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

Relaxation Time

Random Motion + Organized Motion.

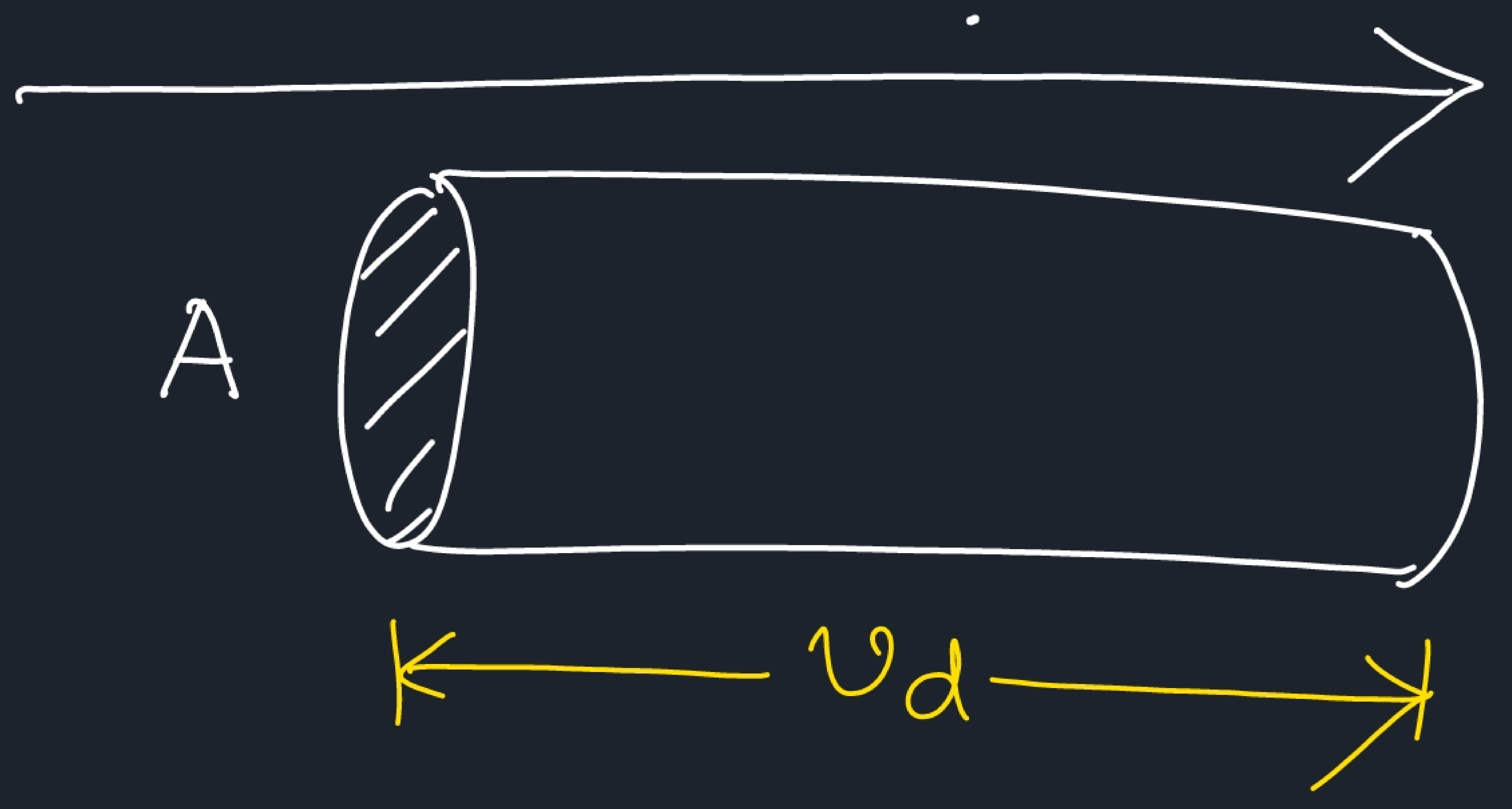
N_e

$$\boxed{\vec{J} = \sigma \vec{E}} \Rightarrow \text{OHM's Law.}$$

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

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

$$\frac{I}{A} = \sigma \frac{V}{l} \qquad I = \frac{A}{l}\frac{1}{\rho} V$$



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

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

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

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

$$\boxed{V = RI}$$

Problem:-

Cu wire

$A = 4\, mm^2$

$l = 4\, m$

$I = 10\, A$

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

$v_d = ?$

$I = N_e e A v_d$

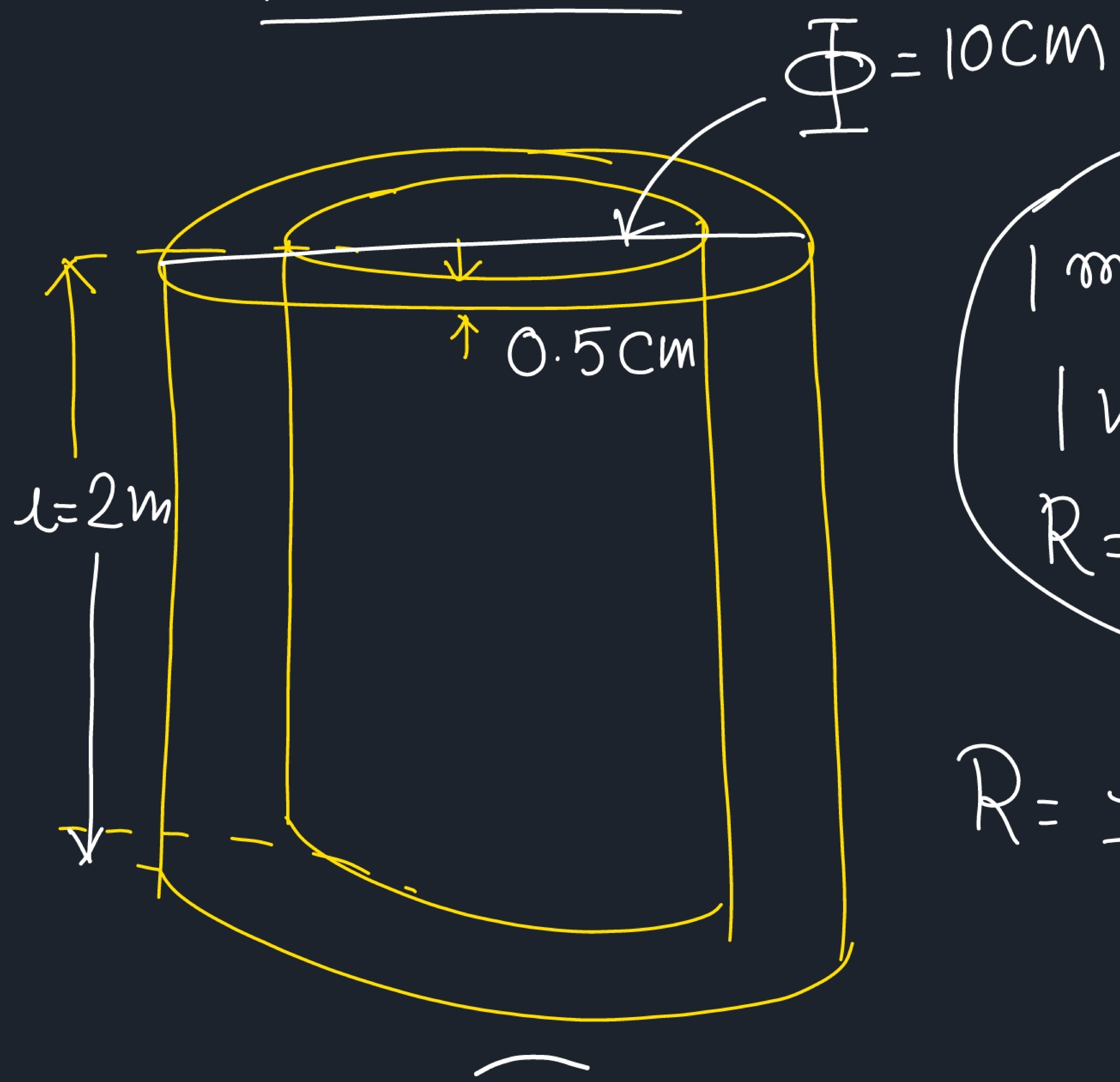
$$v_d = \frac{I}{N_e e A}$$

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

$$= 1.95 \times 10^{-4}\; m/sec.$$

0.000195

Problem:-



$\rho_{cu} = ?$

1m length of
$1 mm^2$ of cu tube
$R = 0.015\ \Omega$

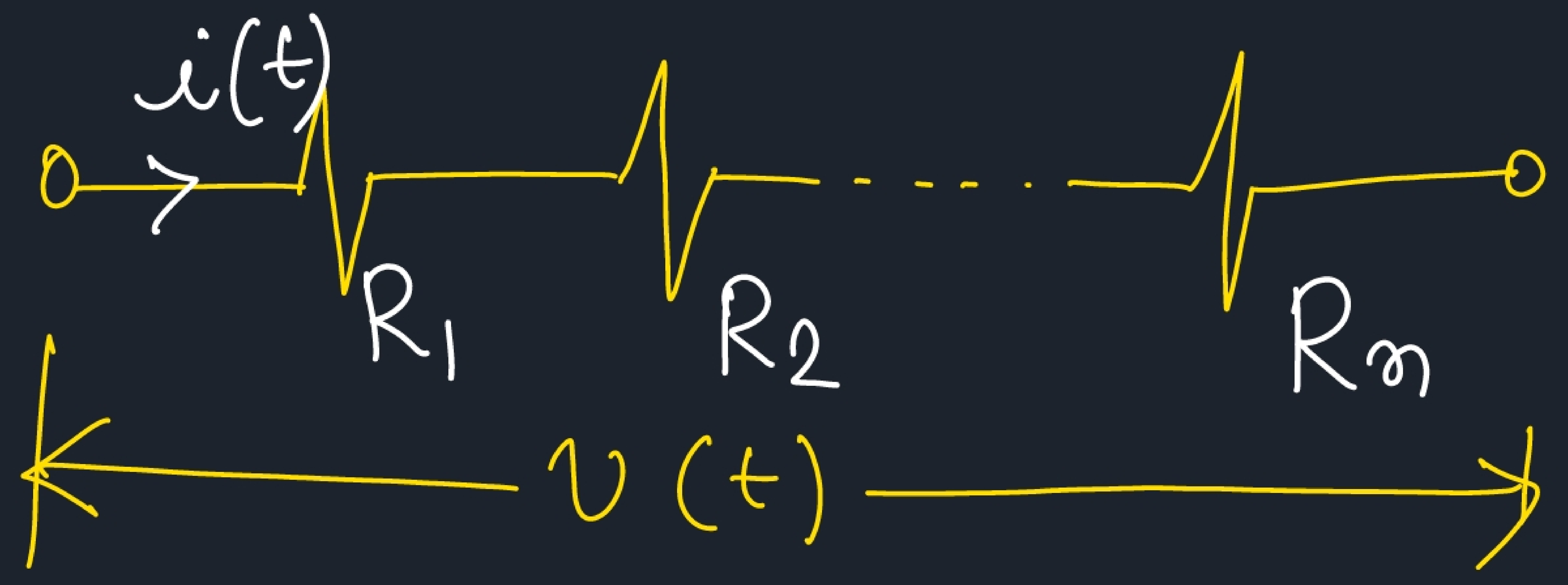
$$R = \frac{\rho l}{A}$$

$$\rho = \frac{RA}{l}$$

$$= \frac{0.015 \times 1 \times 10^{-6}}{1}$$

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

$$A = \pi \left\{ r_{ext}^2 - r_{int}^2 \right\} = ? \quad 20.1038 \times 10^{-6}\ \Omega$$



