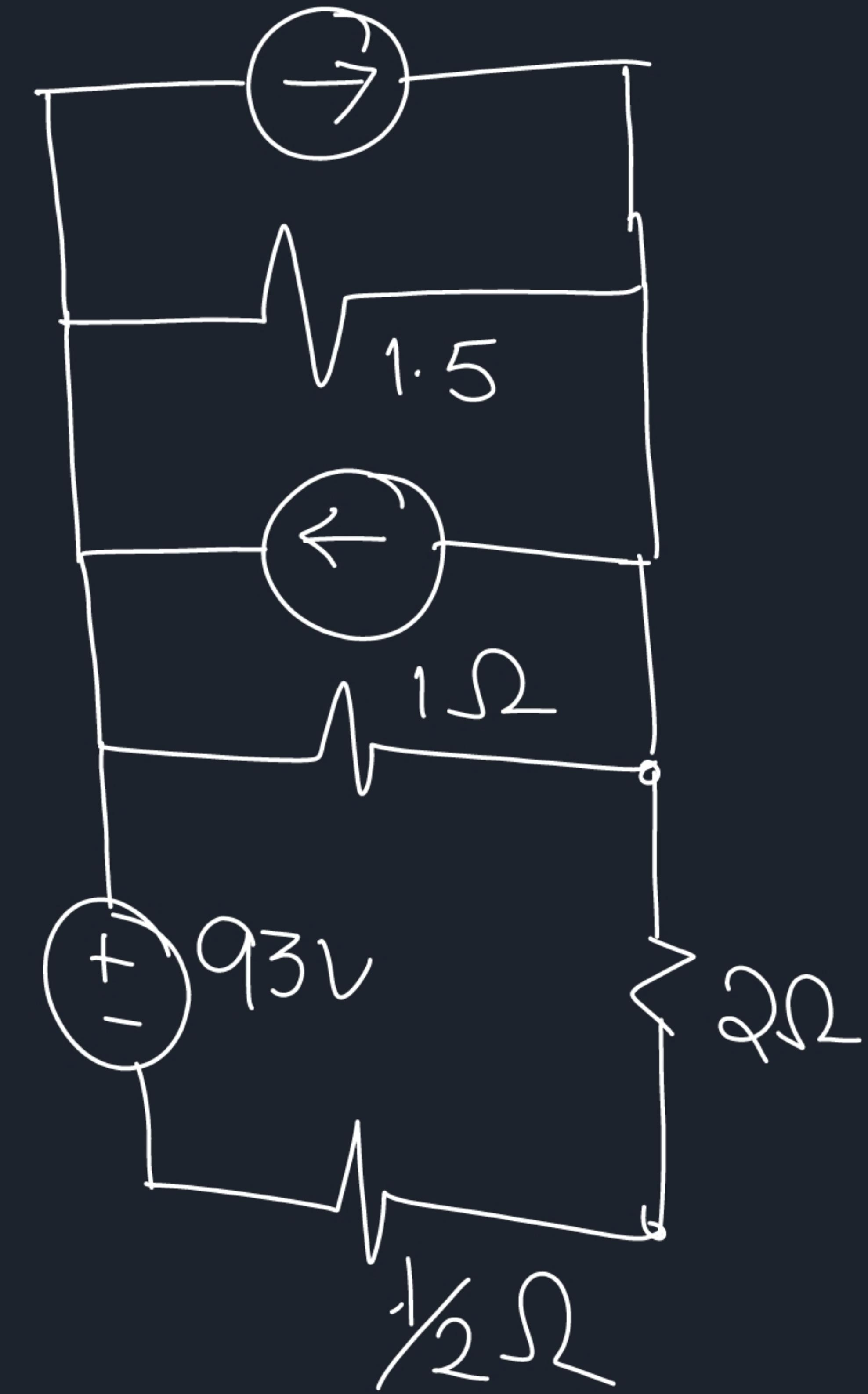
 Problem :-



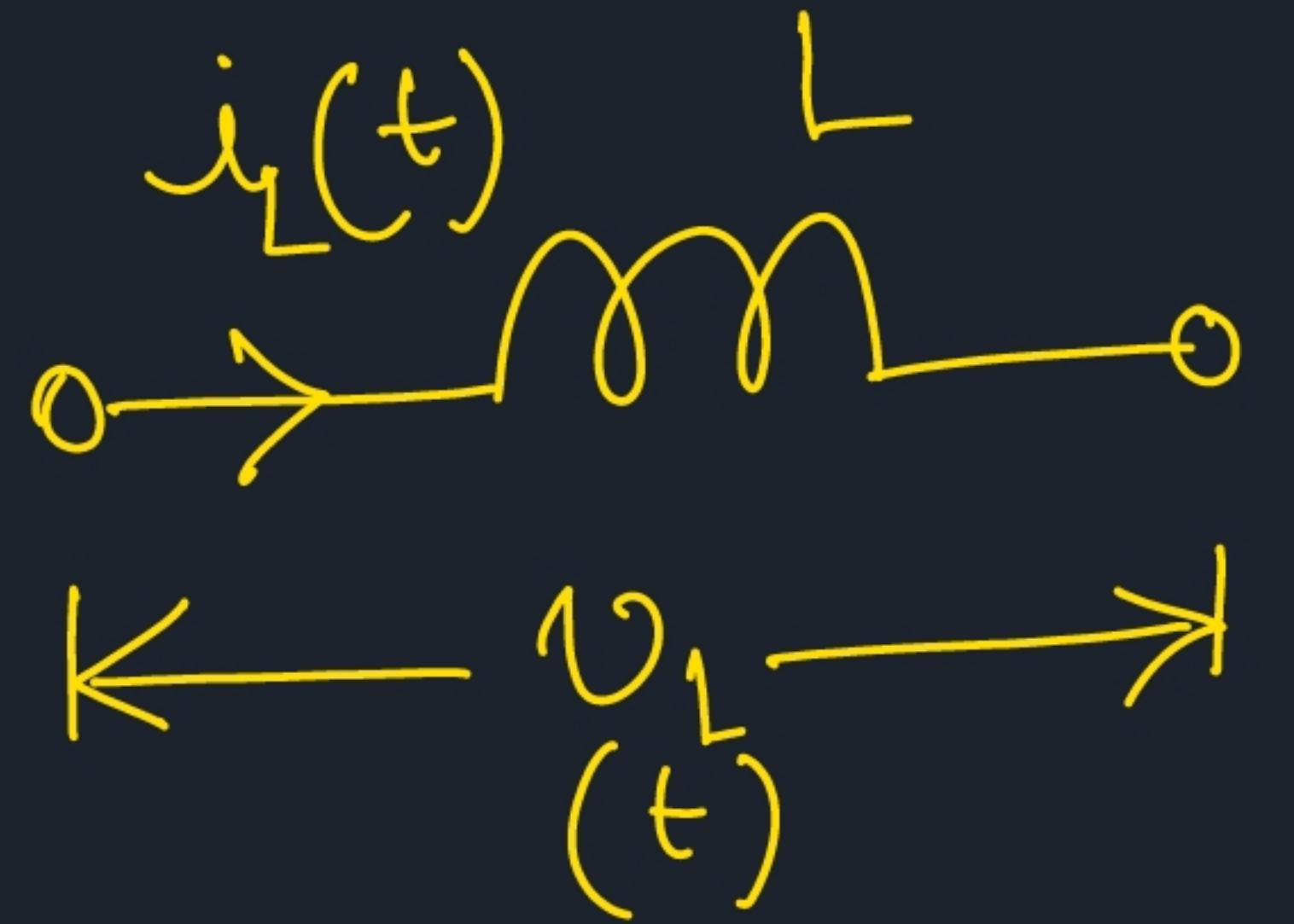


28 Amps.

75 76



 Inductor :-



$$v_L(t) = L \frac{di_L(t)}{dt}$$

$$i_L(t) = \frac{1}{L} \int_{-\infty}^t v_L(t) dt = \underbrace{\frac{1}{L} \int_{-\infty}^0 v_L(t) dt}_{I_0} + \frac{1}{L} \int_0^t v_L(t) dt$$

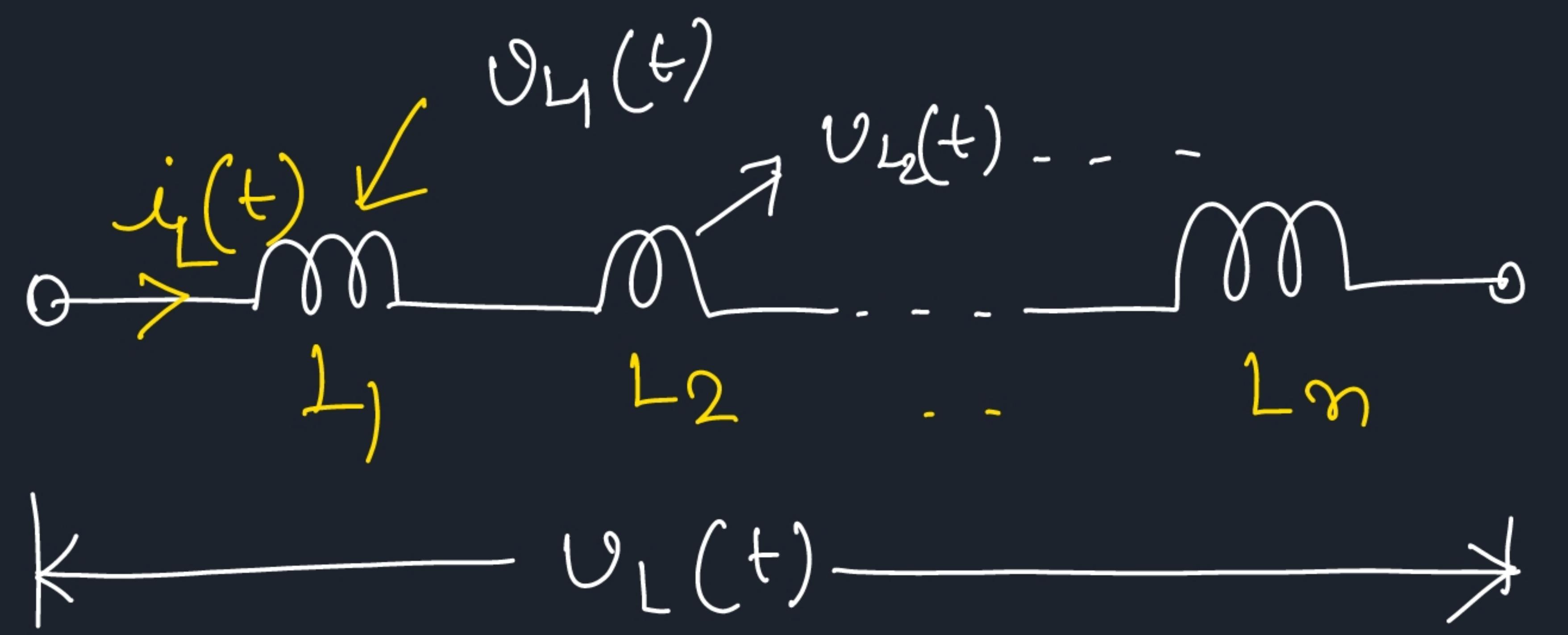
$$i_L(t) = I_0 + \frac{1}{L} \int_0^t v_L(t) dt \xrightarrow{\text{Area of } v_L(t) \text{ plot}} \underline{\underline{\text{Volt-Sec.}}}$$

$$\boxed{N\phi = LI}$$

ψ = flux linkage

$$V = -N \frac{d\phi}{dt}$$

$$= -L \frac{di}{dt}$$



$$V_{L1}(t) : V_{L2}(t) : \dots : V_{Lm}(t) \\ = L_1 : L_2 : \dots : L_m$$

$$V_L(t) = V_{L1}(t) + V_{L2}(t) + \dots + V_{Lm}(t)$$

$$= L_1 \frac{di_L(t)}{dt} + L_2 \frac{di_L(t)}{dt} + \dots + L_m \frac{di_L(t)}{dt}$$

$$= L_{eq} \frac{di_L(t)}{dt}$$

$$V_{Lm} = \frac{L_m}{\sum_{j=1}^n L_j} V_L(t)$$

$$L_{eq} = \frac{1}{\frac{1}{L_1} + \frac{1}{L_2} + \dots + \frac{1}{L_n}}$$

Capacitor :-



$$\left[i_C(t) = C \frac{dV_C(t)}{dt} \right]$$

$$V_C(t) = \frac{1}{C} \int_{-\infty}^t i_C(t) dt = \frac{1}{C} \int_{-\infty}^0 i_C(t) dt + \frac{1}{C} \int_0^t i_C(t) dt$$

$\underbrace{\qquad\qquad}_{\text{Amp-Sec.}}$

$V_C(0)$

$$V_C(t) = V_C(0) + \frac{1}{C} \int_0^t i_C(t) dt$$

$$C_{eq}^S = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \dots + \frac{1}{C_n}}$$

$$C_{eq}^P = C_1 + C_2 + \dots + C_n$$

$$V_R(t) = R i_R(t)$$

$$V_L(t) = L \frac{di_L(t)}{dt}$$

$$V_C(t) = \frac{1}{C} \int_{-\infty}^t i_C(t) dt$$

Linear & Nonlinear Element.

$$y = mx$$

$$\left. \begin{array}{l} i_{R1}(t) \\ \downarrow \\ V_{R1}(t) \end{array} \right\} \quad \left. \begin{array}{l} i_{R2}(t) \\ \downarrow \\ V_{R2}(t) \end{array} \right\} \quad \left. \begin{array}{l} a i_R(t) \\ \downarrow \\ a V_R(t) \end{array} \right\}$$