$$v(t) = v_1(t) + v_2(t) + \dots + v_n(t)$$

$$= i(t)R_1 + i(t)R_2 + \dots + i(t)R_n$$

$$= \underbrace{\left(\sum_{j=1}^{n} R_j\right)}_{R^{S}_{eq}} i(t)$$

$$v_1(t) : v_2(t) : \dots : v_n(t)$$

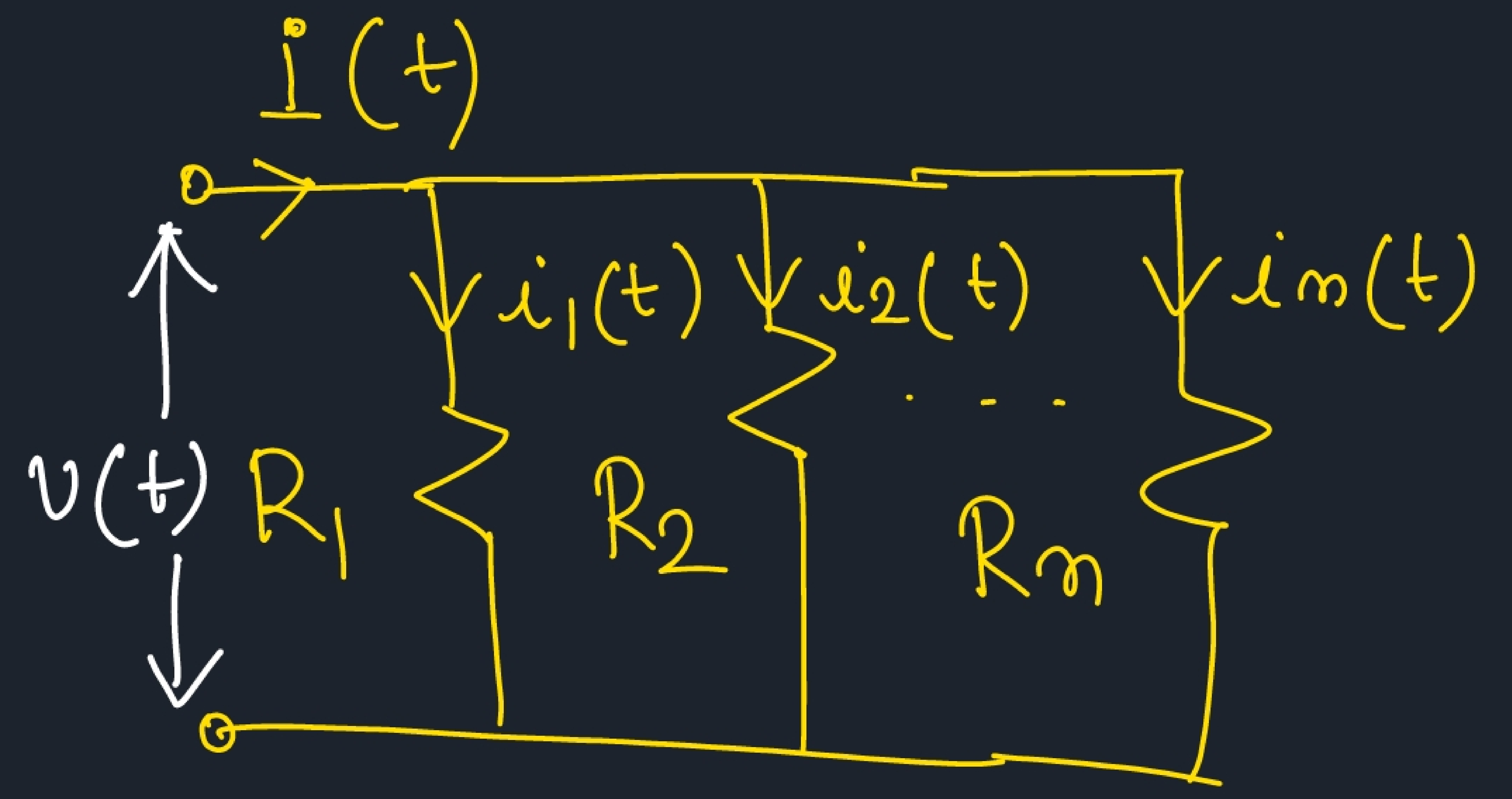
$$= R_1 : R_2 : \dots : R_n$$

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

$$p_1(t) : p_2(t) \dots p_n(t)$$

$$= R_1 : R_2 : \dots : R_n$$

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



$$i(t) = i_1(t) + i_2(t) + \dots + i_n(t)$$

$$= \frac{v(t)}{R_1} + \frac{v(t)}{R_2} + \dots + \frac{v(t)}{R_n}$$

$$= v(t) \sum_{j=1}^{n} \frac{1}{R_j} \rightarrow R_{eq}^{P}$$

$$i_1(t) : i_2(t) \dots i_n(t)$$

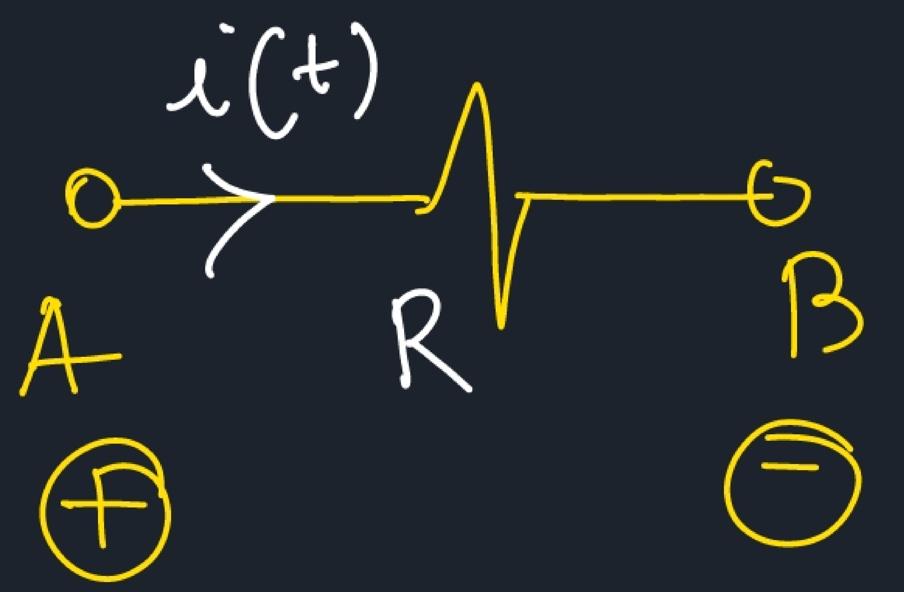
$$= G_1 : G_2 \dots : G_n$$

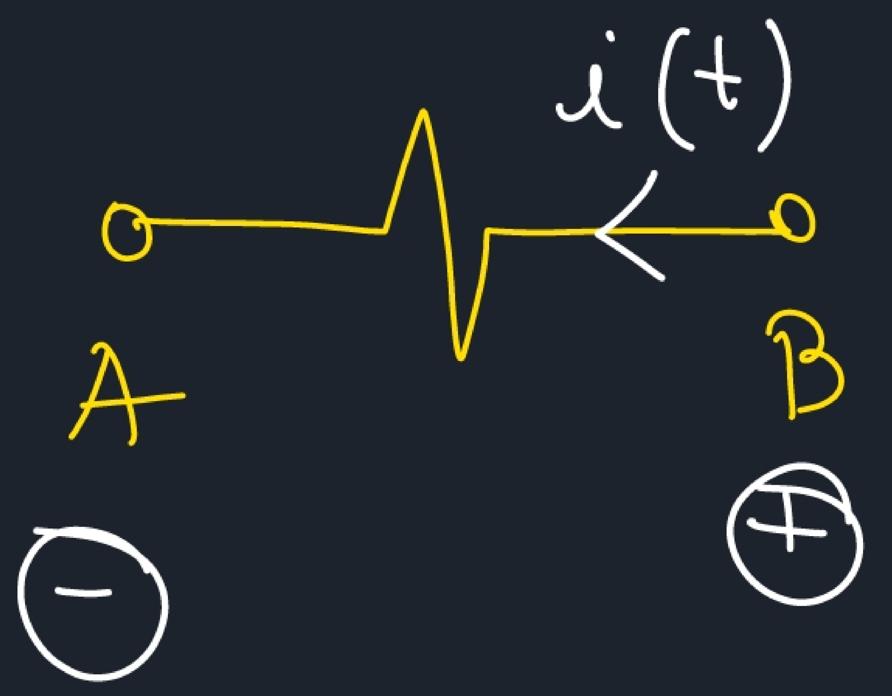
$$\boxed{i_m(t) = \frac{G_m}{\sum_{j=1}^{n} G_j} i(t)}$$