1. Additivity
2. Homogeneity } \Rightarrow Superposition.

$$\begin{aligned} y &= f(x) \\ y_1 &= f(x_1) \\ y_2 &= f(x_2) \end{aligned} \quad \begin{aligned} y_1 + y_2 &= f(x_1 + x_2) \\ ay &= f(ax) \end{aligned}$$

$$y = mx + c$$

x_1, x_2 Non linear

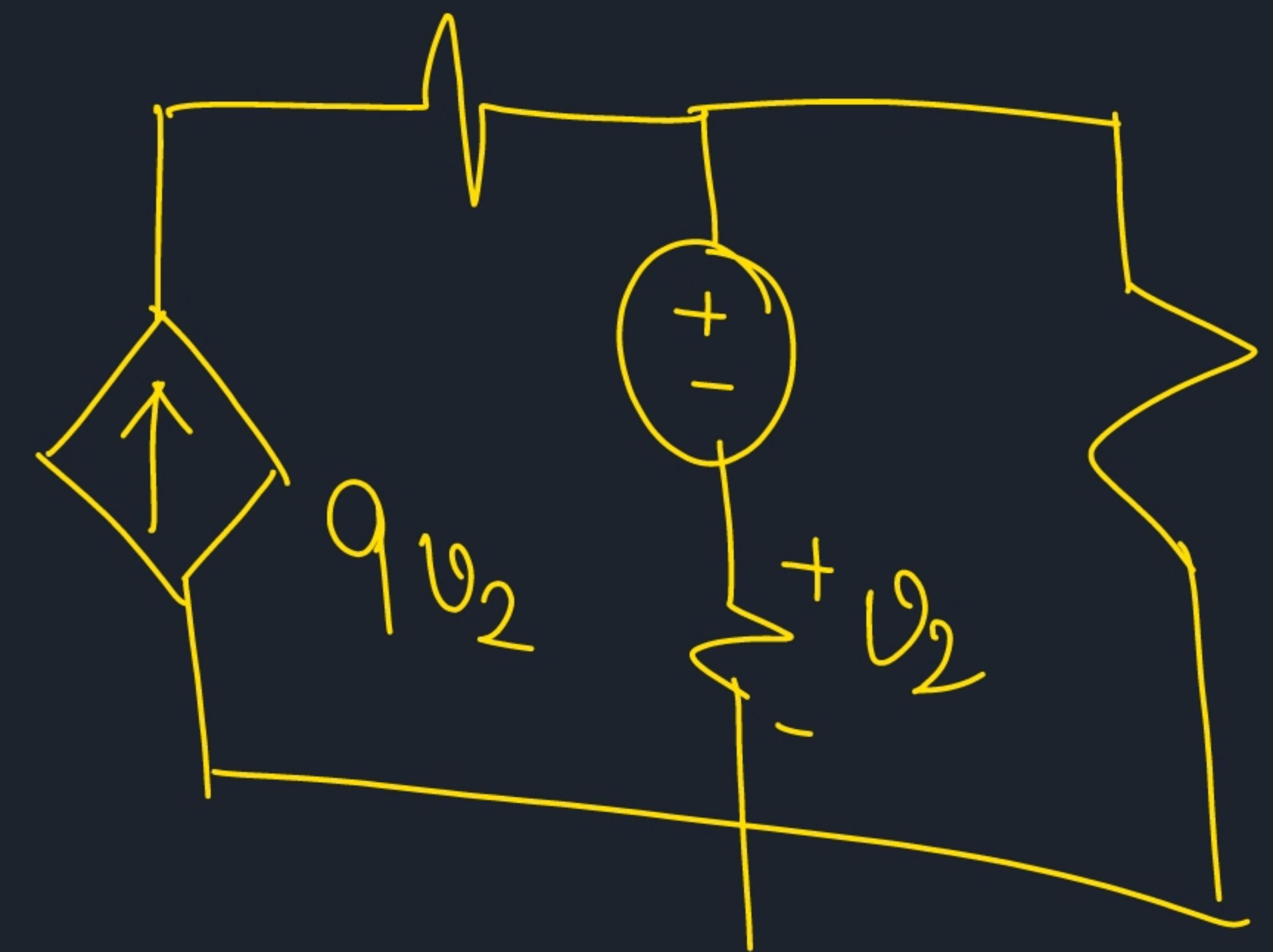
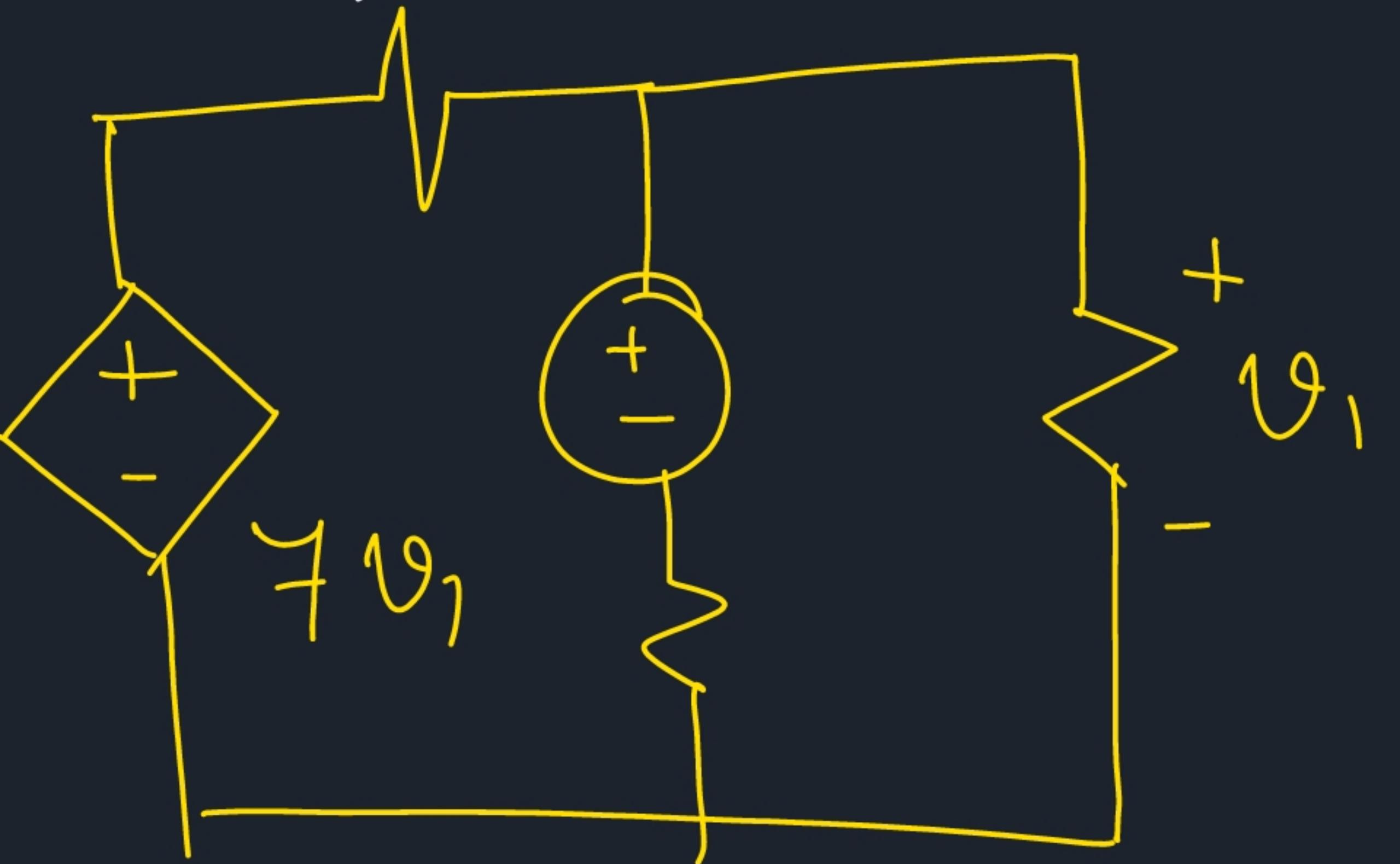
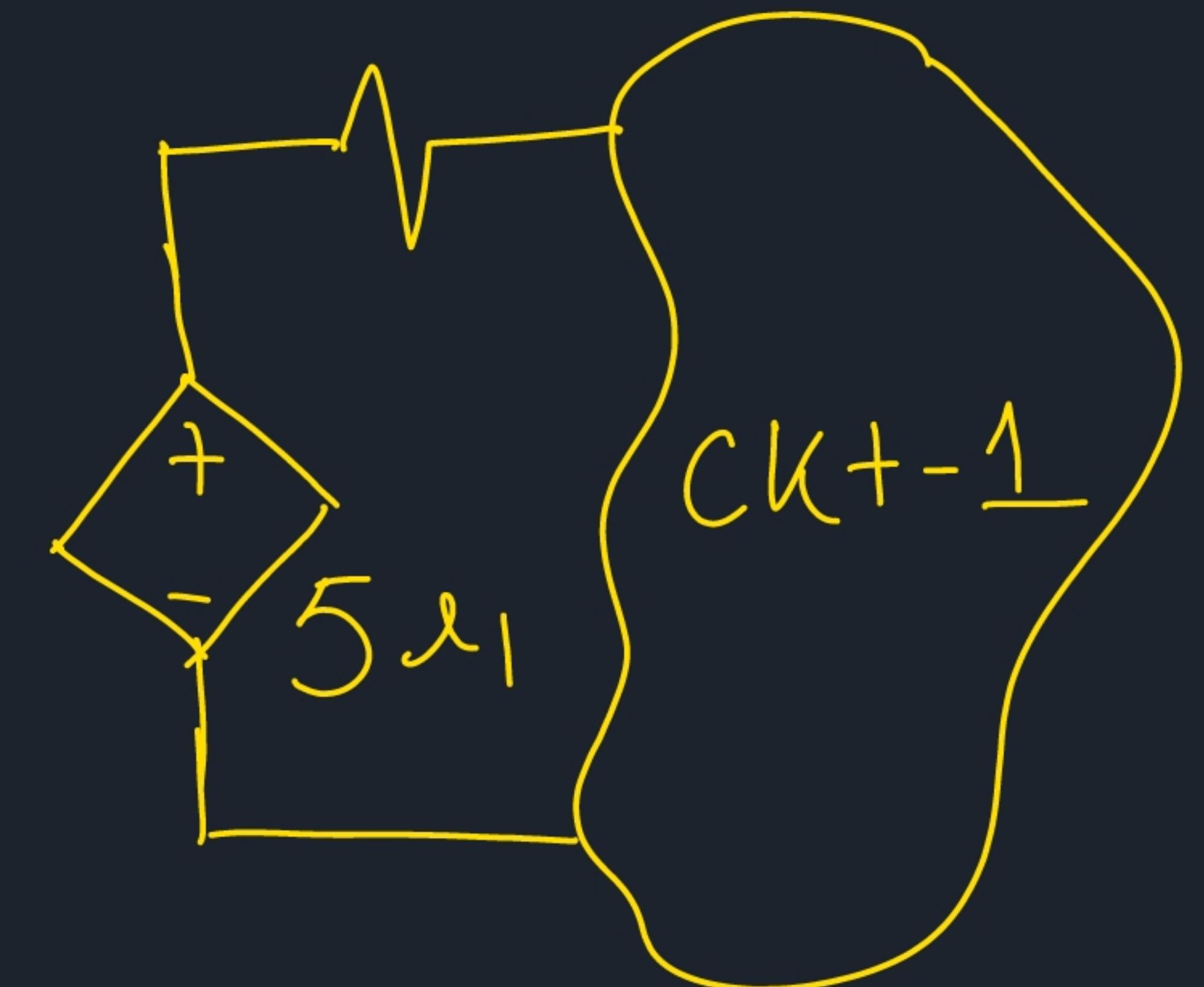
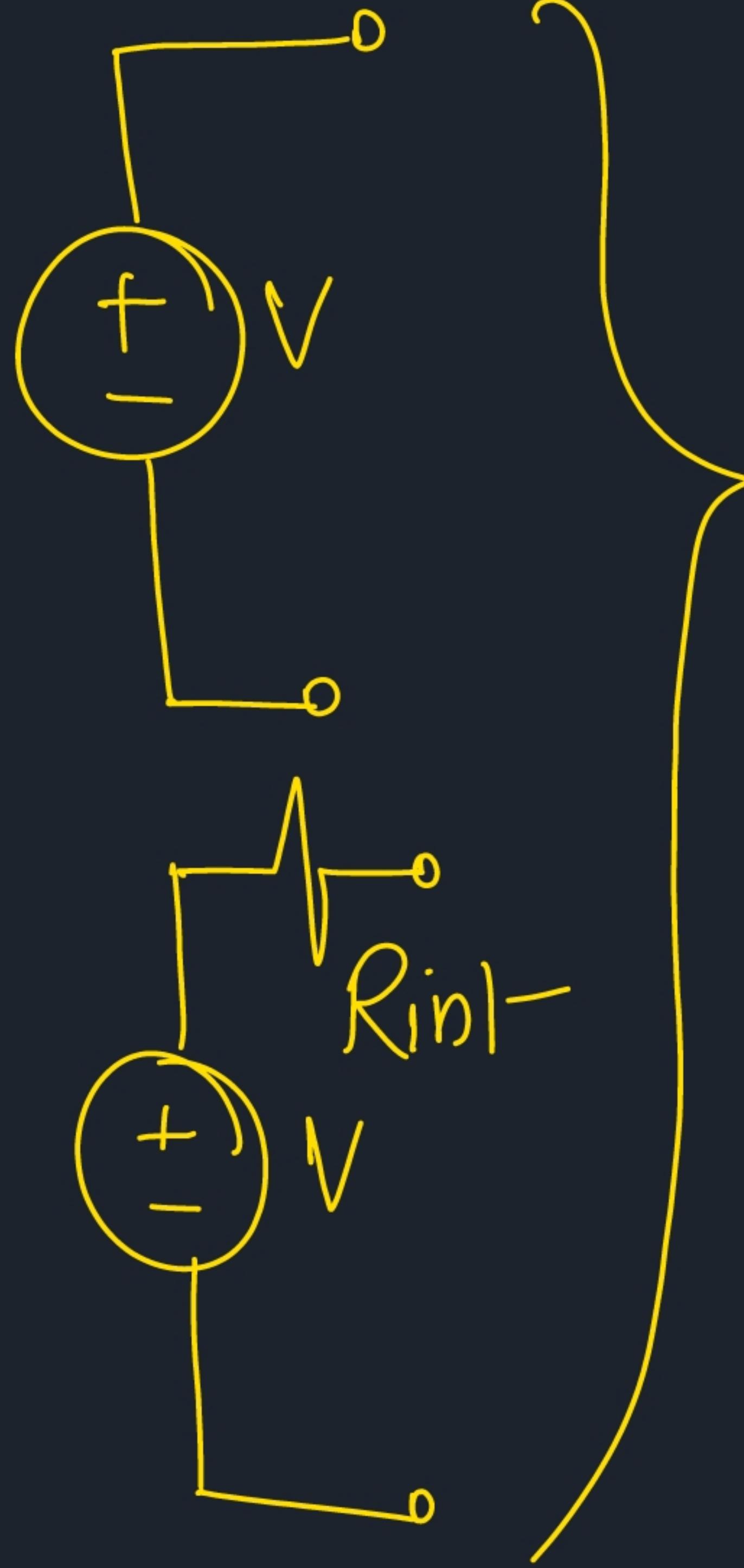
$$\begin{aligned} & ax_1 \\ & ay_1 \end{aligned} \quad \boxed{v_L(t) = L \frac{di_L(t)}{dt}}$$