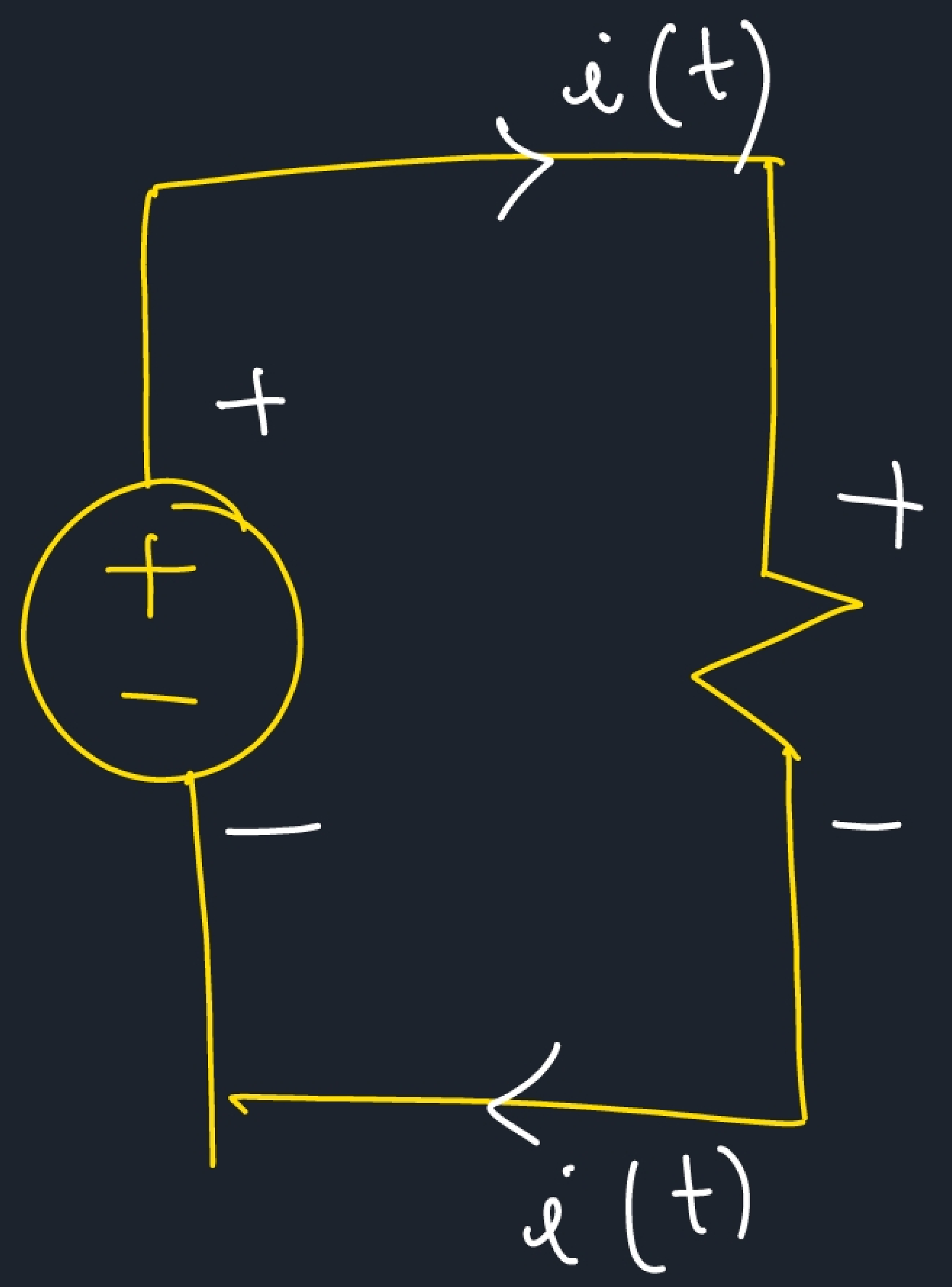
$$p_1(t) : p_2(t) \dots p_n(t)$$

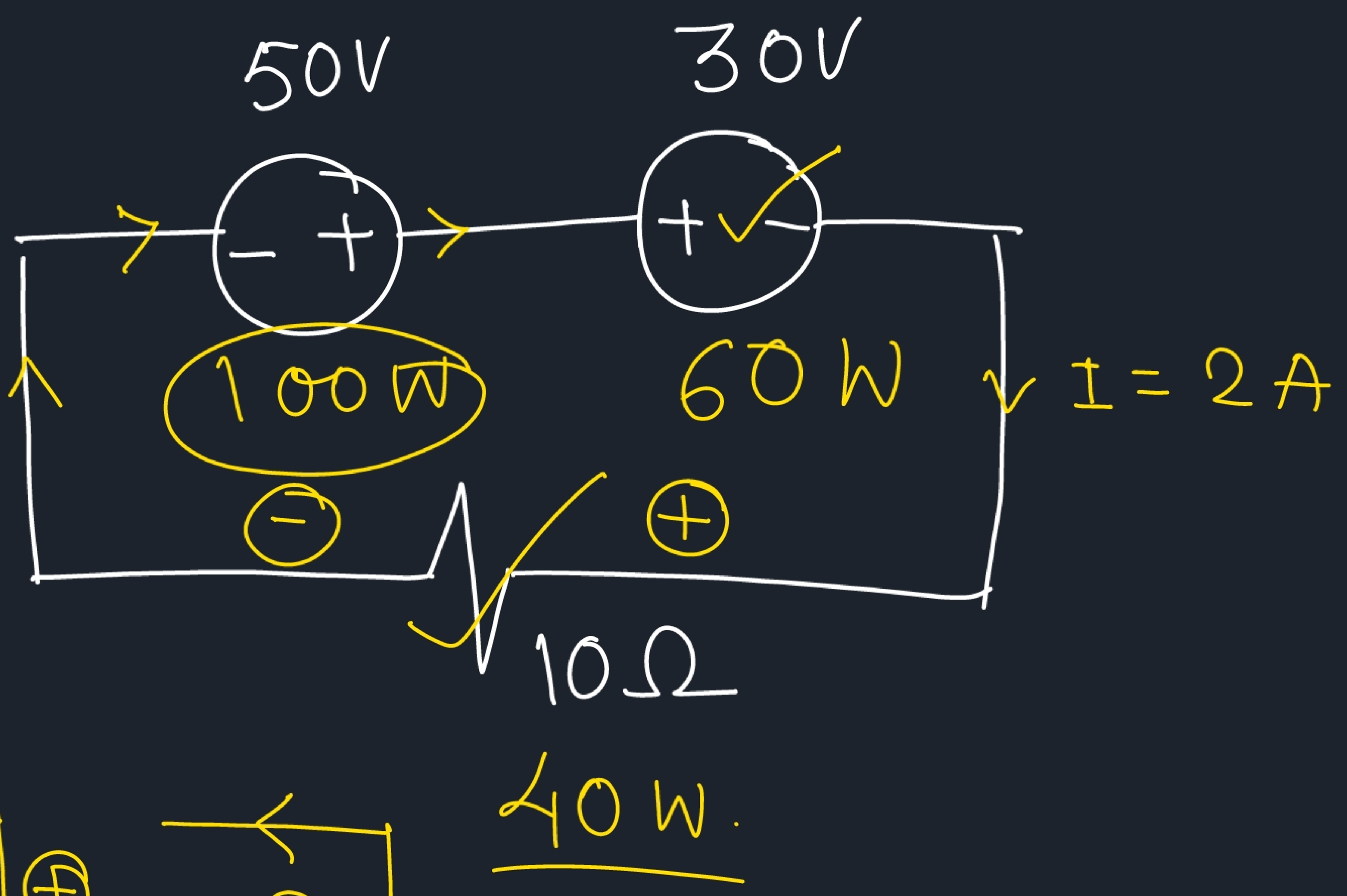
$$= G_1 : G_2 \dots : G_n$$

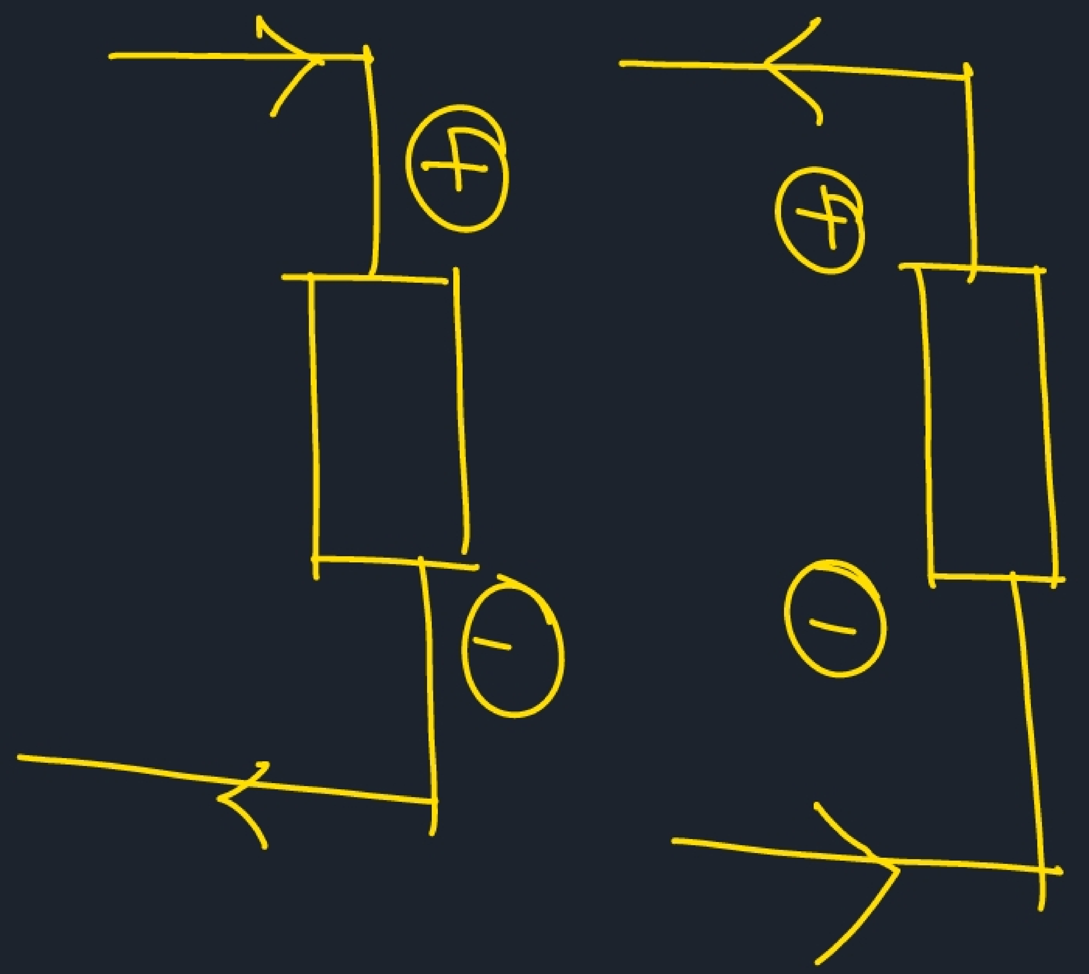
$$p_m(t) = \frac{G_m}{\sum_{j=1}^{n} G_j} p(t)$$

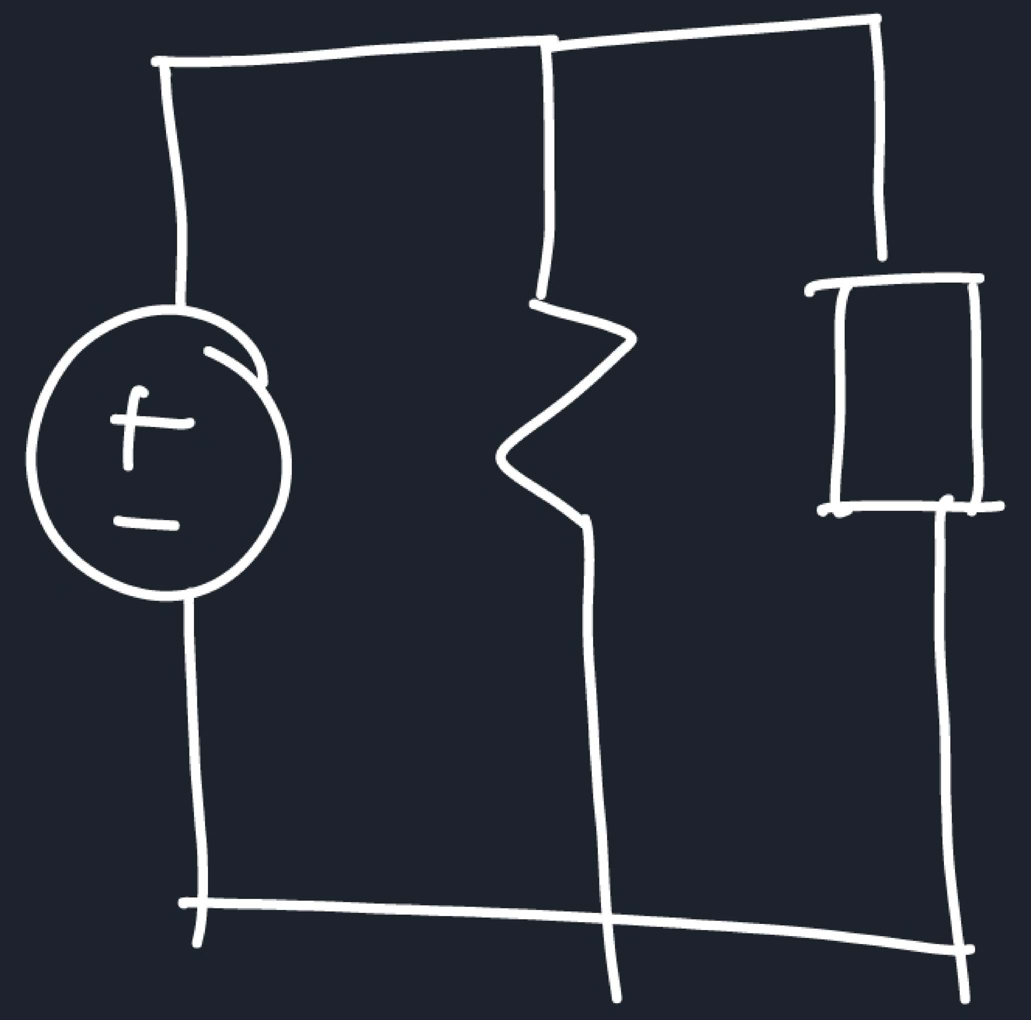

i(t)
R
A
B
+
−

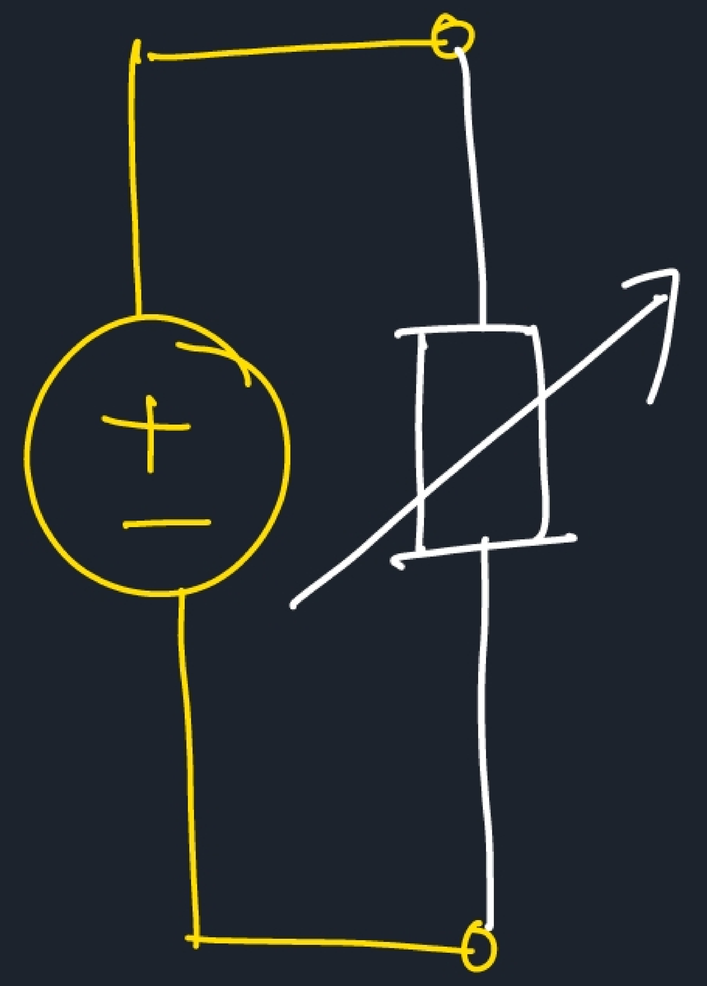

i(t)
A
B
−
+

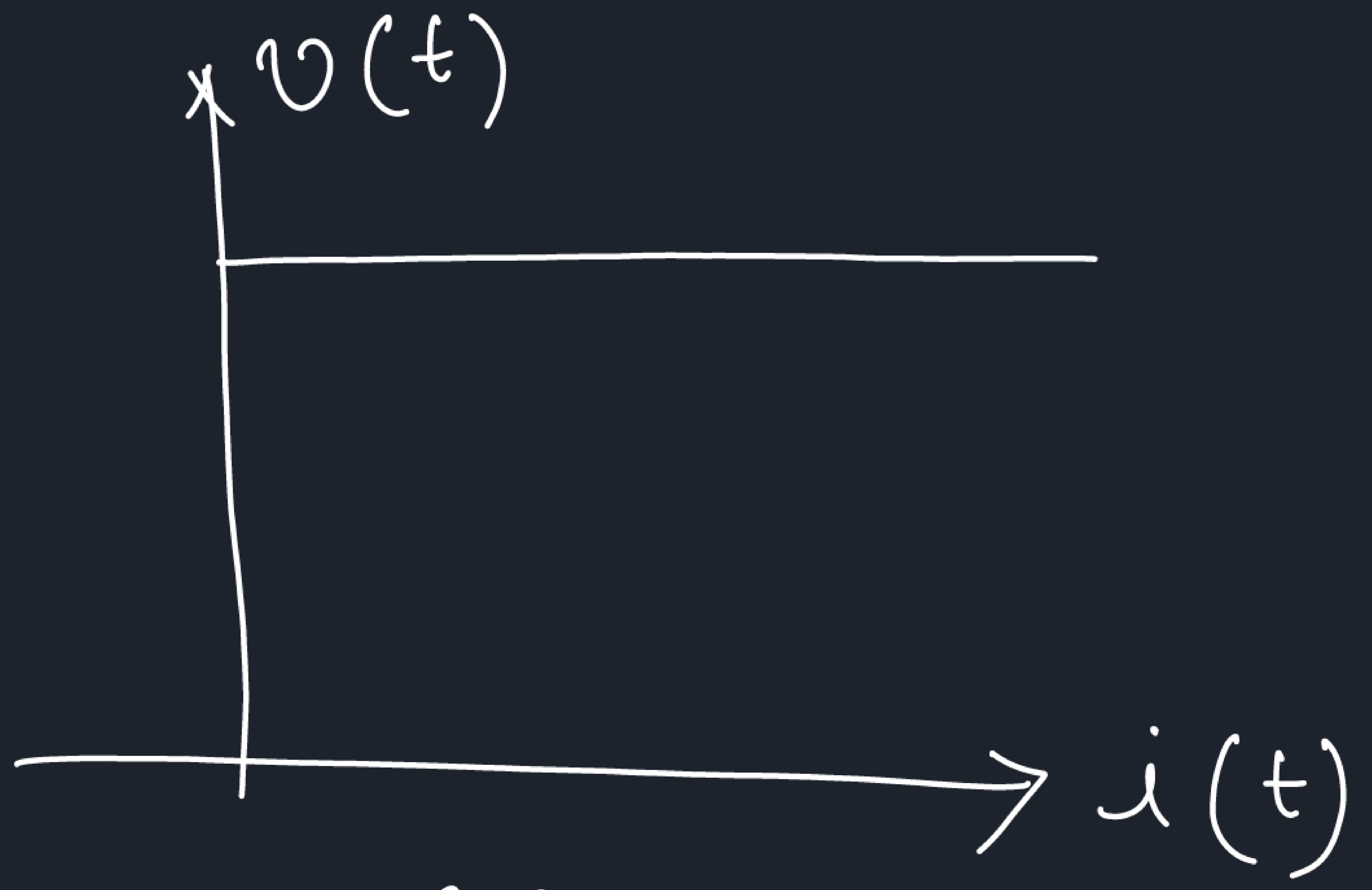

i(t)
+
−
+
−
i(t)

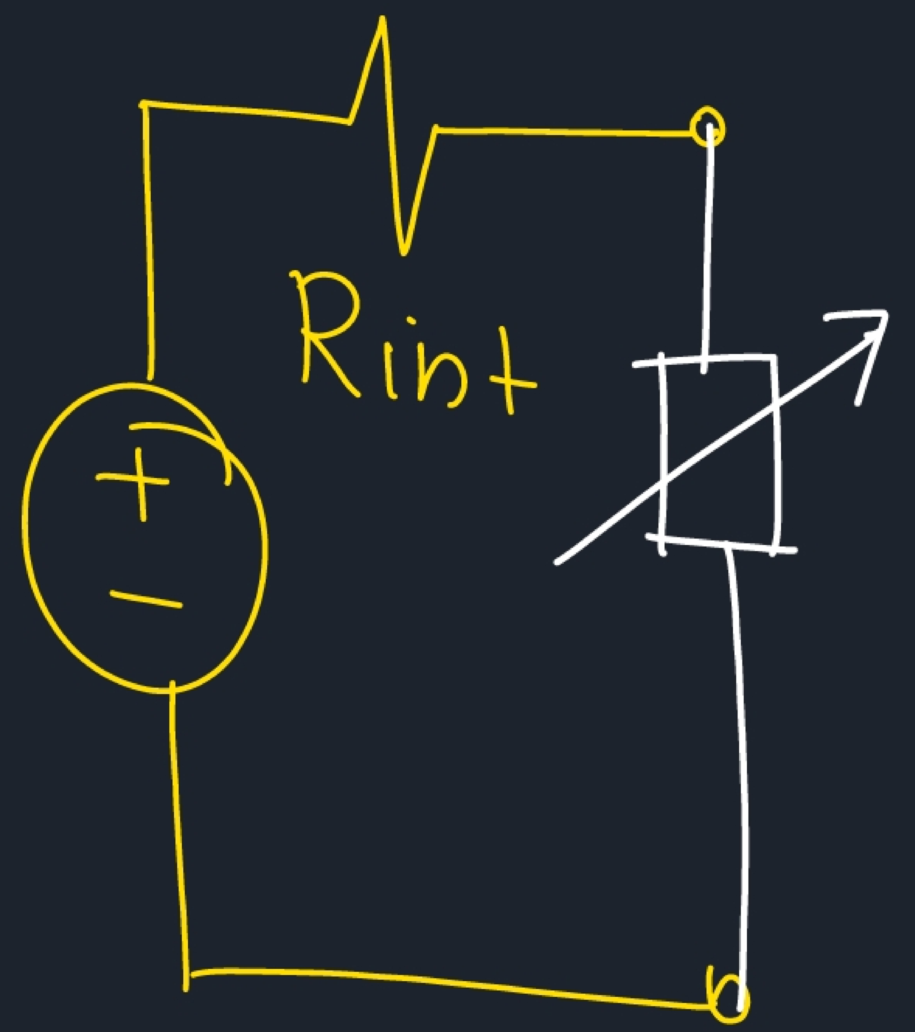

50V
30V
− +
+ −
100W
60W
I = 2A
−
+
10Ω
40W.

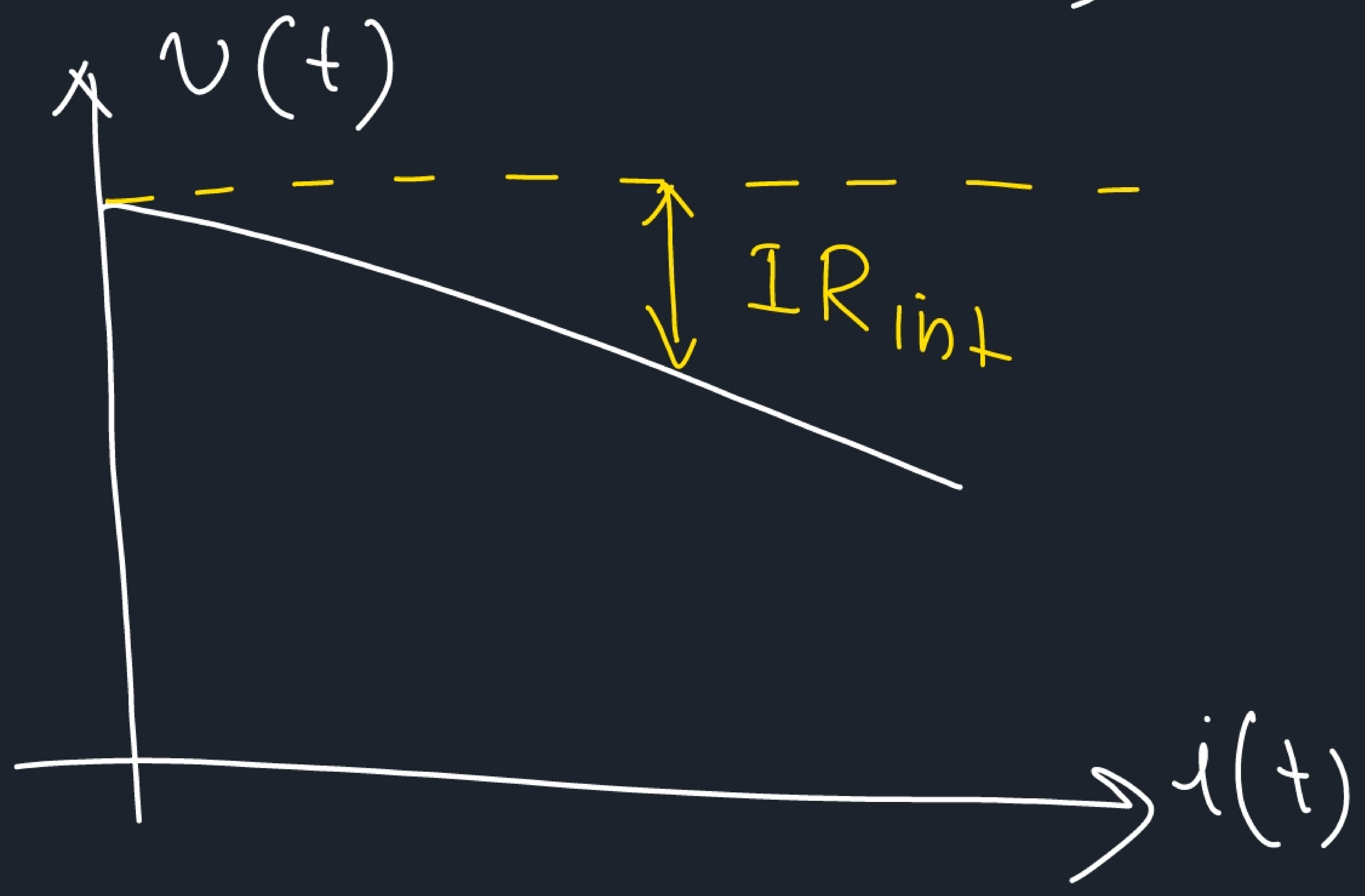

+
−
+
−





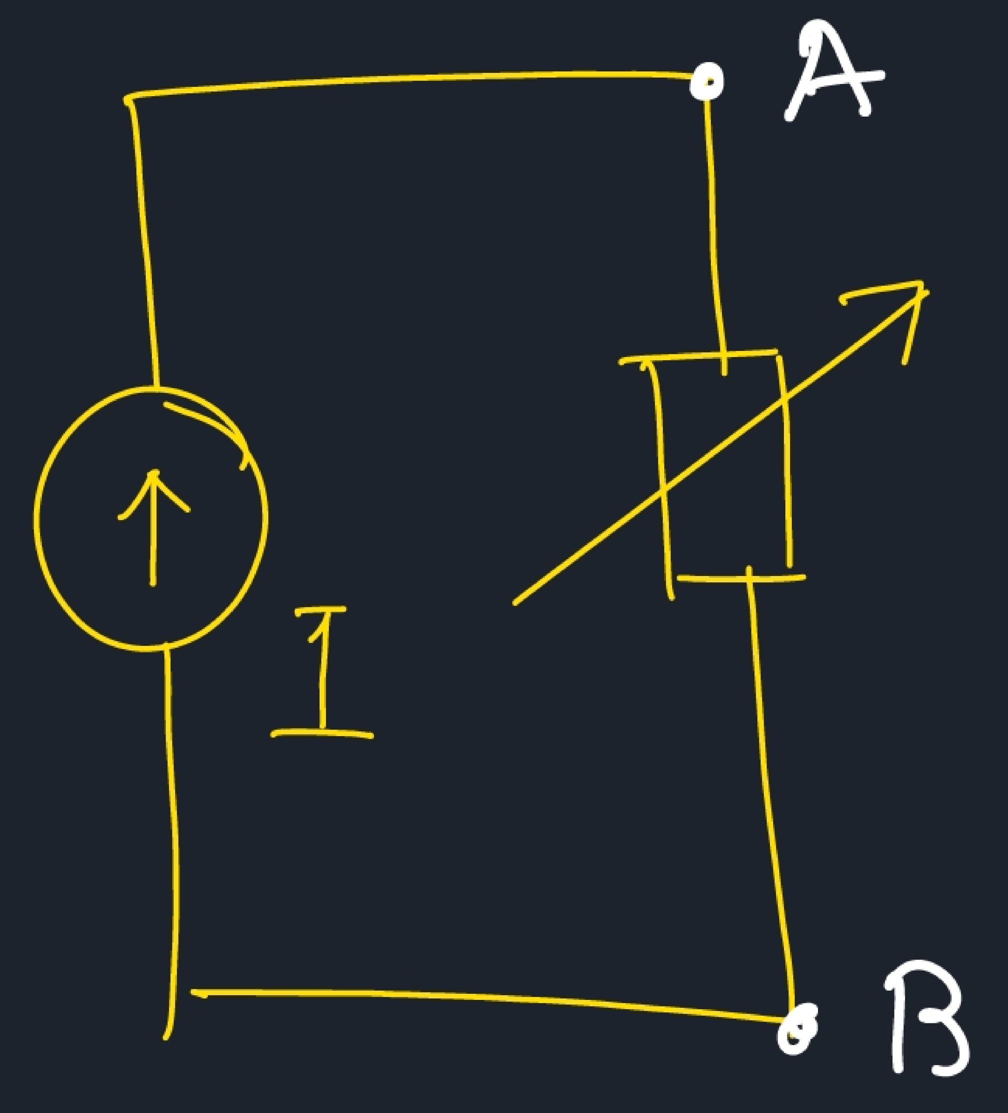

v(t)
i(t)

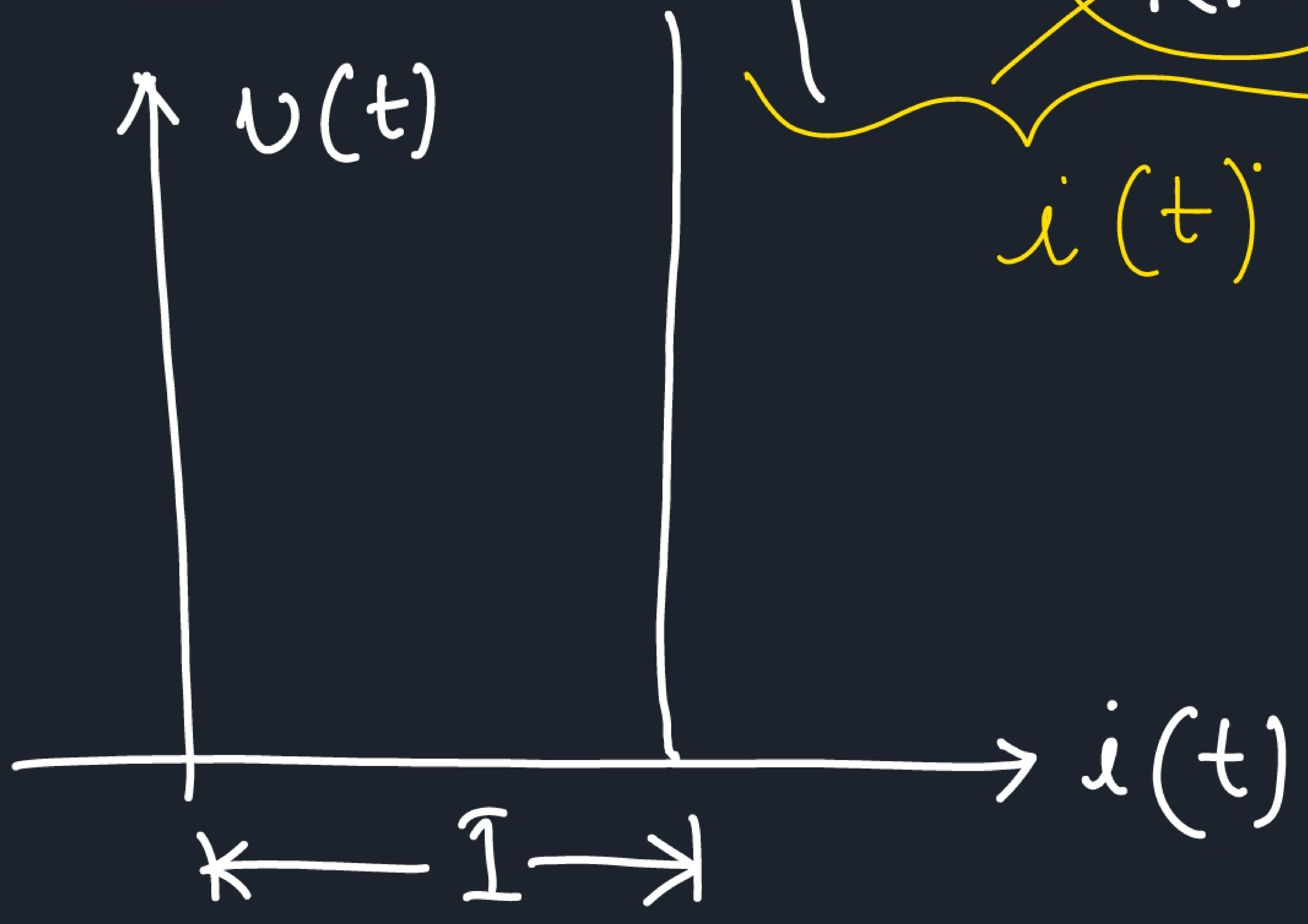

Rint


v(t)
IRint
i(t)