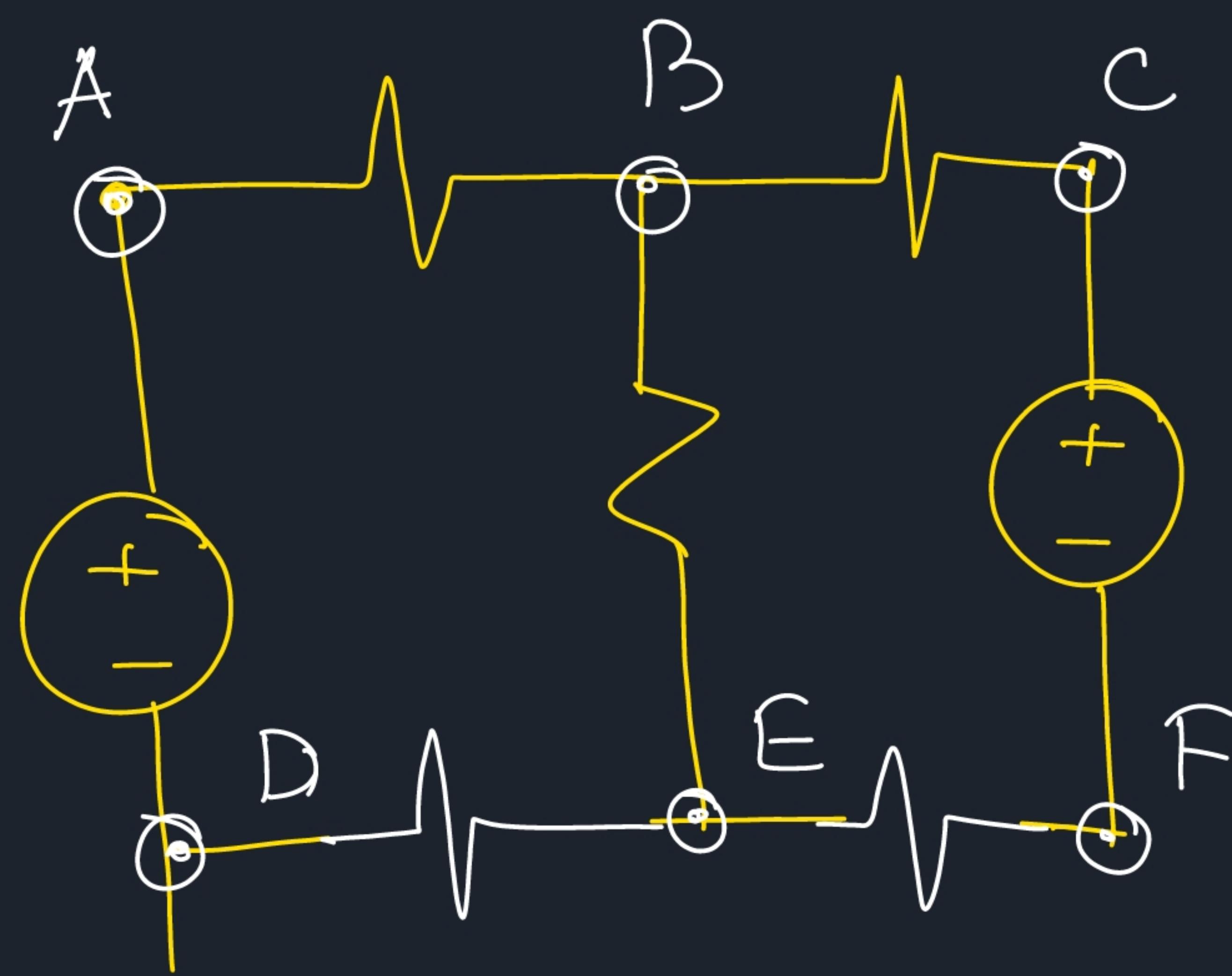
$$i_L(t) = \left(I_0 + \int_0^t v_L(t) dt \right)$$

$$v_L(t) = L \frac{di_L(t)}{dt}$$

$$i_C(t) = C \frac{dw_C(t)}{dt}$$

Dependent & Independent :- (Sources)





NODE

JUNCTION \Rightarrow B, E

BRANCH \Rightarrow

LOOP \Rightarrow MESH \Rightarrow

NETWORK ANALYSIS.

DIRECT

MESH ANALYSIS

NODAL "

SUPERPOSITION

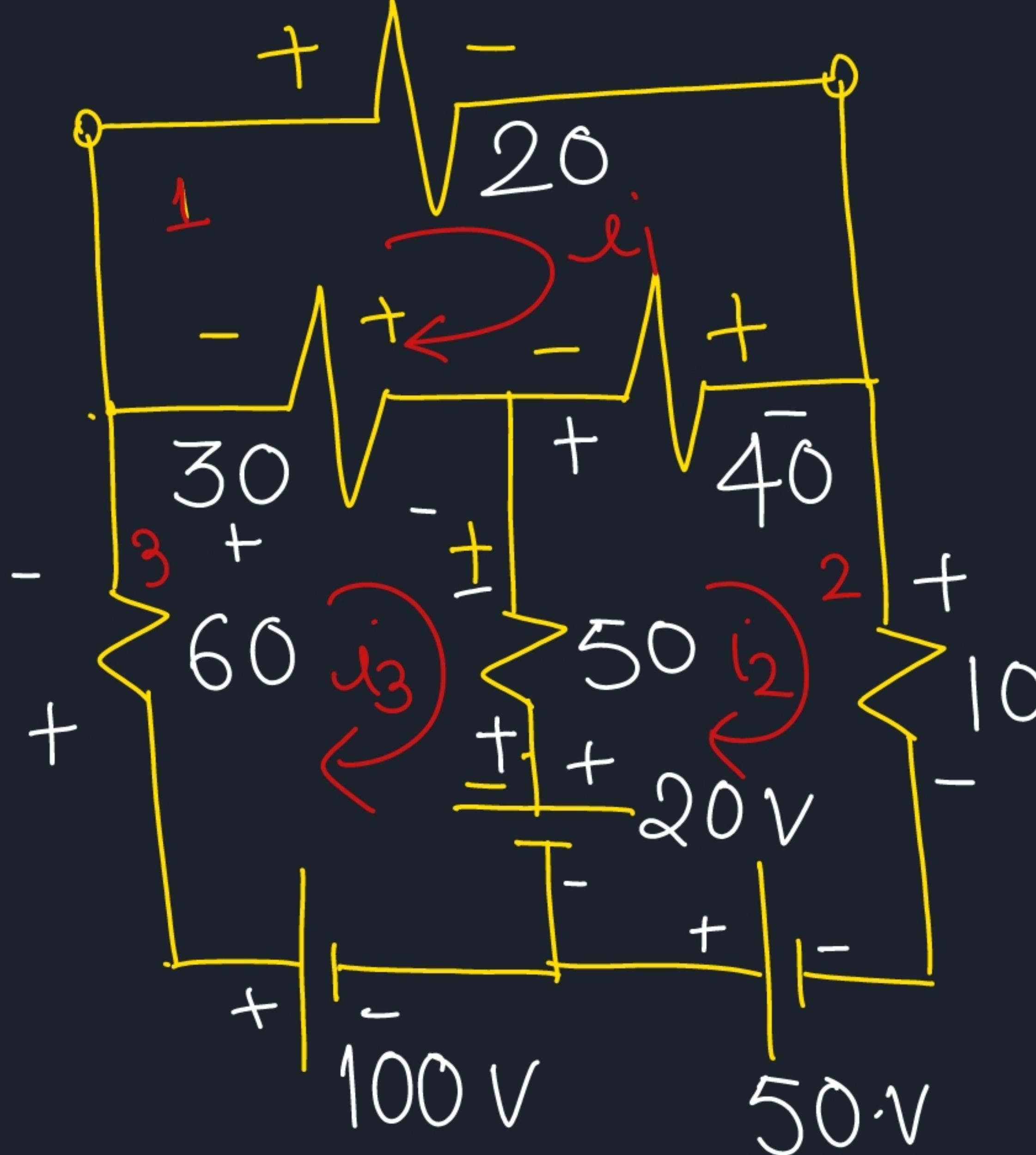
INDIRECT

THEVENIN'S

NORTON'S

$\text{Y}-\Delta$ Transform.

MESH ANALYSIS:-



$$I = f(i_1, i_2, i_3)$$

MESH - 1

$$-20i_1 - 40(i_1 - i_2) - 30(i_1 - i_3) = 0$$

MESH - 2 $\Rightarrow i_1(20 + 40 + 30) - i_2(40) - i_3(30) = 0 \dots (iv)$

$$-40(i_2 - i_1) - 10i_2 + 50 + 20 - 50(i_2 - i_3) = 0 \dots (v)$$

MESH - 3 $\Rightarrow -40i_1 + i_2(50 + 40 + 10) - 50i_3 = 50 + 20 \dots (vi)$

$$-60i_3 - 30(i_3 - i_1) - 50(i_3 - i_2) - 20 + 100 = 0 \dots (vii)$$

$$\Rightarrow -30i_1 - 50i_2 + i_3(60 + 30 + 50) = 100 - 20 \dots (viii)$$

$$A \bar{I} = C$$

$$\bar{I} = A^{-1} C$$

$$\begin{aligned} i_1 &= 1.49 \text{ A} \\ i_2 &= 2.12 \text{ A} \\ i_3 &= 1.65 \text{ A} \end{aligned}$$

$$\left[\begin{array}{ccc} 90 & -40 & -30 \\ -40 & 100 & -50 \\ -30 & -50 & 140 \end{array} \right] \left[\begin{array}{c} i_1 \\ i_2 \\ i_3 \end{array} \right] = \left[\begin{array}{c} 0 \\ 50+20 \\ 100-20 \end{array} \right]$$

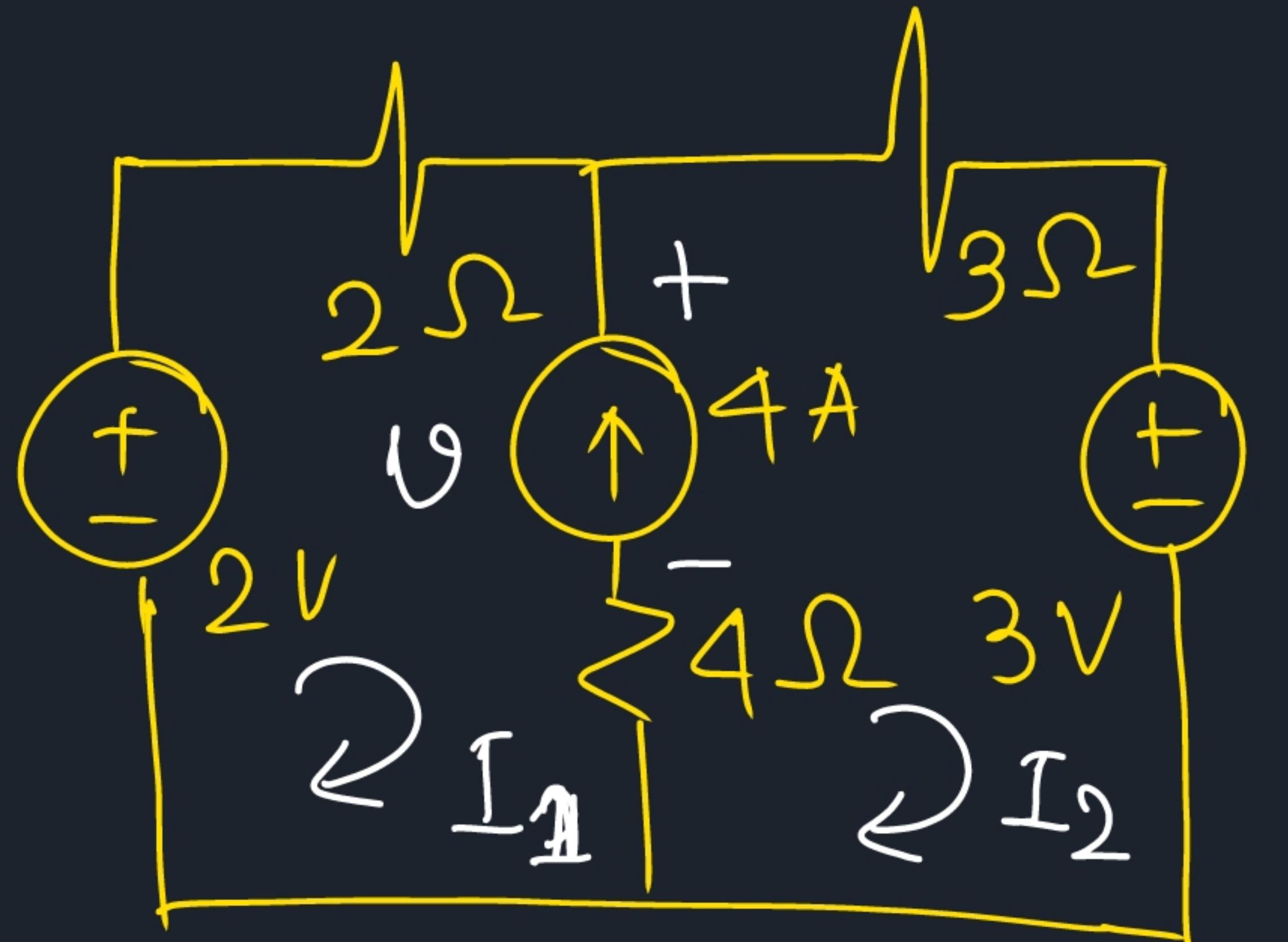
A I C

CRAMER'S RULE :-

$$i_1 = \frac{\det \begin{bmatrix} 0 & -40 & -30 \\ 70 & 100 & -50 \\ 80 & -50 & 140 \end{bmatrix}}{\det \begin{bmatrix} 90 & -40 & -30 \\ -40 & 100 & -50 \\ -30 & -50 & 140 \end{bmatrix}} = ?$$

$$i_2 = \frac{\det \begin{bmatrix} 90 & 0 & -30 \\ -40 & 70 & -50 \\ -30 & 80 & 140 \end{bmatrix}}{\det \begin{bmatrix} 90 & -40 & -30 \\ -40 & 100 & -50 \\ -30 & -50 & 140 \end{bmatrix}} = ?$$

$$i_3 = \frac{\det \begin{bmatrix} 90 & -40 & 0 \\ -40 & 100 & 70 \\ -30 & 50 & 80 \end{bmatrix}}{\det \begin{bmatrix} 90 & -40 & -30 \\ -40 & 100 & -50 \\ -30 & -50 & 140 \end{bmatrix}} = ?$$

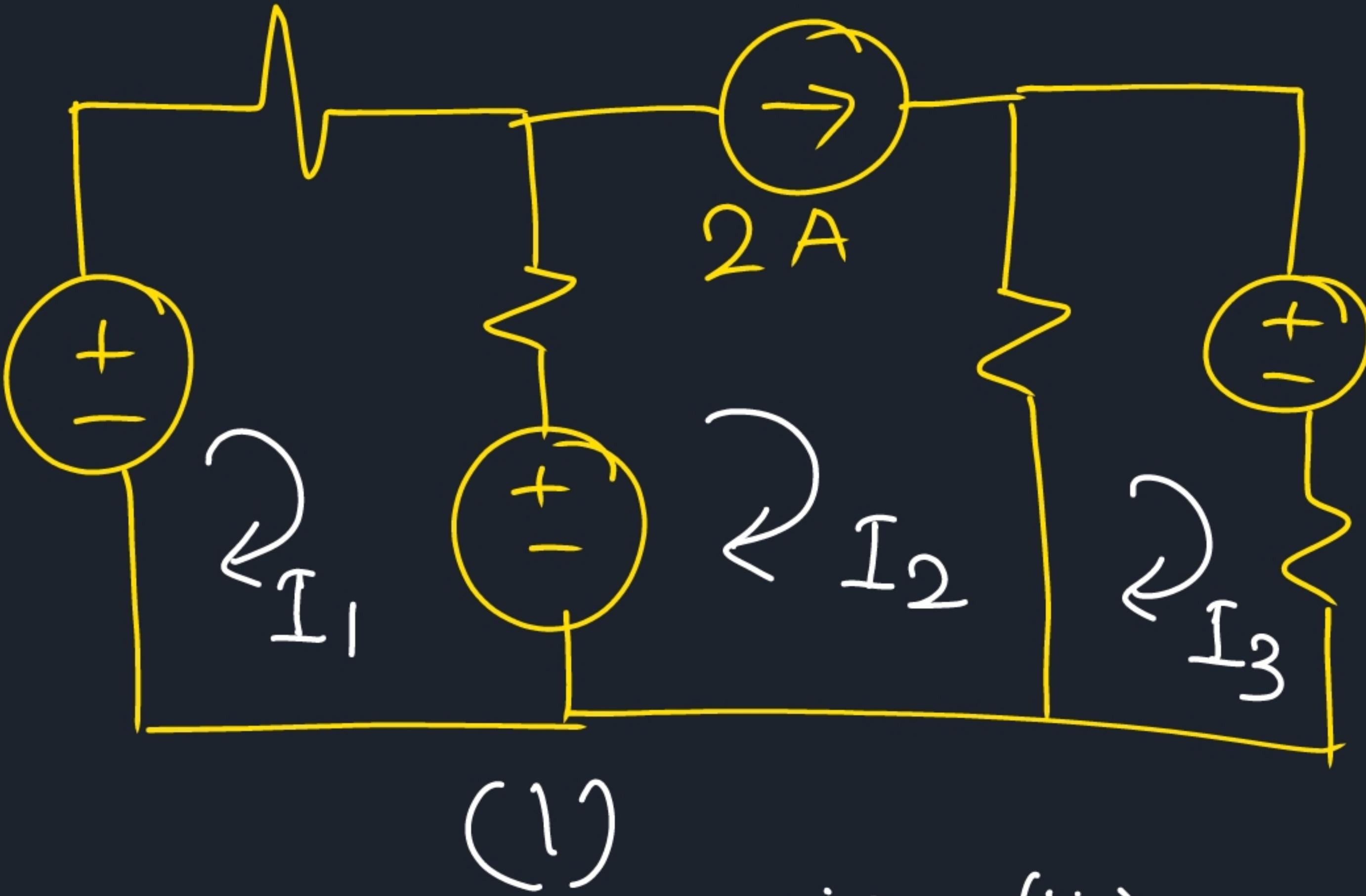


(II)

$$I_2 - I_1 = 4 \quad \dots (i)$$

$$2 - 2I_1 - 2V - 4(I_1 - I_2) = 0 \quad \dots (ii)$$

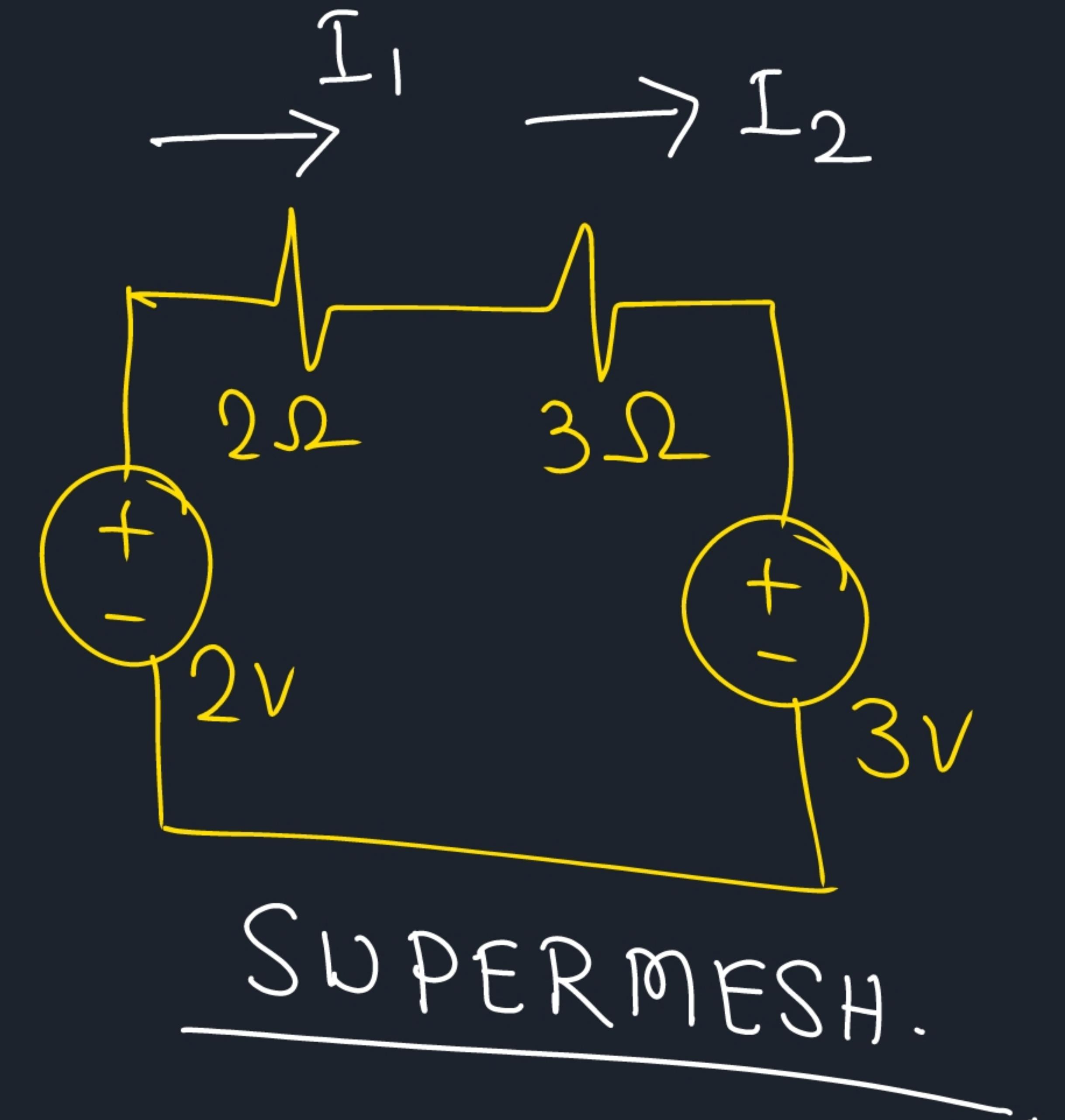
$$-4(I_2 - I_1) + 2V - 3I_2 - 3 = 0 \quad \dots (iii)$$



(I)

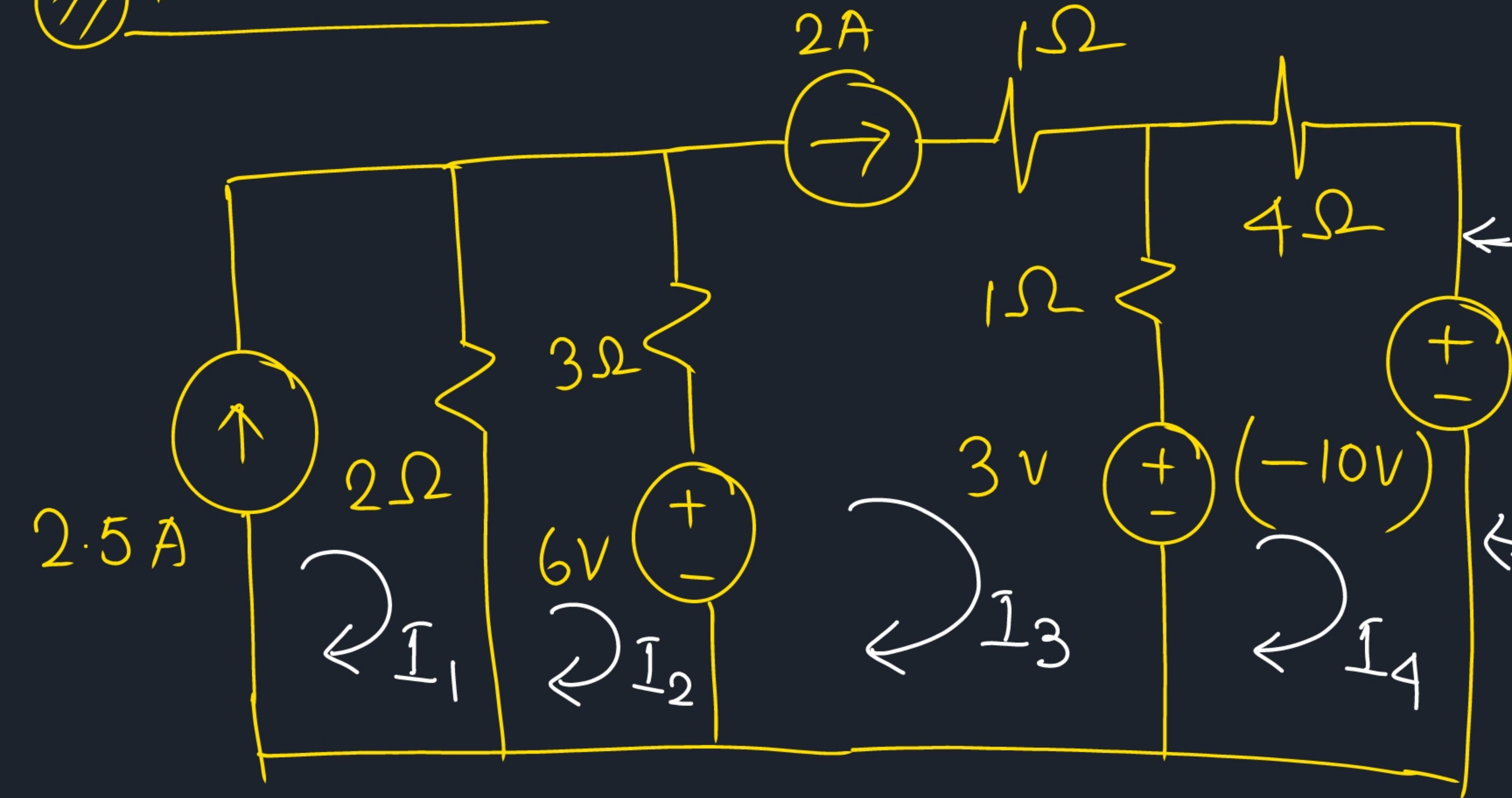
(i) + (ii)

$$2 - 2I_1 - 3I_2 - 3 = 0 \quad \dots (iv)$$



SUPERMESH.