Current Source:-

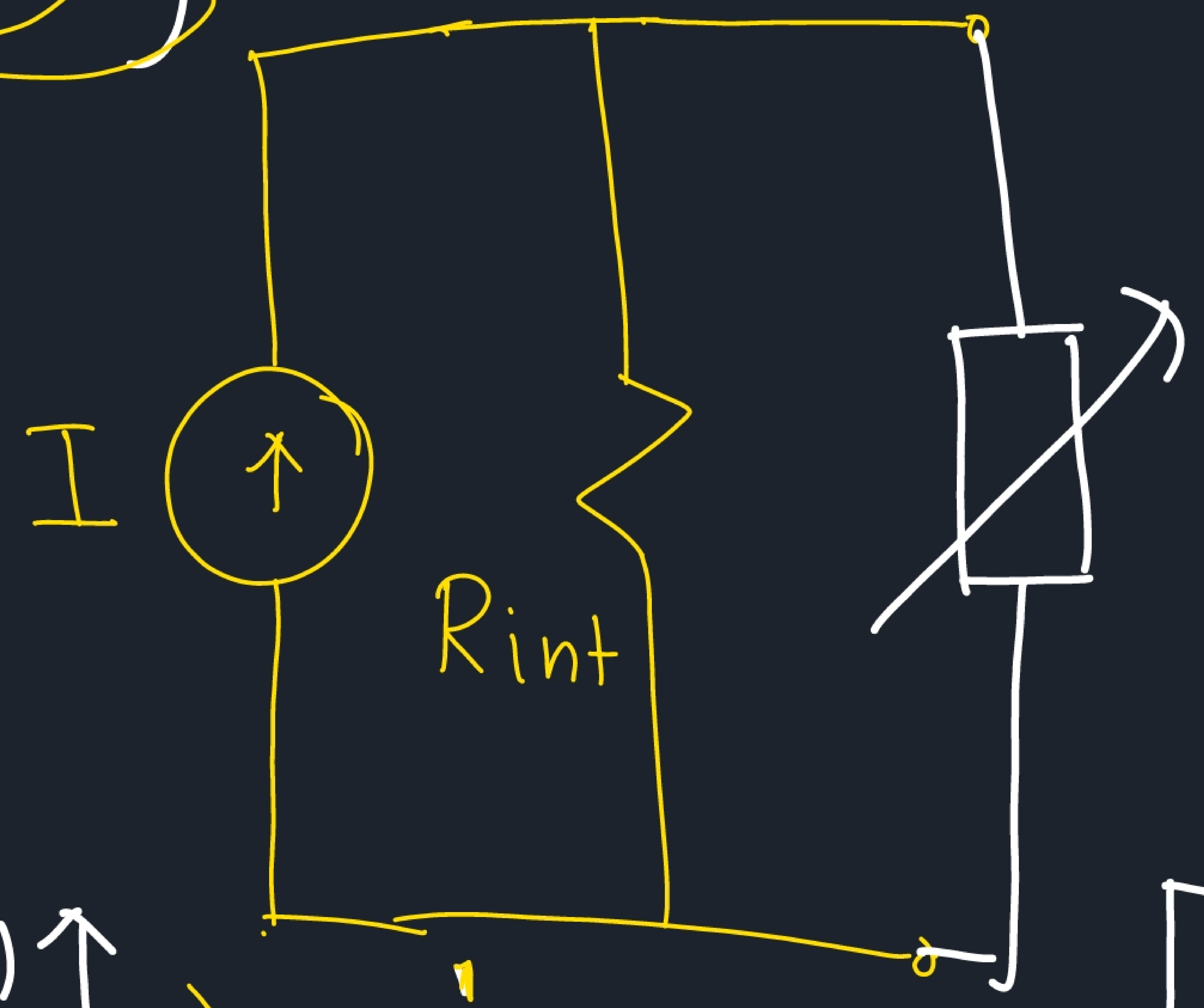
$$\underbrace{\left\{ I - \cancel{\frac{v(t)}{R_{int}}}^{\approx 0} \right\}}_{i(t)} \qquad R_{load} = v(t)$$

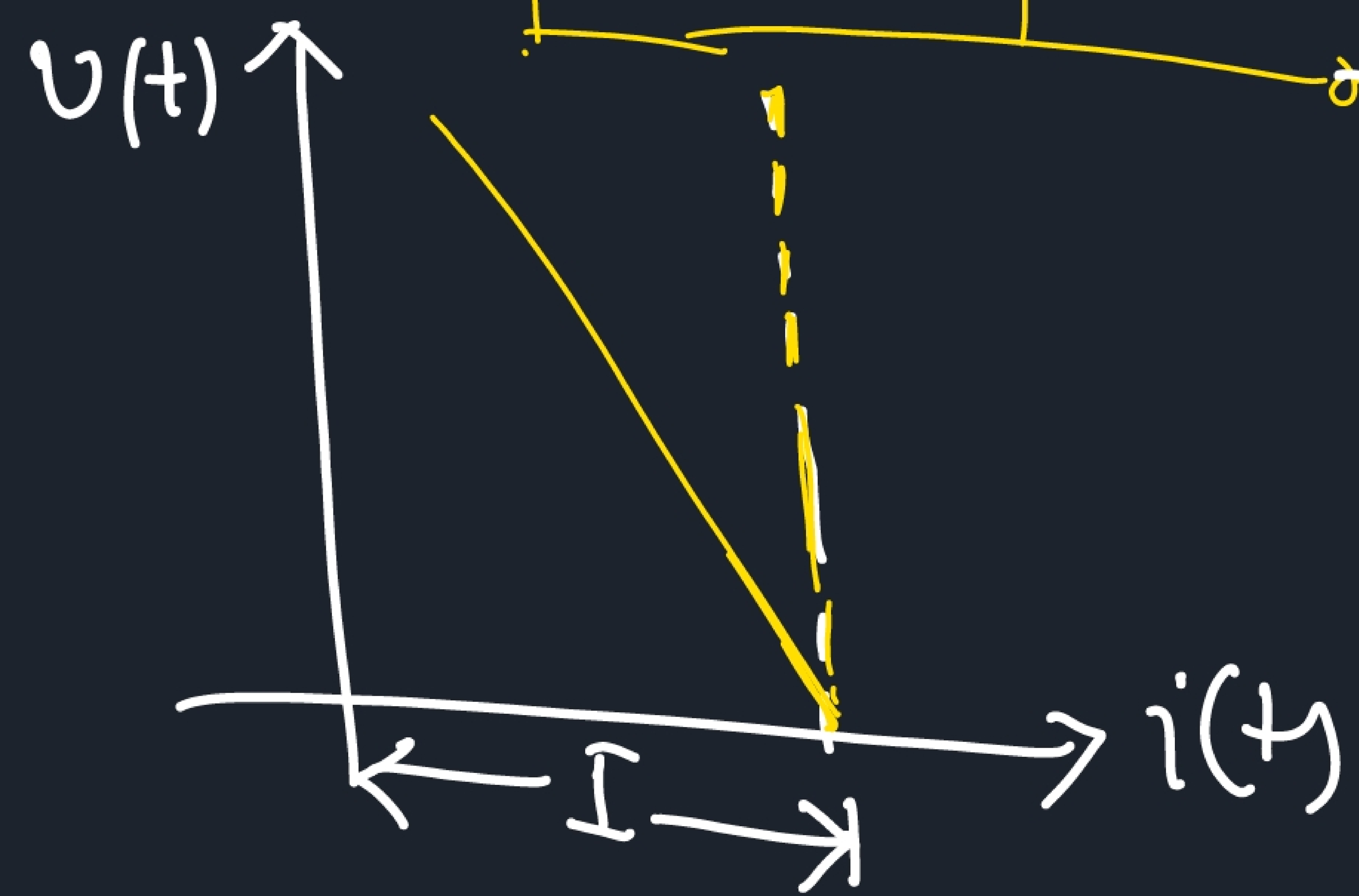


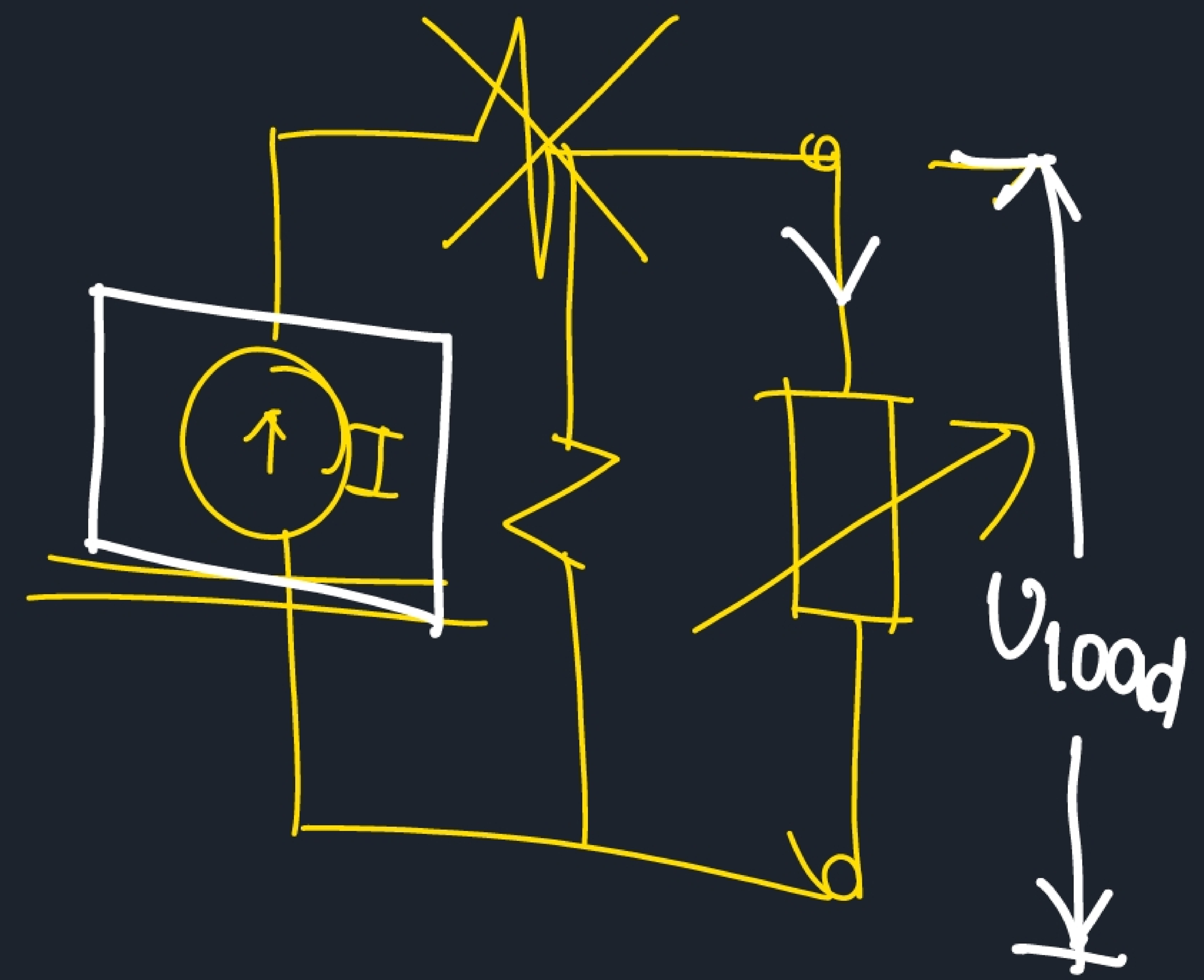


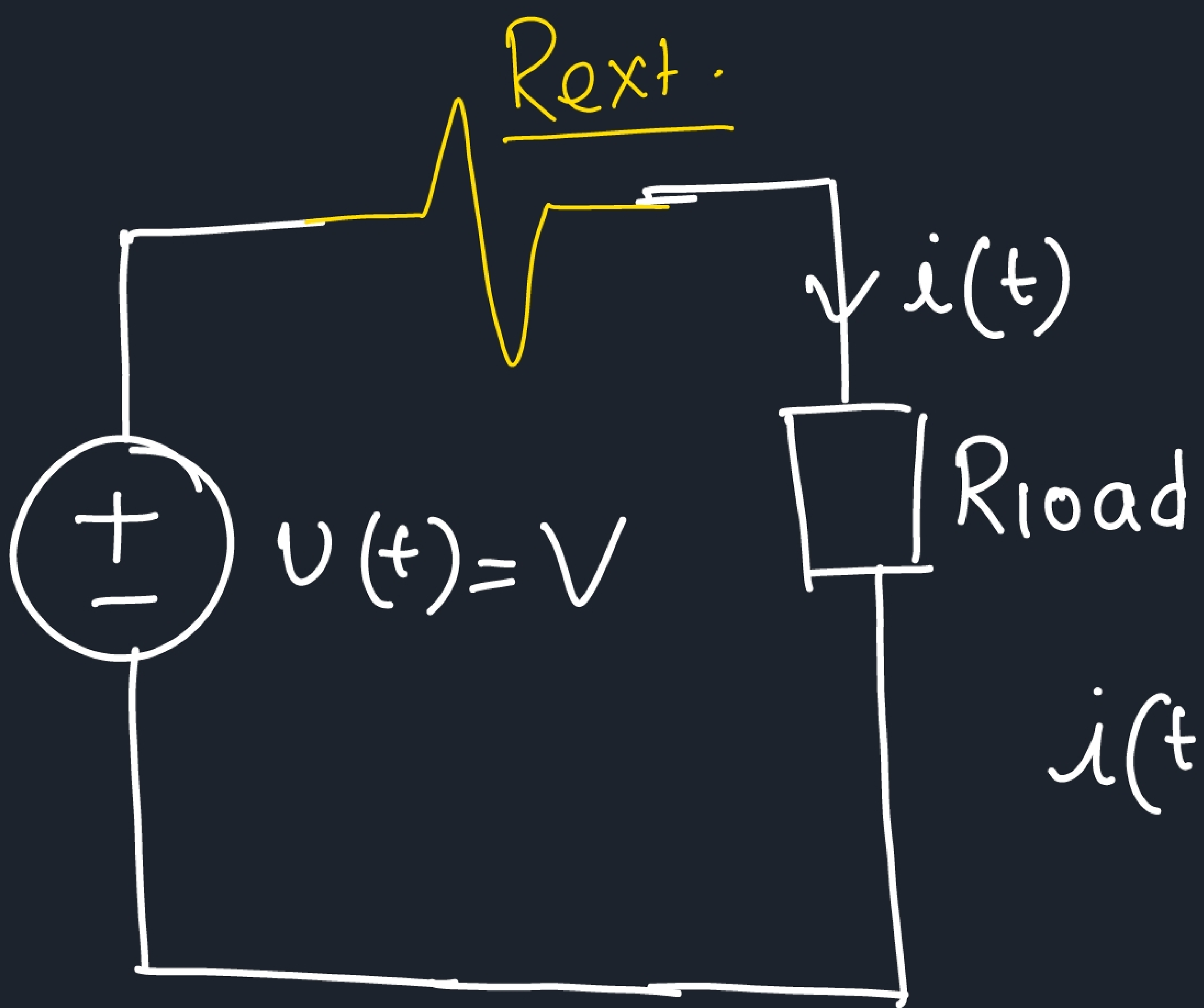
Ideal Current Source.

$$i(t) = I - \frac{v(t)}{R_{int}}.$$



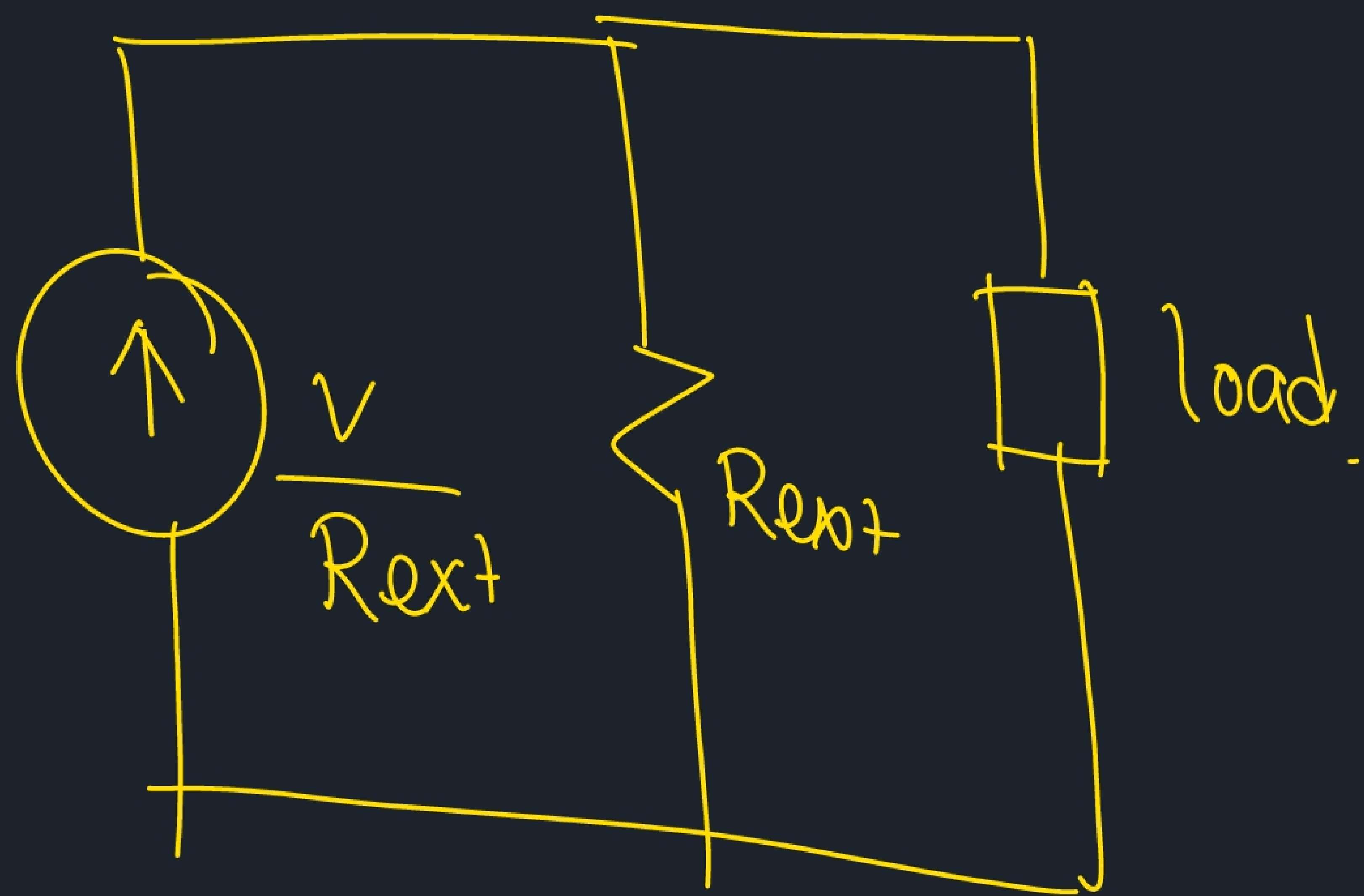




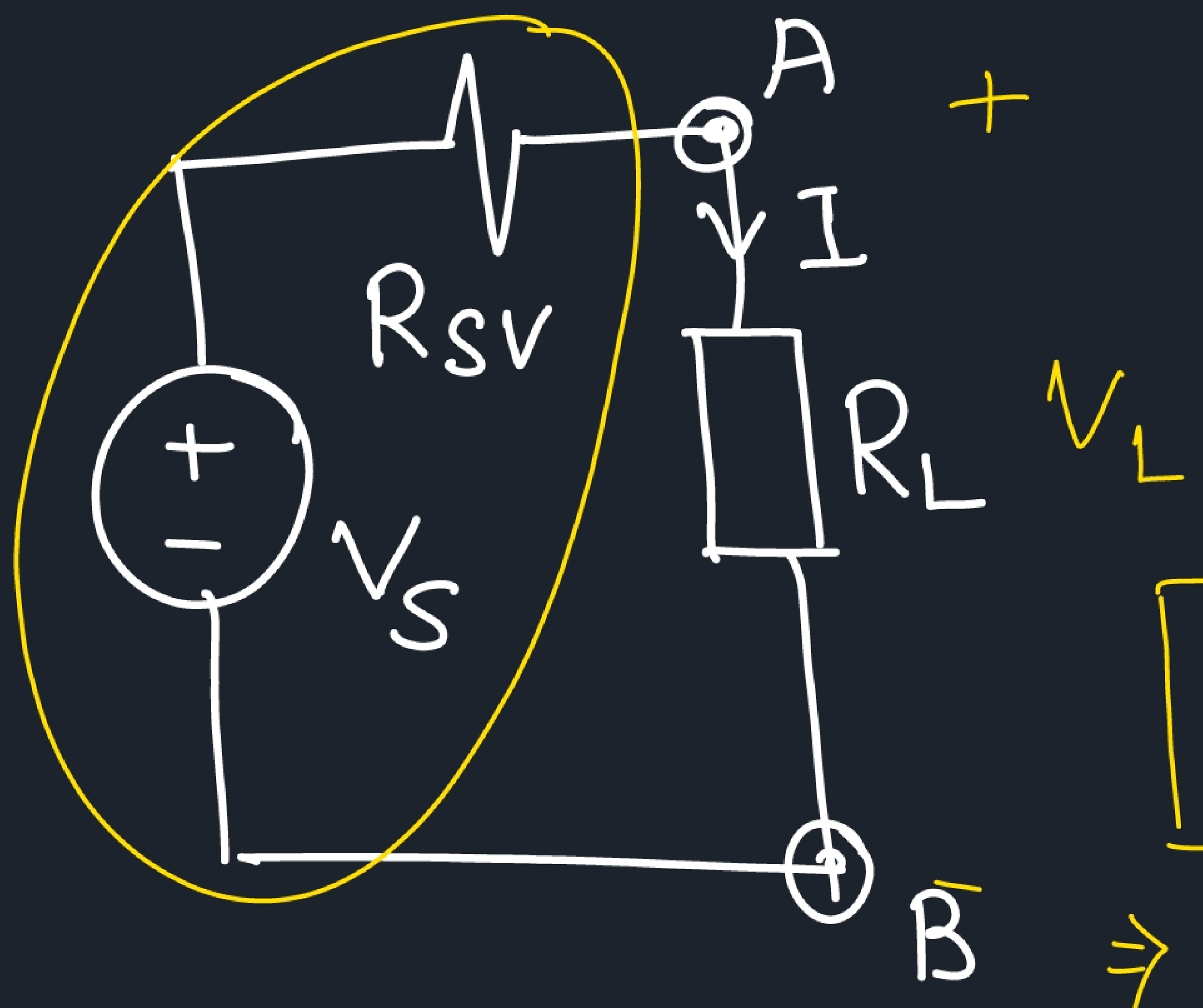


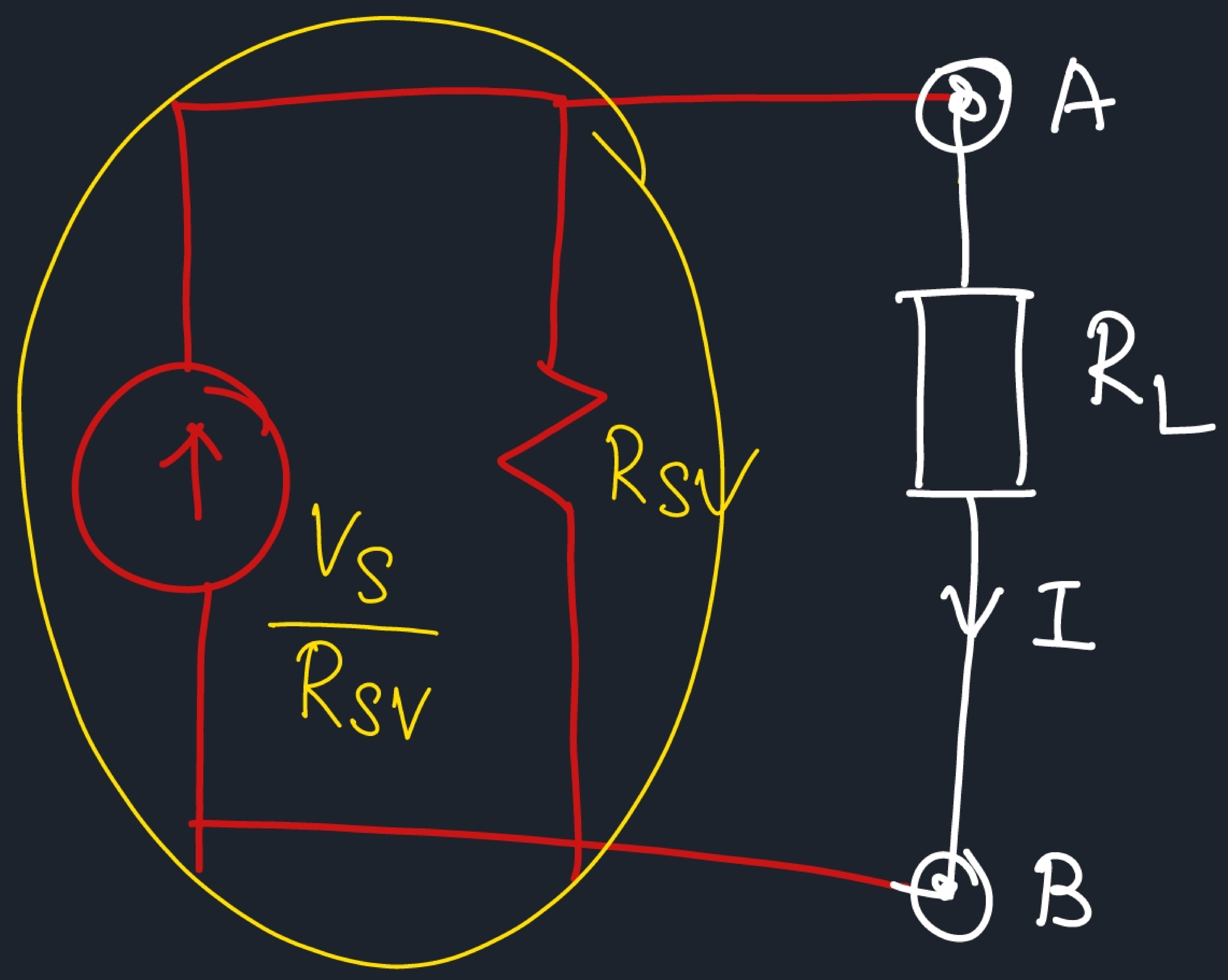
$$i(t) = \frac{v(t)}{R_{load} + R_{ext}}.$$