Problem:-



$$I_1 = 2.5 \text{ Amps.}$$

$$I_3 = 2 \text{ Amps}$$

MESH-2 :-

$$-2(I_2 - 2.5) - 3(I_2 - 2) - 6 = 0$$

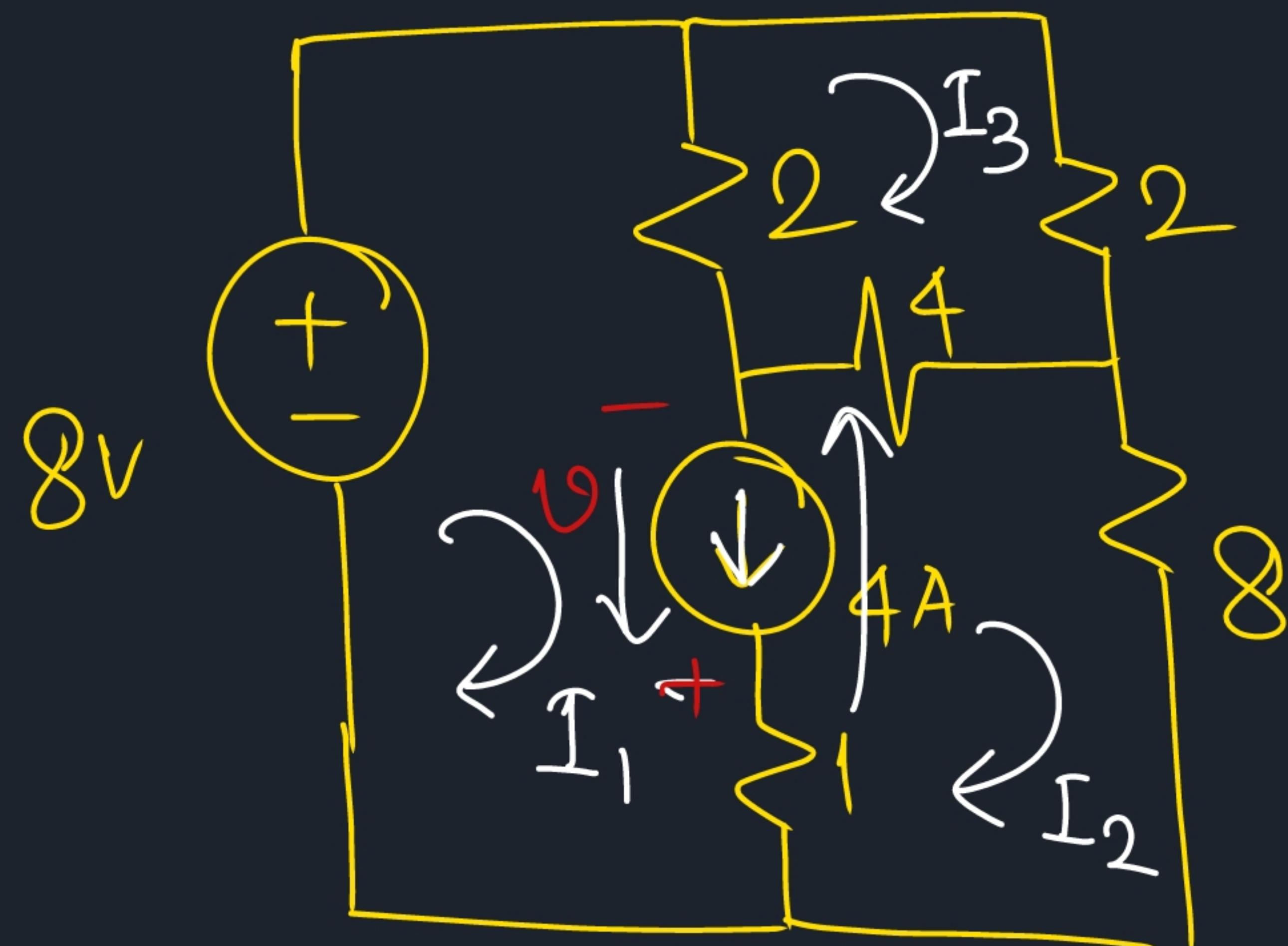
$$I_2 = ? \underline{1 \text{ Amps.}}$$

MESH-4 :-

$$3 - 1(I_4 - 2) - 4I_4 - (-10) = 0$$

$$I_4 = ? \underline{3 \text{ Amps}}$$

 Problem :-



$$I_1 = 4.632 \text{ A}$$

$$I_2 = 0.632 \text{ A}$$

$$I_3 = 1.4736 \text{ A}$$

$$I_1, I_2, I_3 = ?$$

MESH - 3

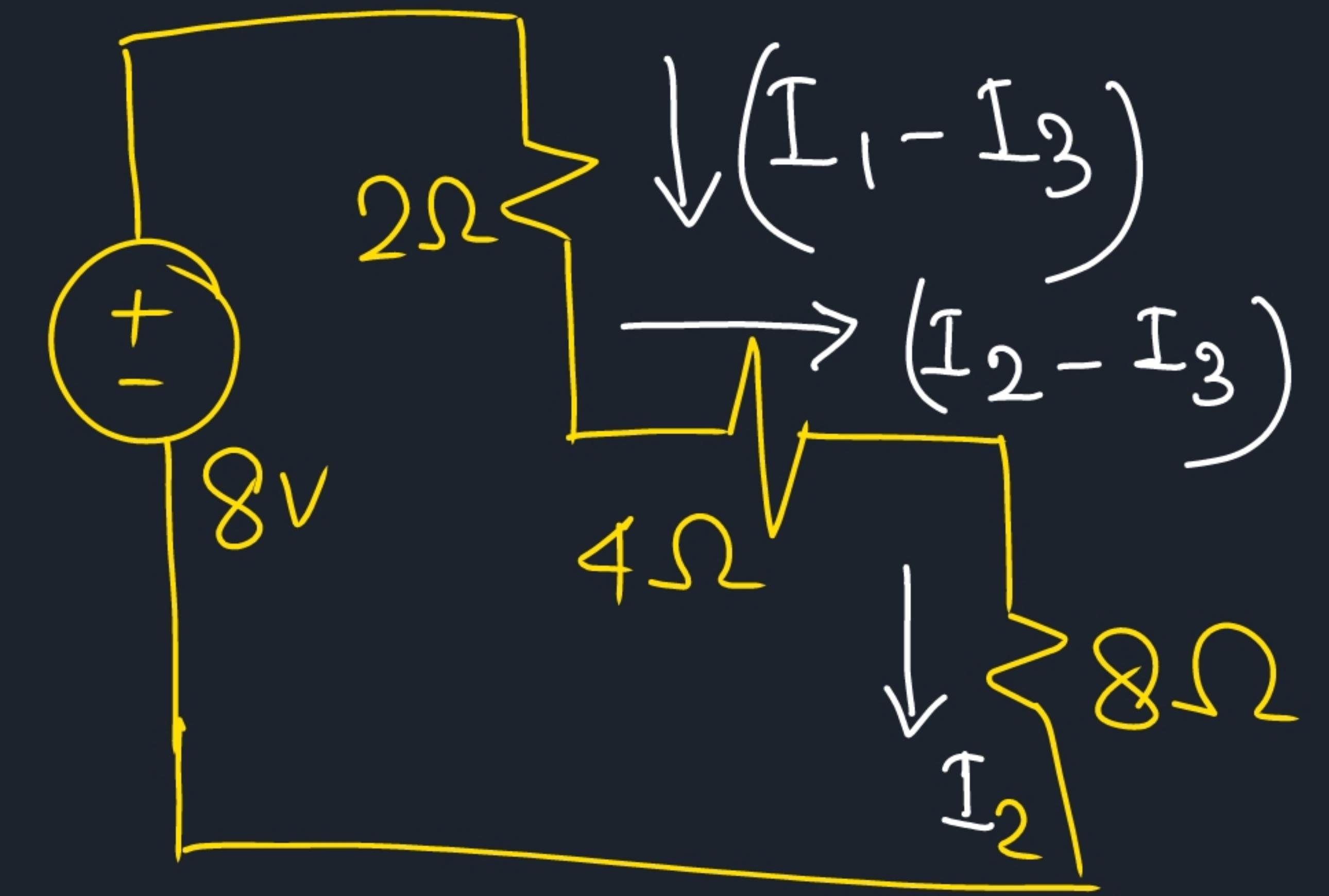
$$-2I_1 - 4I_2 + 8I_3 = 0 \dots \text{(i)}$$

$$I_1 - I_2 = 4 \dots \text{(ii)}$$

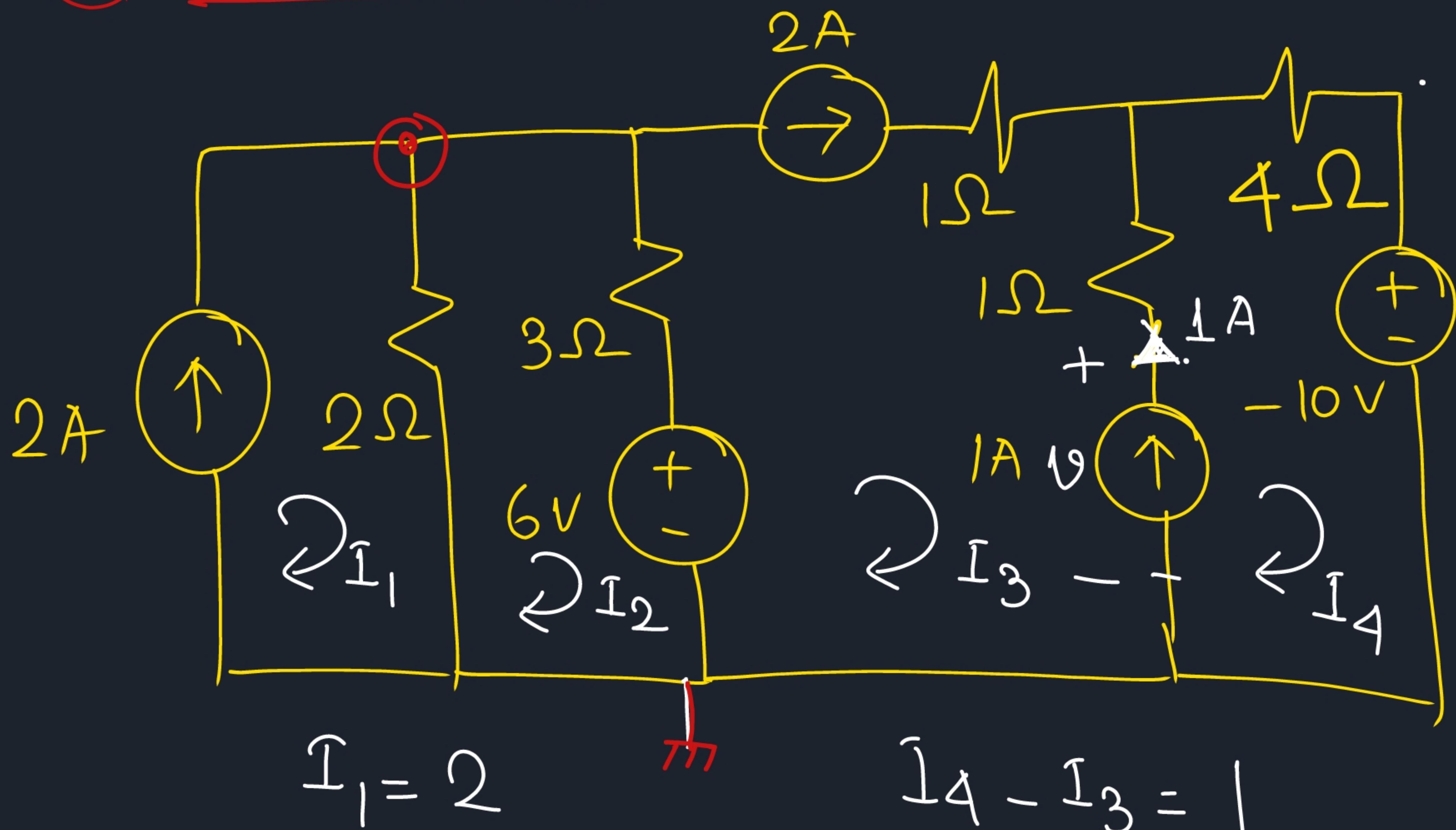
$$8 = 2(I_1 - I_3) + 4(I_2 - I_3) + 8I_2 \quad \dots \text{(iii)}$$

$$8 - 2(I_1 - I_3) + 10 - 1(4) = 0$$

$$\underline{\underline{V = ?}}$$



III Problem:-



$$I_1 = 2$$

$$I_4 - I_3 = 1$$

↓
2A

$$V - 1(+1) - 4 \times 3 + 10 = 0$$

$V = 3V$

$$\text{Power Delivered} = 3W$$

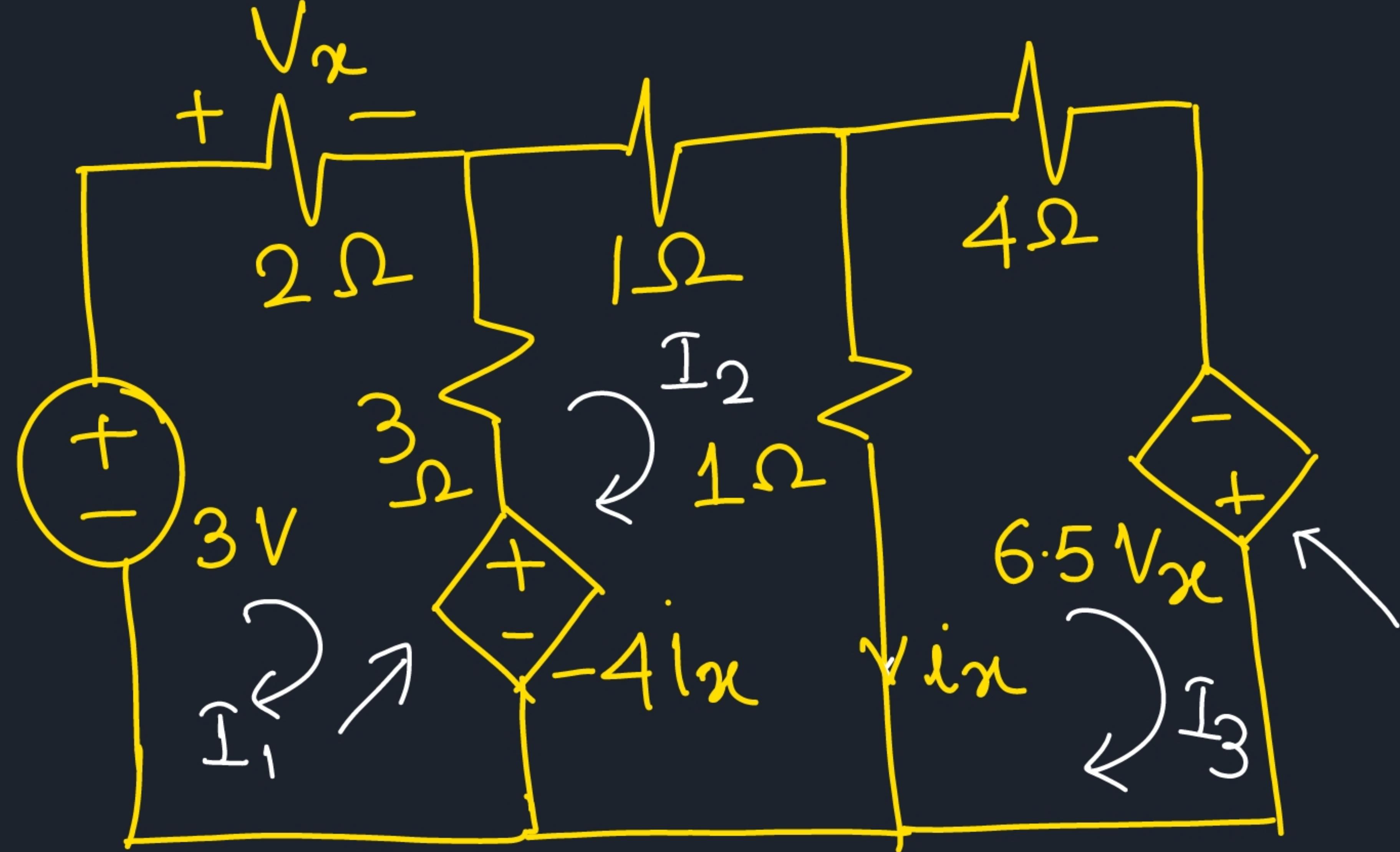
$$I_4 - I_3 = 1$$

$$I_4 = 3 \text{ Amps.}$$

$$-2(I_2 - 2) - 3(I_2 - 2) - 6 = 0$$

$I_2 = 0.8$

Problem:-



$$V_x = 2I_1$$

$$i_x = I_2 - I_3$$

$$I_1 = ? \text{ } 1A$$

$$I_2 = ? \text{ } 2A$$

$$I_3 = ? \text{ } 3A$$

$$\frac{\text{MESH-1 :-}}{3 - 2I_1 - 3(I_1 - I_2) - (-4(I_2 - I_3)) = 0} \quad \dots \dots \dots (i)$$

$$\frac{\text{MESH-2 :-}}{-4(I_2 - I_3) - 3(I_2 - I_1) - 1 \times I_2 - 1(I_2 - I_3) = 0} \quad \dots \dots \dots (ii)$$

$$\frac{\text{MESH-3 :-}}{-1 \times (I_3 - I_2) - 4I_3 + 6.5 \times 2I_1 = 0} \quad \dots \dots \dots (iii)$$