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



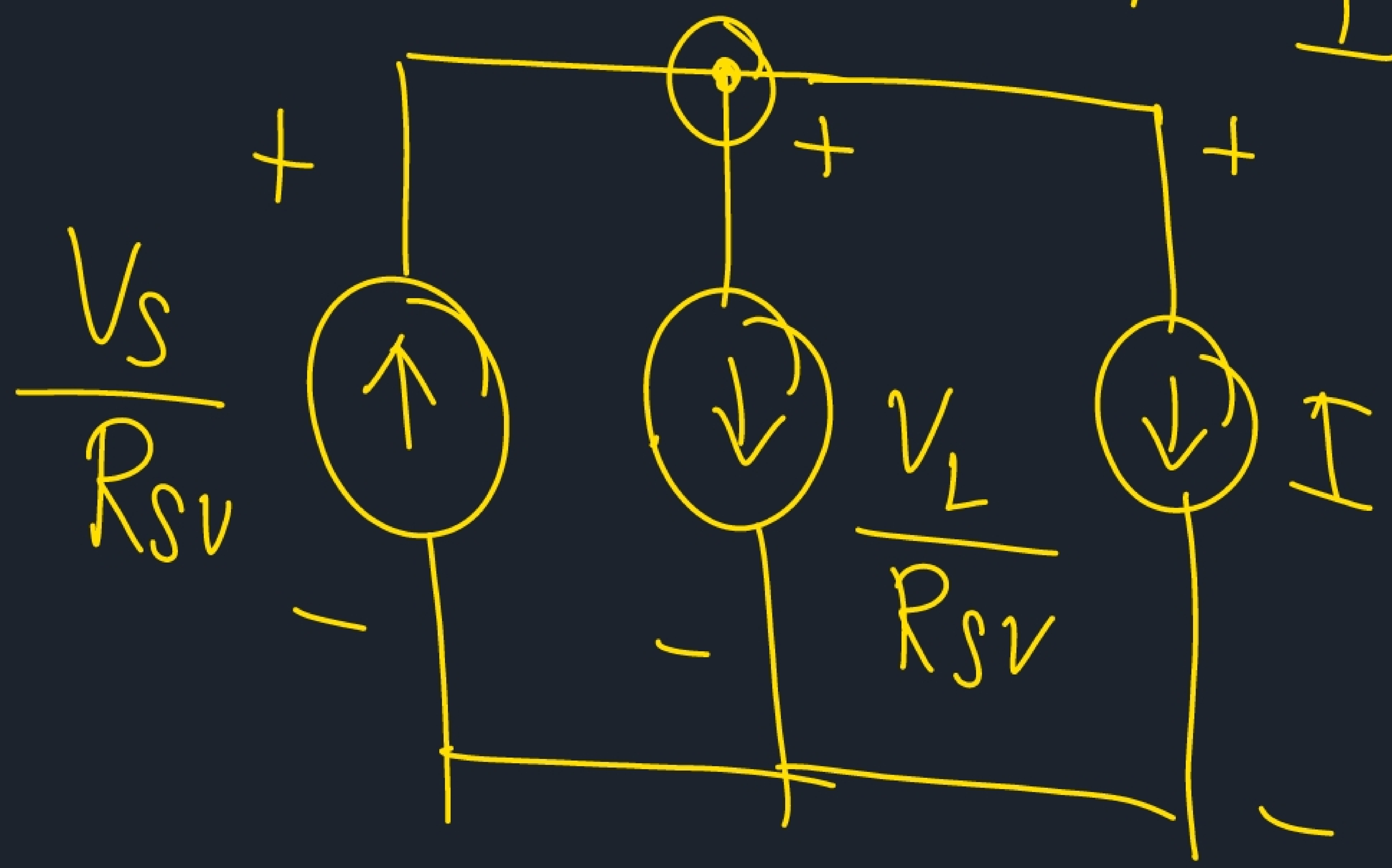
Source Transformation:-



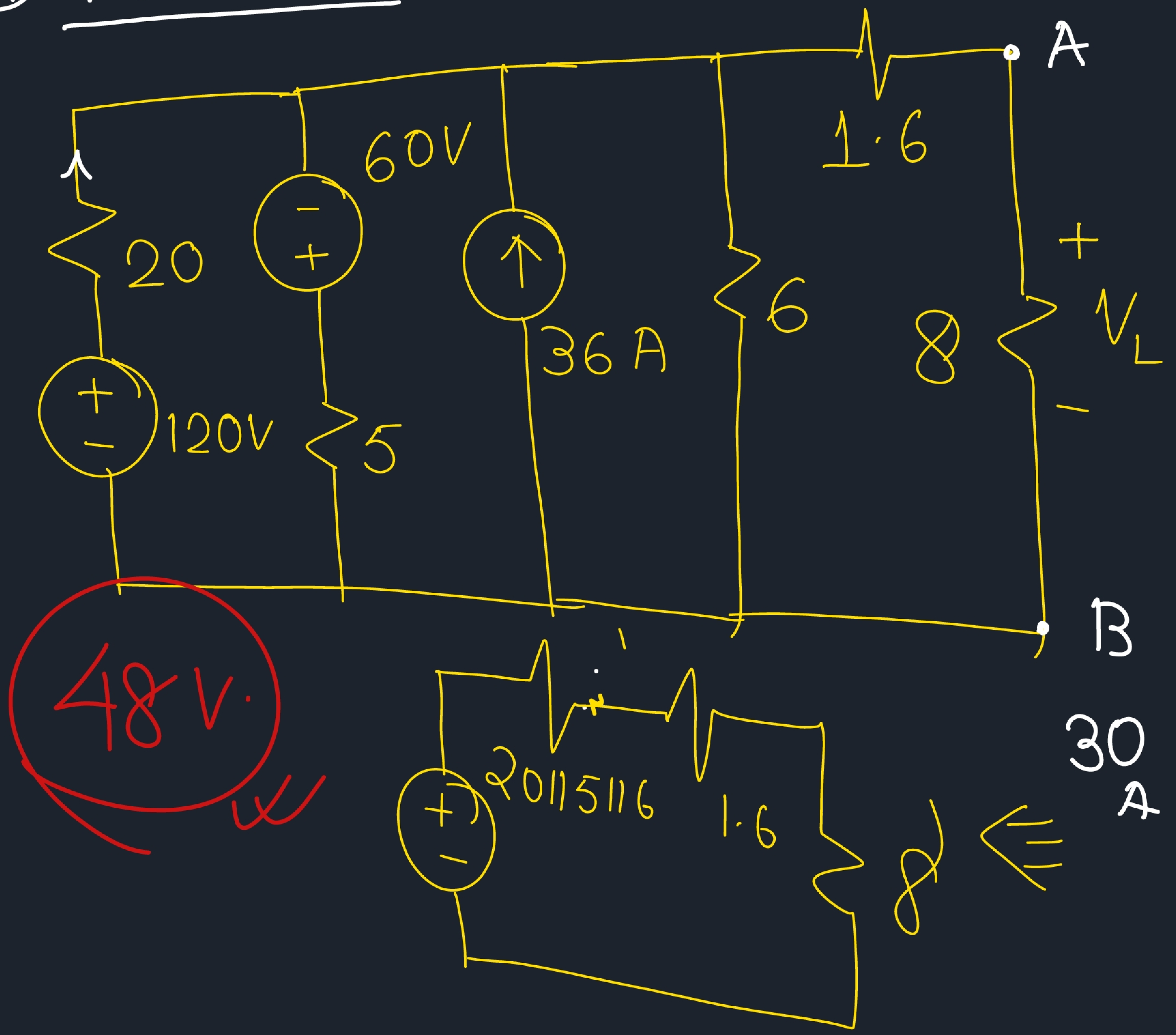


$$\boxed{V_L = V_S - R_{SV} I}$$

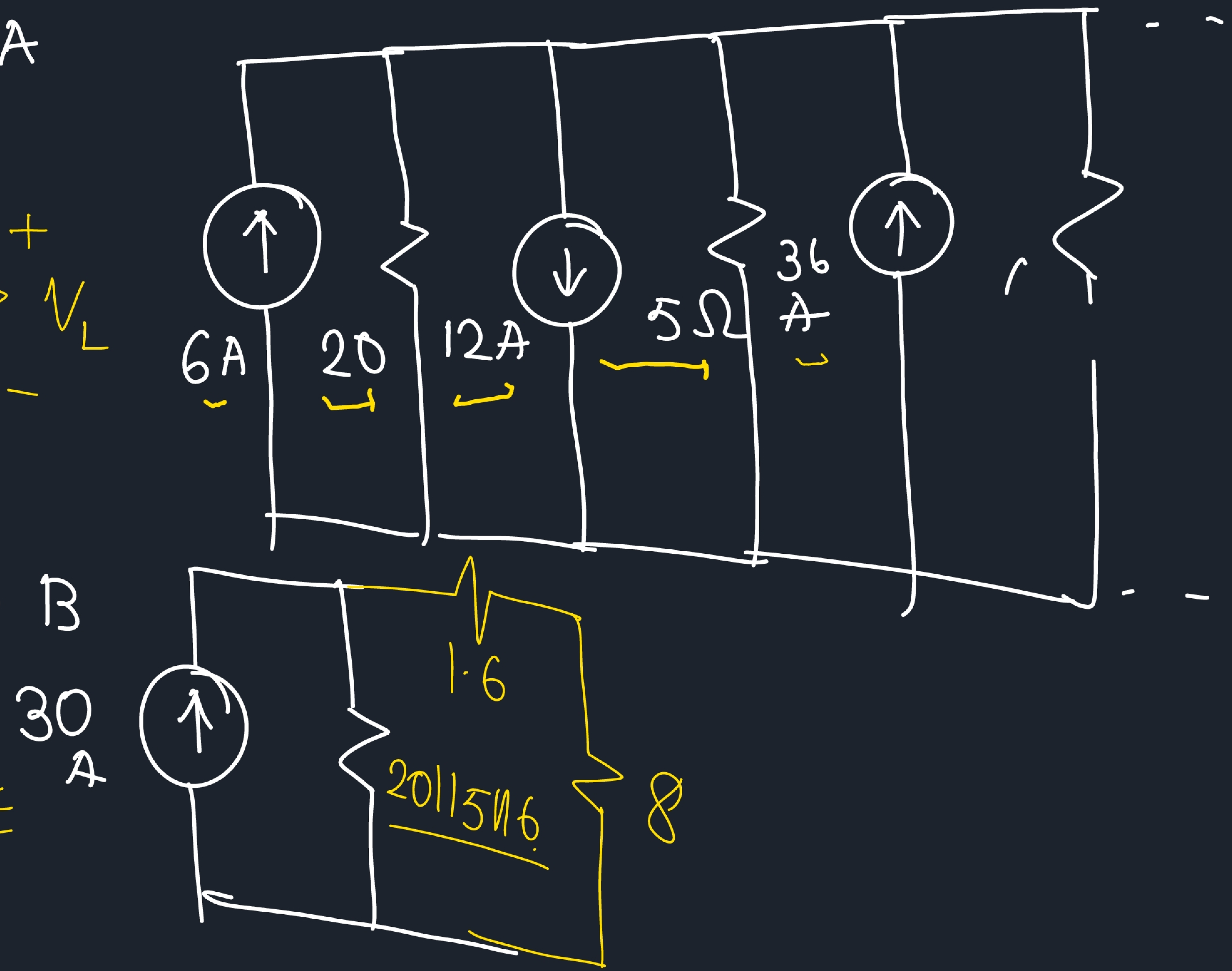
$$\Rightarrow I = -\frac{V_L}{R_{SV}} + \frac{V_S}{R_{SV}}$$



Problem :-



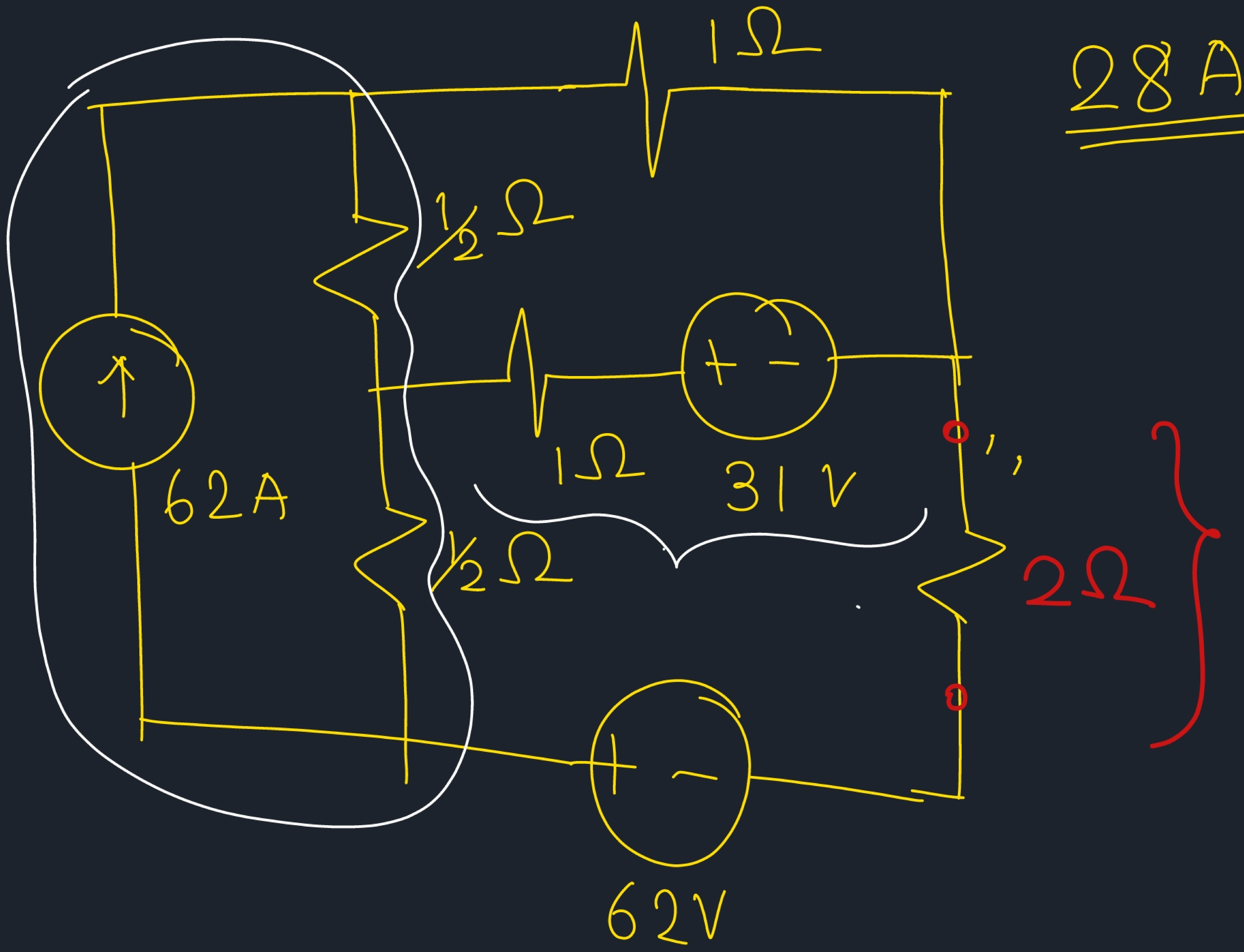
A
B
20
60V
120V
5
36 A
6
1.6
8
+
V_L
−
48V.
2011516
1.6
8