$$V_x = ? \text{ } 2 \text{ Volts}$$

$$i_x = ? \text{ } -1 \text{ Amps.}$$

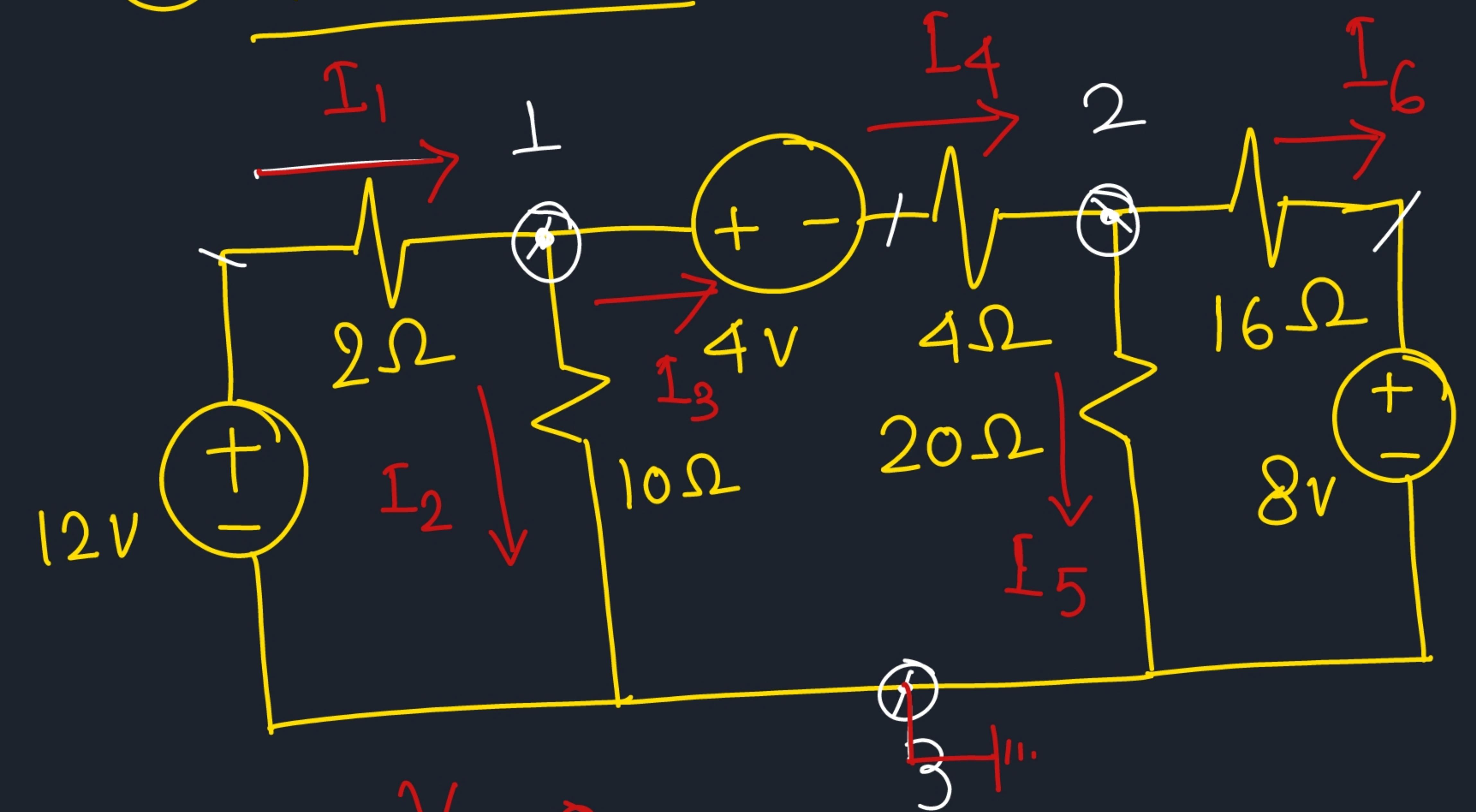
MESH ANALYSIS

1. Identify MESH -
2. Assume Random Mesh currents
3. Write KVL & Solve
4. Get actual Values of branch currents.

NODAL ANALYSIS

1. Identify nodes.
2. Assume the node voltages.
3. Write KCL & solve.
4. - - - - - node voltage.

Problem :-



$$V_3 = 0$$

$$V_1 = ? \quad 9.82 \text{ V}$$

$$V_2 = ? \quad 5.39 \text{ V}$$

NODE - 1 :-

$$I_1 = I_2 + I_3$$

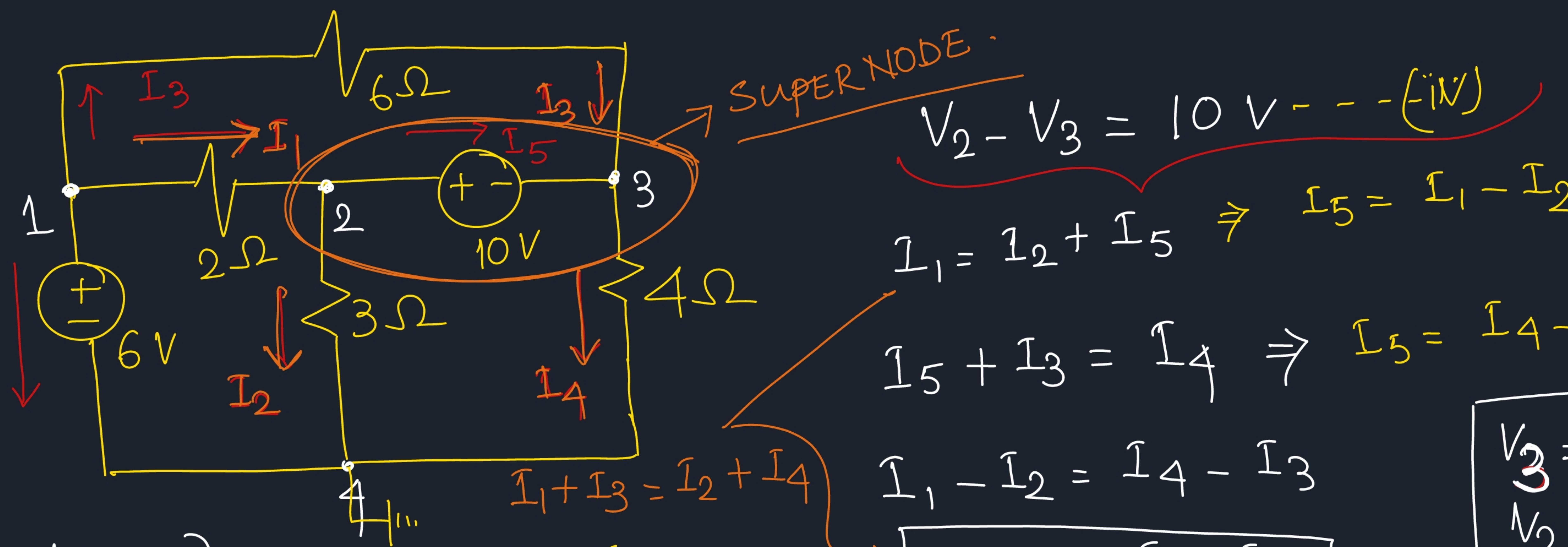
$$\Rightarrow \frac{12 - V_1}{2} = \frac{V_1}{10} + \frac{V_1 - V_2 - 4}{4}$$

NODE - 2 :-

$$I_4 = I_5 + I_6$$

$$\Rightarrow \frac{V_1 - V_2 - 4}{4} = \frac{V_2}{20} + \frac{V_2 - 8}{16} \quad \dots \text{--- (ii)}$$

$$-V_1\left(\frac{1}{4}\right) + V_2\left(\frac{1}{4} + \frac{1}{20} + \frac{1}{16}\right) = \frac{8}{16} - \frac{4}{4} \quad \dots \text{--- (iii)}$$



$$\left. \begin{array}{l} V_1 = ? \\ V_2 = ? \\ V_3 = ? \end{array} \right\}$$

$$V_1 = 6V \quad \dots (i)$$

$$I_1 + I_3 = I_2 + I_4 \quad \text{--- (ii)}$$

$$\Rightarrow I_1 + I_3 = I_2 + I_4$$

$$\Rightarrow \frac{V_1 - V_2}{2} + \frac{V_1 - V_3}{6} = \frac{V_2}{3} + \frac{V_3}{4} \quad \dots (v)$$

$$\Rightarrow V_1 \left(\frac{1}{2} + \frac{1}{6} \right) - V_2 \left(\frac{1}{2} + \frac{1}{3} \right) - V_3 \left(\frac{1}{6} + \frac{1}{4} \right) = 0 \quad \text{--- (vi)}$$

SUPER NODE :

$$V_2 - V_3 = 10V \quad \dots (\text{vii})$$

$$I_1 = I_2 + I_5 \Rightarrow I_5 = I_1 - I_2 \quad \dots (i)$$

$$I_5 + I_3 = I_4 \Rightarrow I_5 = I_4 - I_3 \quad \dots (ii)$$

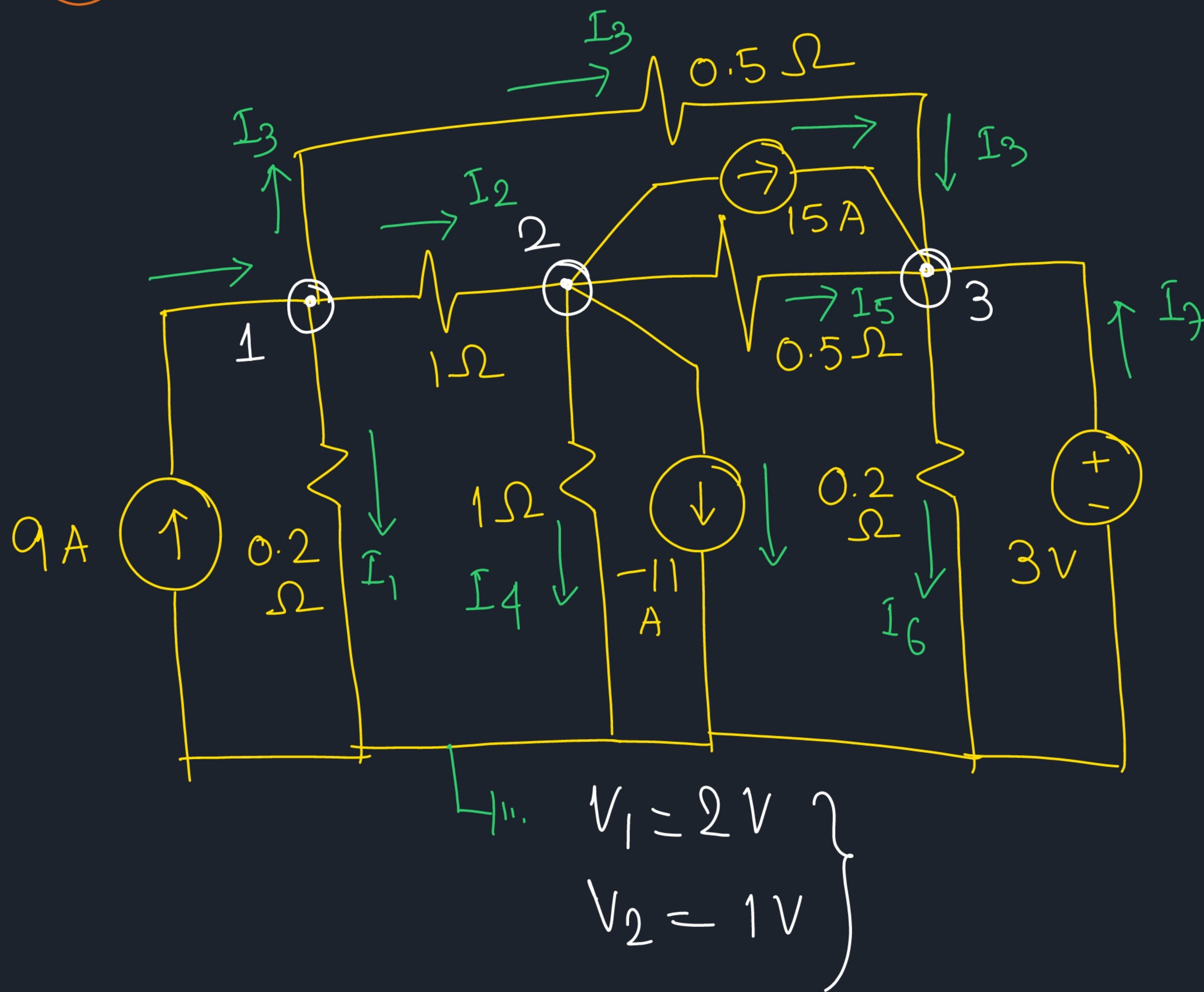
$$\boxed{\begin{array}{l} V_3 = -3.4667V \\ V_2 = 6.53V \end{array}}$$

$$I_5 = ? \quad \frac{V_1 - V_2}{2} - \frac{V_2}{3}$$

$$-1.644A$$

111

Problem:-



NODE-1

$$I_1 + I_2 + I_3 = 9$$

$$\Rightarrow \frac{V_1}{0.2} + \frac{V_1 - V_2}{1} + \frac{V_1 - V_3}{0.5} = 9 \dots (i)$$

NODE-2

$$I_2 = I_4 + I_5 + 15 - 11$$

$$\Rightarrow I_2 - I_4 - I_5 = 4$$

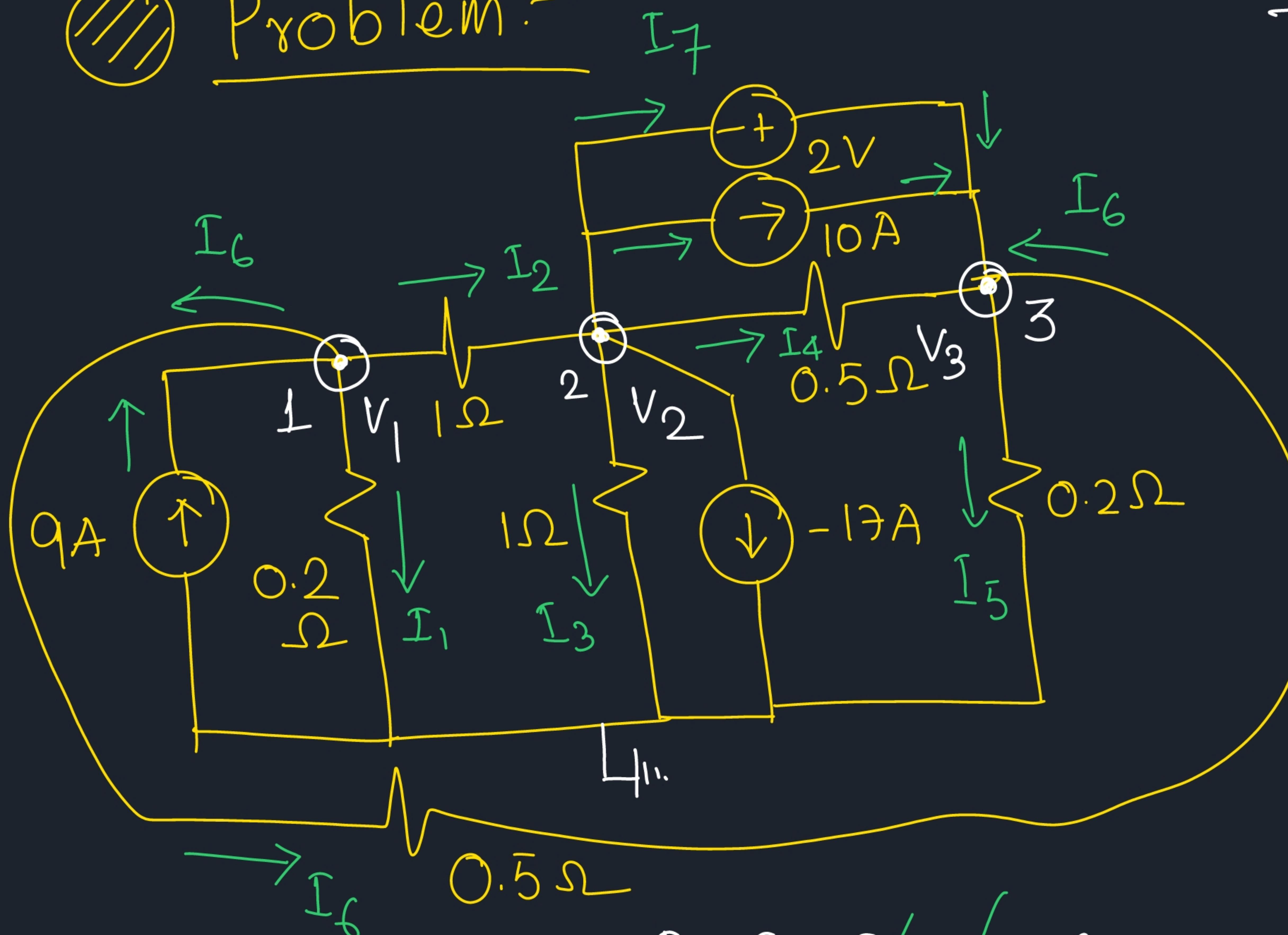
$$\Rightarrow \frac{V_1 - V_2}{1} - \frac{V_2}{1} - \frac{V_2 - V_3}{0.5} = 4 \dots (ii)$$

NODE-3

$$V_3 = 3V \dots (iii)$$



Problem:-



$$\begin{aligned} &I_2 - I_3 - I_4 - 10 - (-17) \\ &= I_5 - I_4 - I_6 - 10 \end{aligned}$$

NODE-1

$$I = I_1 + I_2 + I_6$$

$$I = \frac{V_1}{0.2} + \frac{V_1 - V_2}{1} + \frac{V_1 - V_3}{0.5} \dots (i)$$

NODE-2

$$I_2 = I_3 + I_4 + 10 - I_7$$

$$I_7 = I_2 - I_3 - I_4 - 10 - (-17) \dots (ii)$$

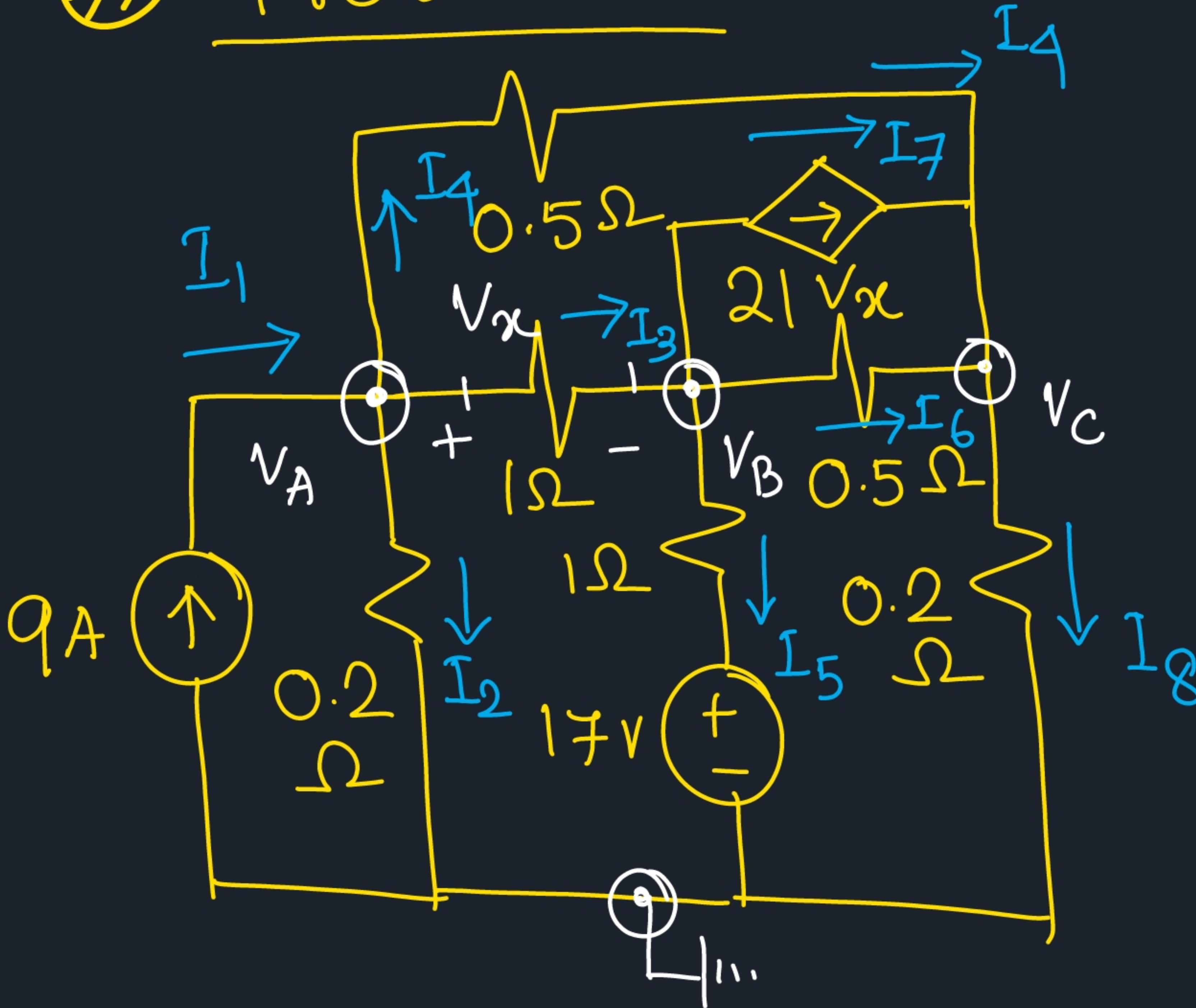
NODE-3

$$I_4 + I_6 + 10 + I_7 = I_5$$

$$\Rightarrow I_7 = I_5 - I_4 - I_6 - 10 \dots (iii)$$

$$\boxed{I_2 + I_6 = I_5 + I_3 + (-17)}$$

 Problem:-



$$V_x = V_A - V_B$$

$$V_A = 2V$$

$$V_B = 1V$$

$$V_C = 3V$$

& NODE-A :-

$$I_1 = I_2 + I_3 + I_4$$

$$\Rightarrow q = \frac{V_A}{0.2} + \frac{V_A - V_B}{1} + \frac{V_A - V_C}{0.5}$$

$$\Rightarrow V_A \left(\frac{1}{0.2} + \frac{1}{1} + \frac{1}{0.5} \right) - V_B \left(\frac{1}{1} \right) - V_C \left(\frac{1}{0.5} \right) = q \dots \dots (i)$$

& NODE-B :- $I_3 = I_5 + I_6 + I_7$

$$\Rightarrow \frac{V_A - V_B}{1} = \frac{V_B - V_C}{0.5} + 21(V_A - V_B)$$

$$\Rightarrow V_A \left(-\frac{1}{1} + 21 \right) + V_B \left(\frac{1}{1} + \frac{1}{0.5} - 21 \right) + V_C \left(-\frac{1}{0.5} \right) = 17 \dots \dots (ii)$$

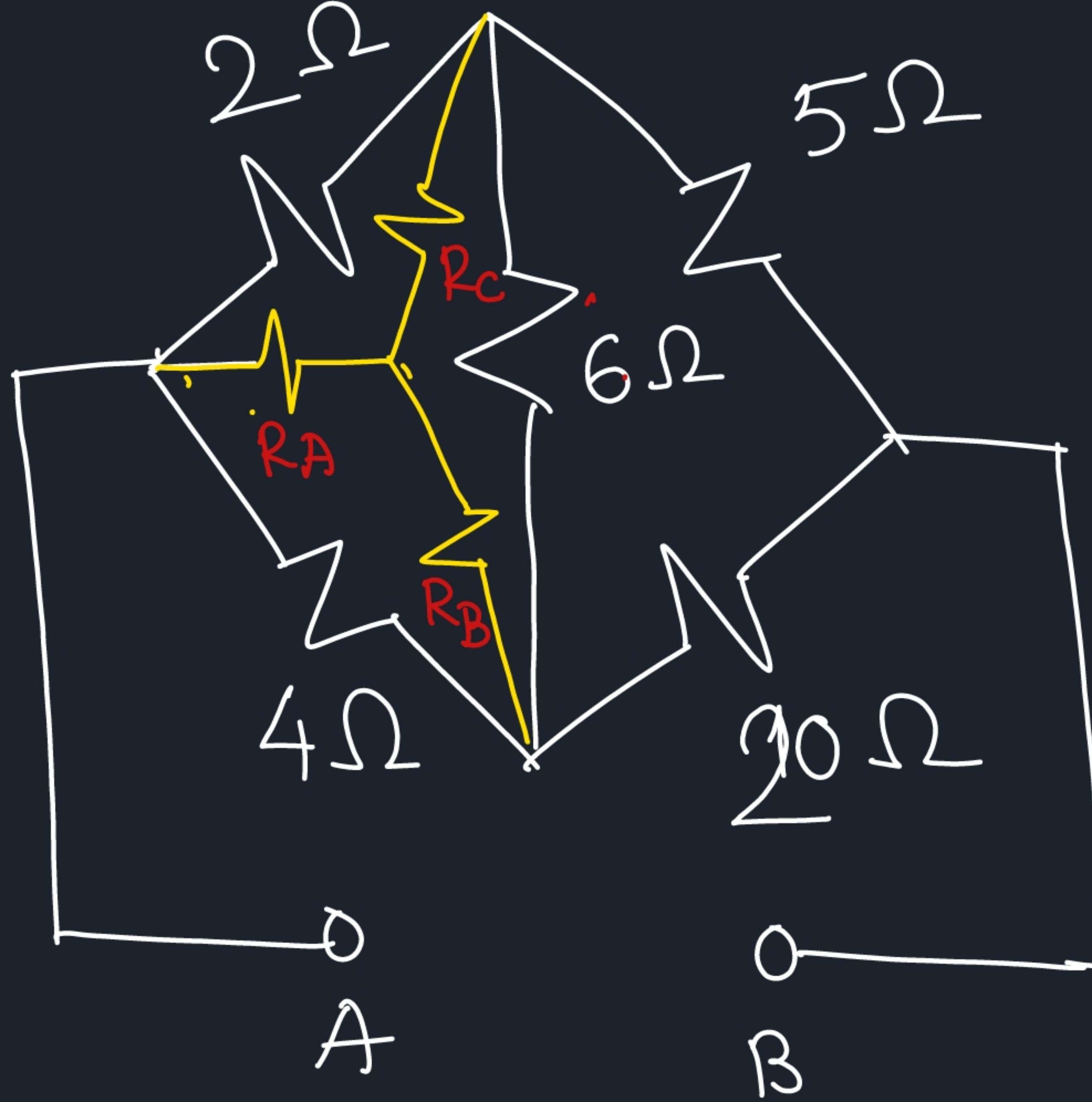
& NODE-C :- $I_6 + I_7 + I_4 - I_8 = 0$

$$\Rightarrow \frac{V_B - V_C}{0.5} + 21(V_A - V_B) + \frac{V_A - V_C}{0.5} - \frac{V_C}{0.2} = 0$$

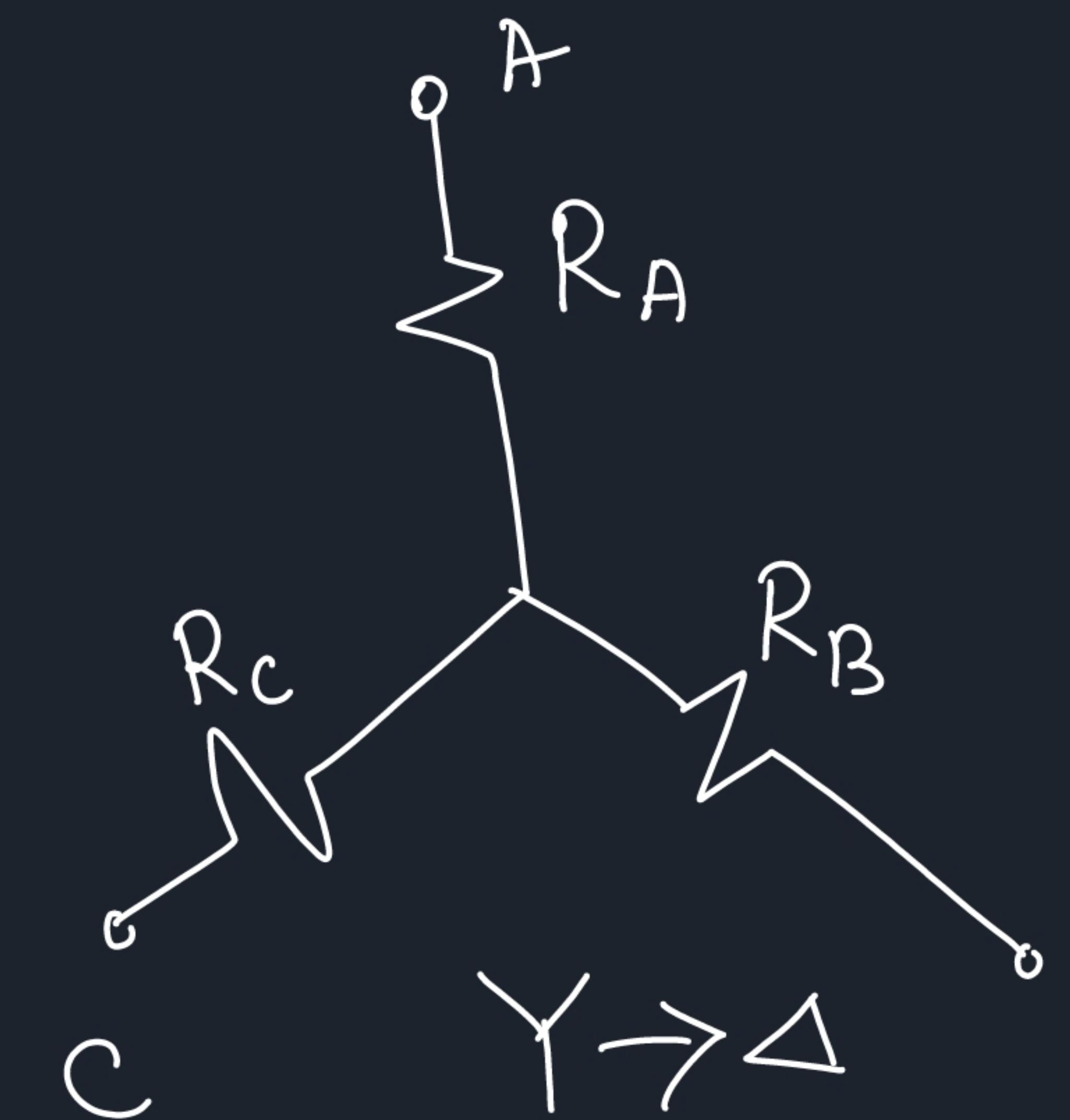
$$\Rightarrow V_A \left(21 + \frac{1}{0.5} \right) + V_B \left(\frac{1}{0.5} - 21 \right) + V_C \left(-\frac{1}{0.5} - \frac{1}{0.5} - \frac{1}{0.2} \right) = 0 \dots \dots (iii)$$



Star-Delta Transform :-



$$R_A = \frac{2 \times 4}{2+4+6}, \quad R_B = \frac{4 \times 6}{2+4+6}, \quad R_C = \frac{2 \times 6}{2+4+6}$$

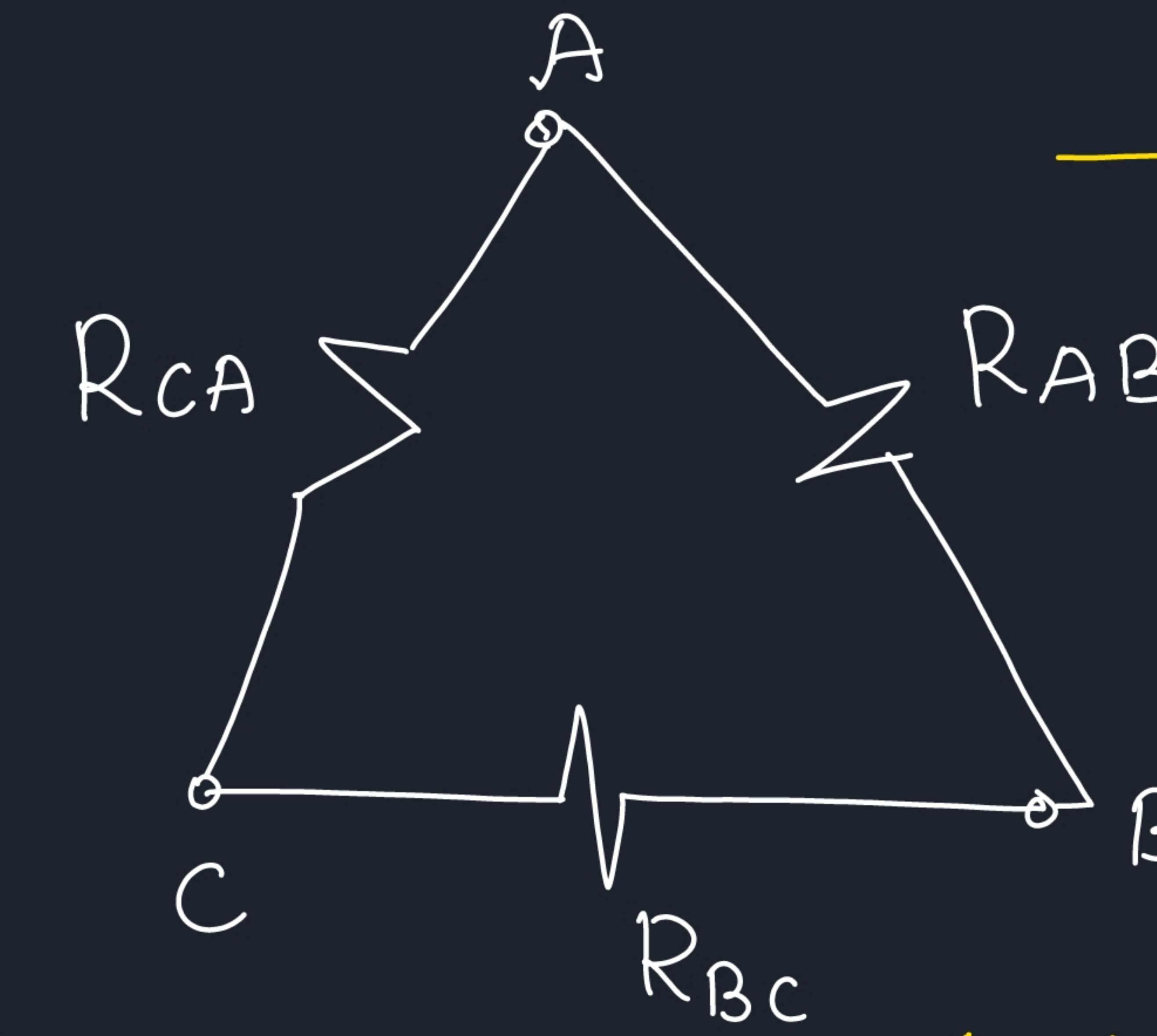


$\Delta \rightarrow Y$

$$R_{AB} = R_A + R_B + \frac{R_A \cdot R_B}{R_C}$$

$$R_{BC} = R_B + R_C + \frac{R_B \cdot R_C}{R_A}$$

$$R_{CA} = R_C + R_A + \frac{R_C \cdot R_A}{R_B}$$

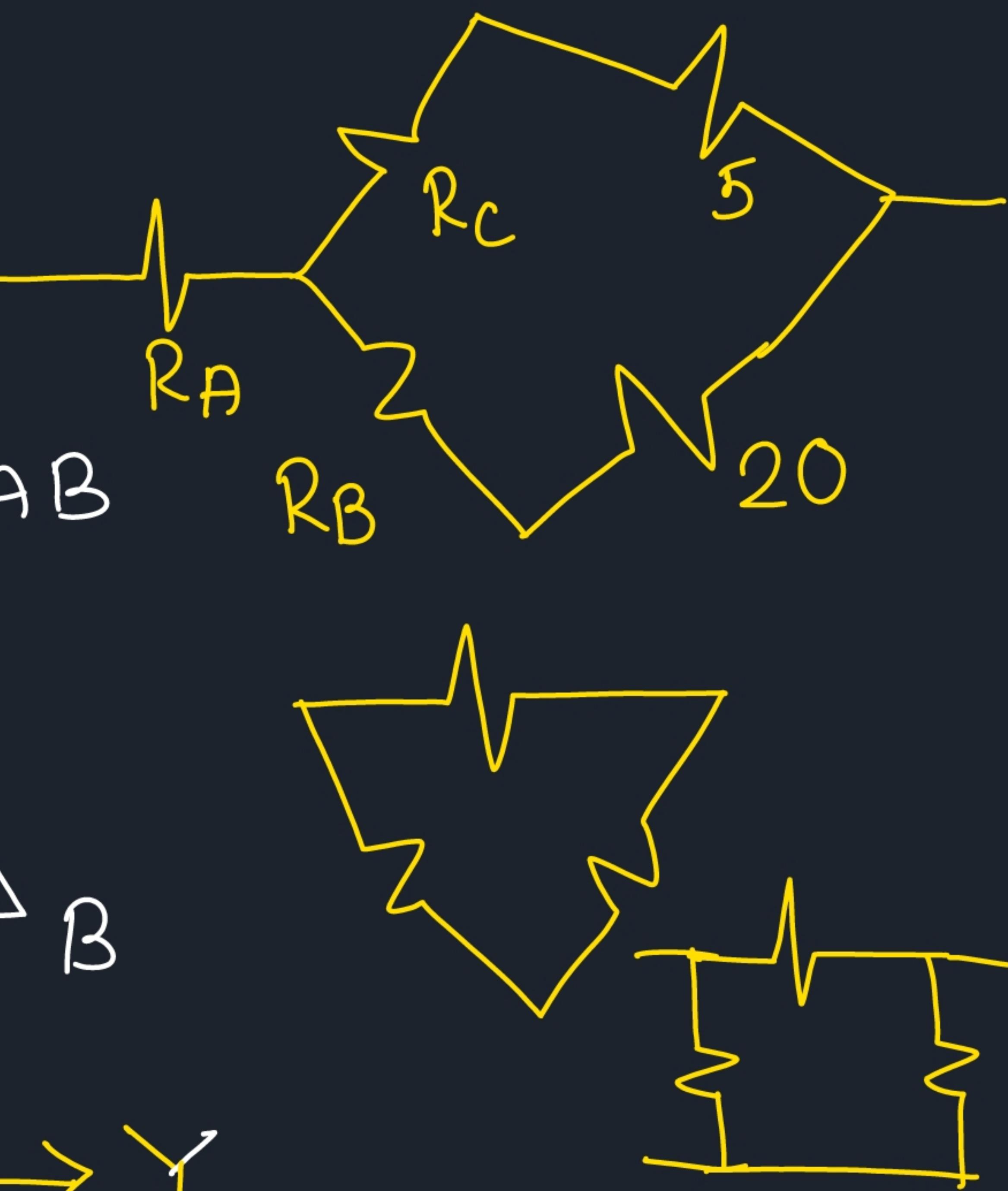


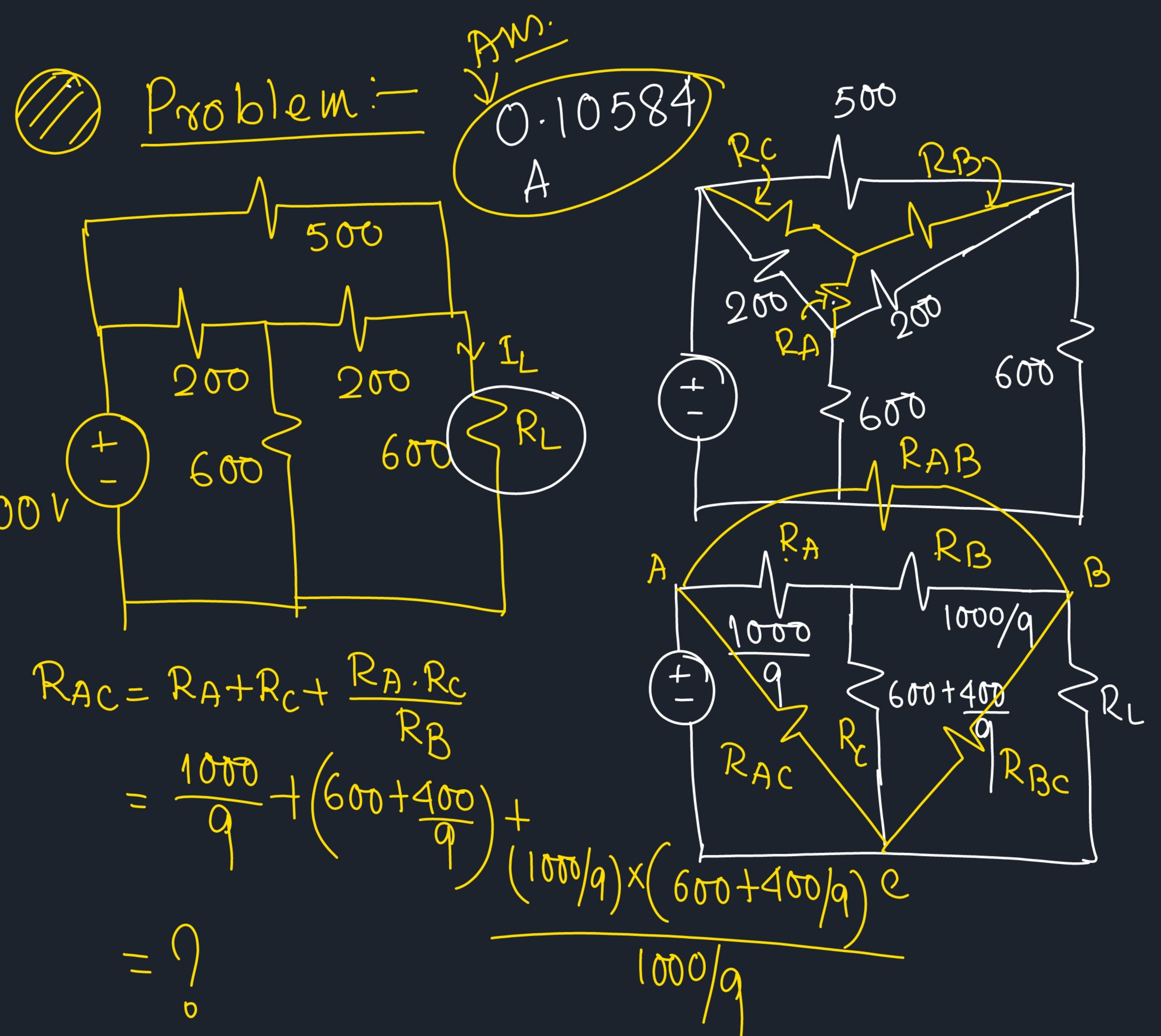
$Y \rightarrow \Delta$

$$R_A = \frac{R_{AB} \cdot R_{CA}}{R_{AB} + R_{BC} + R_{CA}}$$

$$R_B = \frac{R_{AB} \cdot R_{BC}}{R_{AB} + R_{BC} + R_{CA}}$$

$$R_C = \frac{R_{BC} \cdot R_{CA}}{R_{AB} + R_{BC} + R_{CA}}$$





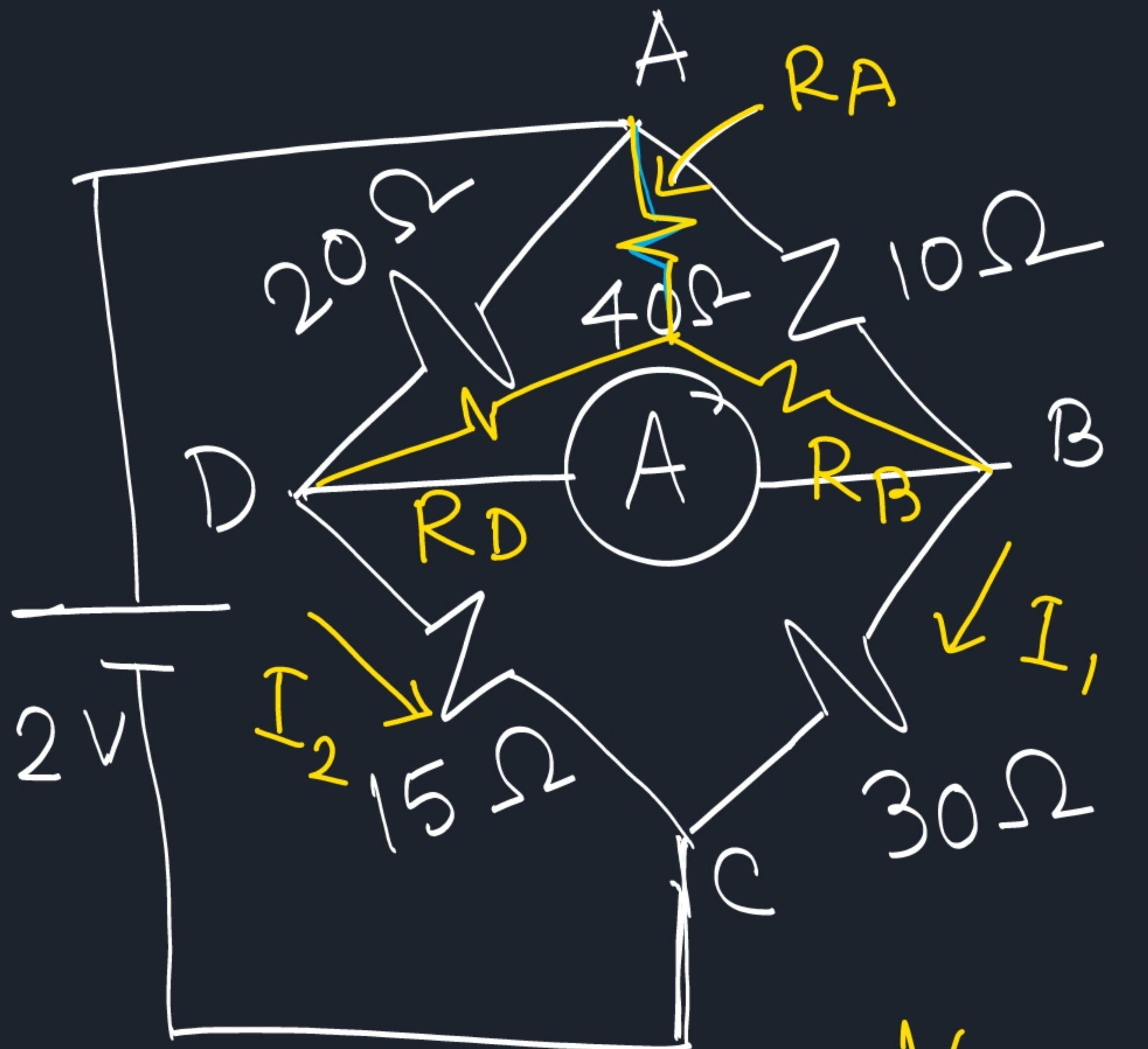
$R_A = \frac{200 \times 200}{200 + 200 + 500} = ? \quad \frac{400}{9} \Omega$

$R_B = \frac{200 \times 500}{900} = \frac{1000}{9} \Omega$

$R_C = \frac{1000}{9} \Omega$

$I_L = \frac{100}{R_{AB} + R_{BC} || R_L} \times \frac{R_{BC}}{R_{BC} + R_L}$

Problem :-



$$\frac{V_{BD}}{40}$$

$$= 11.4649 \text{ mA.} \quad \text{Ans}$$

$$V_{BD} = ?$$

$$V_B - V_D = V_{BD}$$

$$V_{BD} = V_B - V_C - V_D + V_C$$

$$= V_{BC} - V_{DC}$$

$$= (I_1 \times 30 - I_2 \times 15) \text{ Volt}$$

=

$$R_A = \frac{20 \times 10}{20 + 10 + 40} = ? \quad \frac{20}{7}$$

$$R_B = \frac{40}{7} \quad R_D = \frac{80}{7}$$

$$I_1 = ?$$

$$I_2 = ?$$

$$I = ?$$