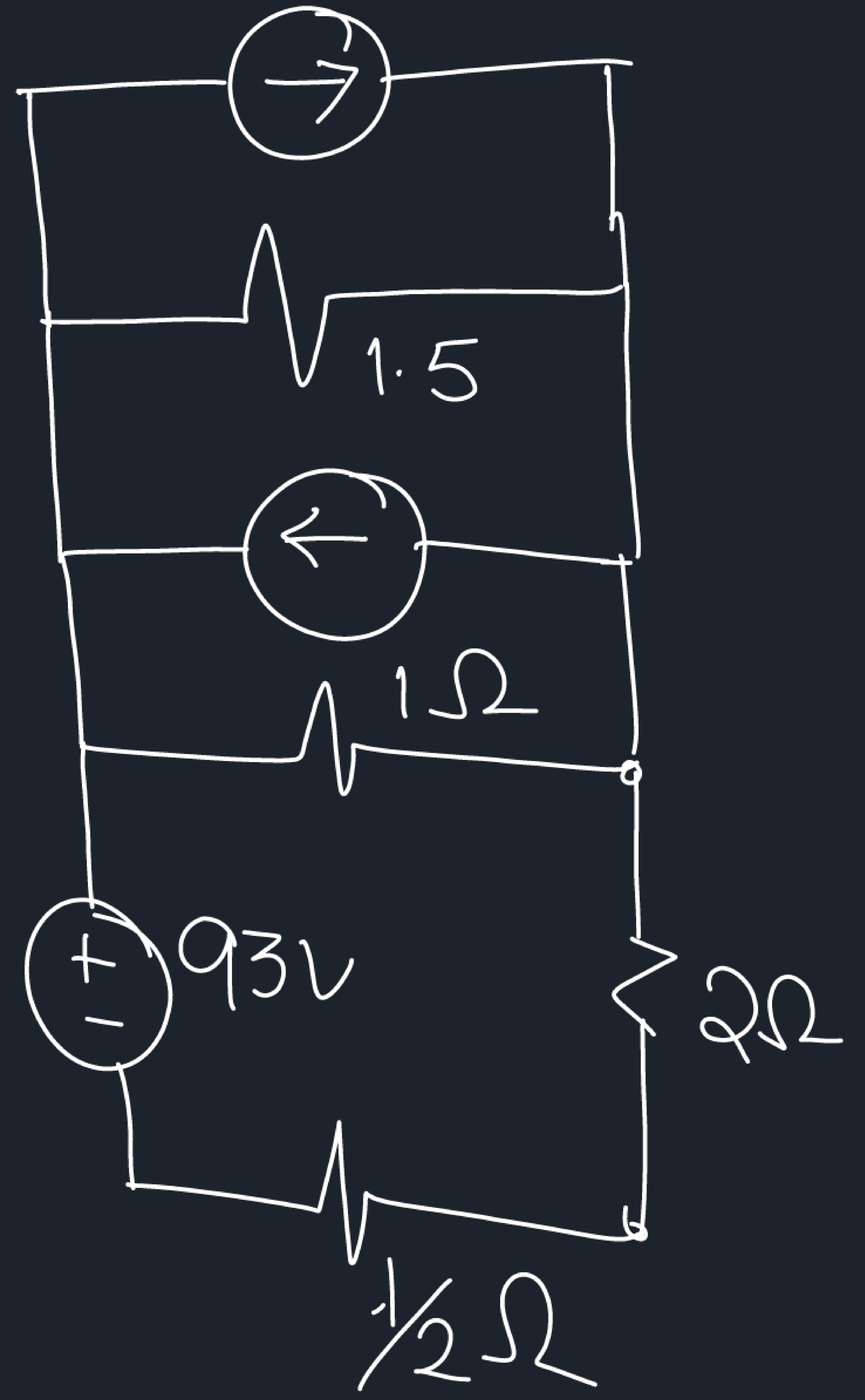


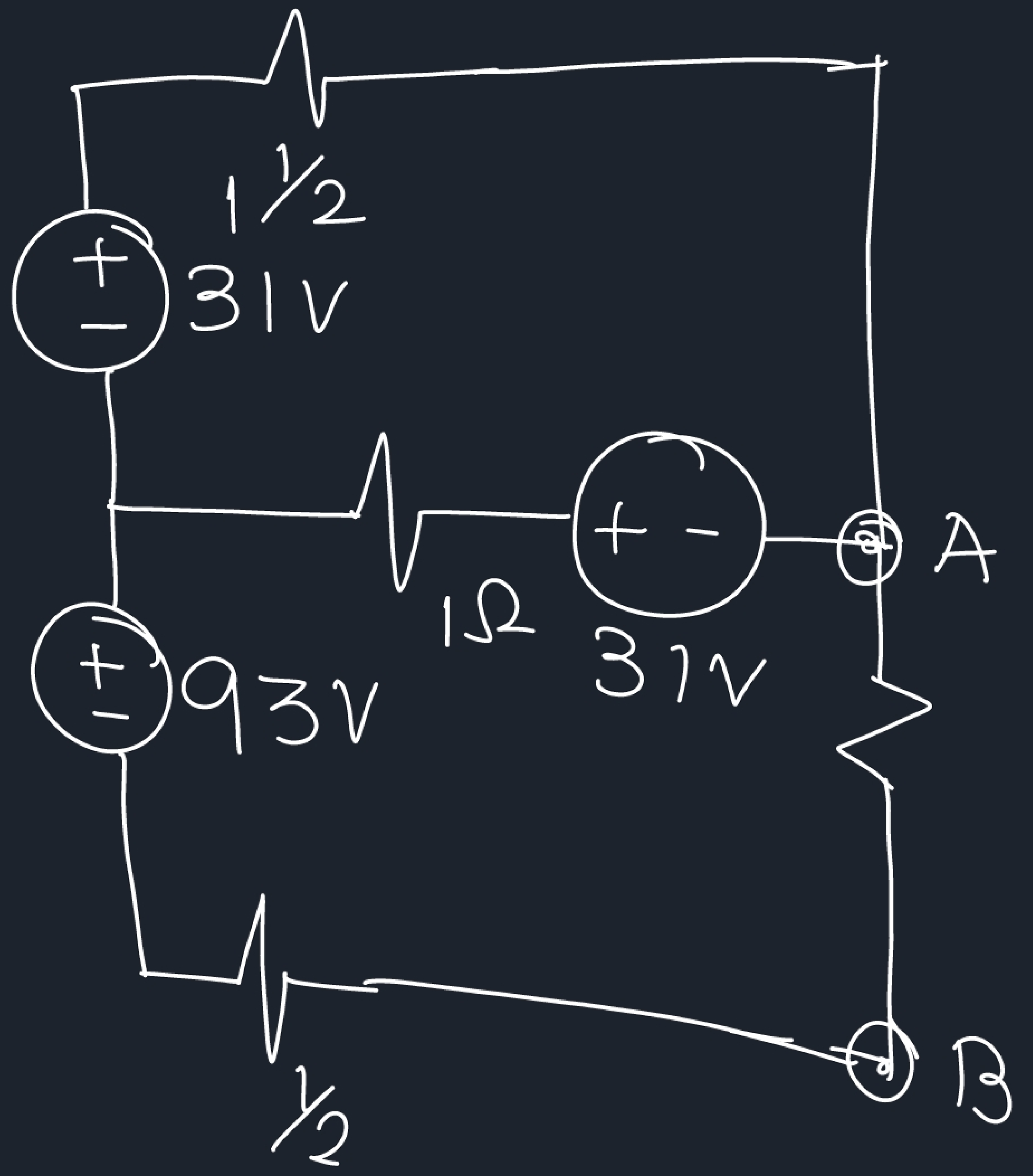
6A
20
12A
5Ω
36 A
30 A
1.6
2011516
8

28 Amps.

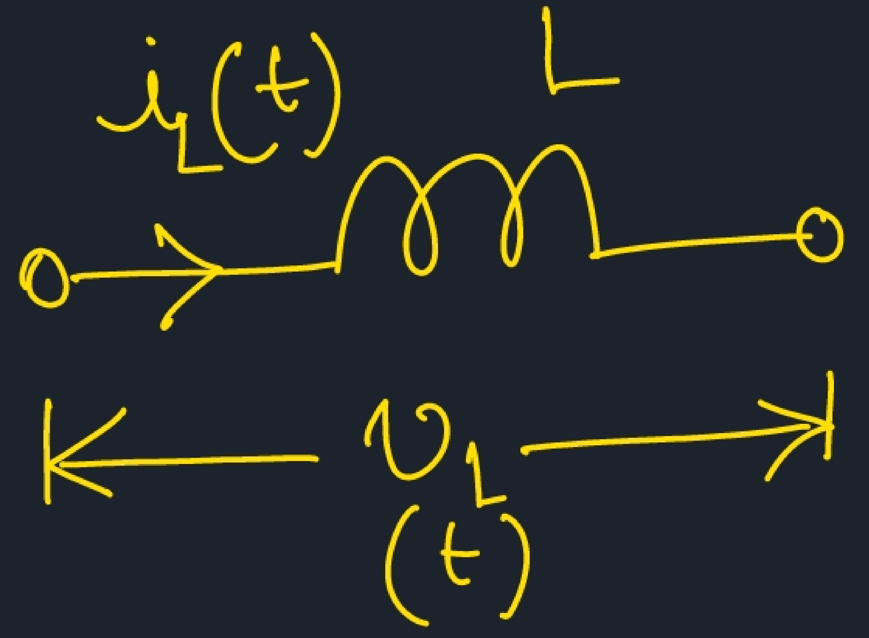
7546







③ Inductor:—



$$i_L(t) = I_0 + \frac{1}{L}\int_0^t \underbrace{v_L(t)\,dt}$$

$\rightarrow$ Volt-Sec.

$\hookrightarrow$ Area of $v_L(t)$ plot.

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

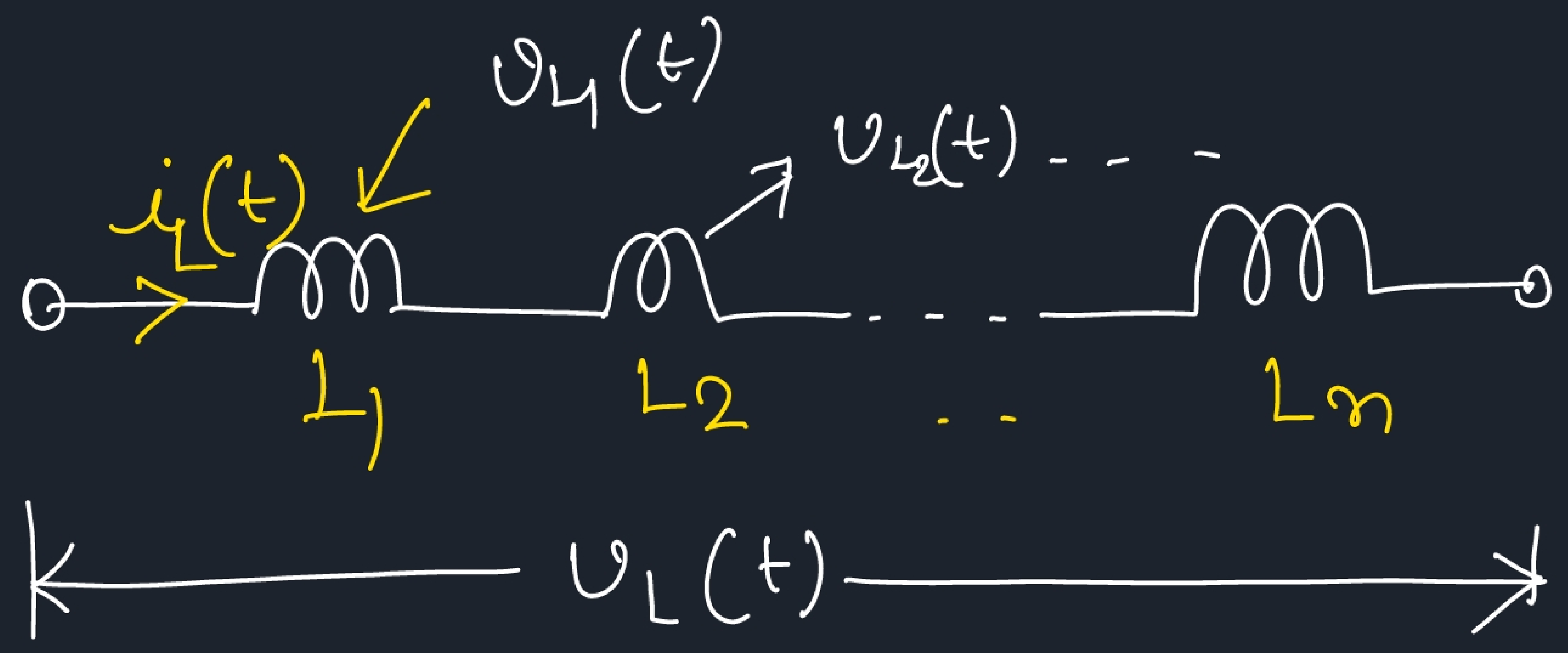
$$i_L(t) = \frac{1}{L}\int_{-\infty}^{t} v_L(t)\,dt = \underbrace{\frac{1}{L}\int_{-\infty}^{0} v_L(t)\,dt}_{I_0} + \frac{1}{L}\int_0^t v_L(t)\,dt$$

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

Ψ = flux linkage

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

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



$$v_{L_1}(t) : v_{L_2}(t) \cdots : v_{L_n}(t) = L_1 : L_2 : \cdots : L_n$$

$$v_L(t) = v_{L_1}(t) + v_{L_2}(t) + \cdots + v_{L_n}(t)$$

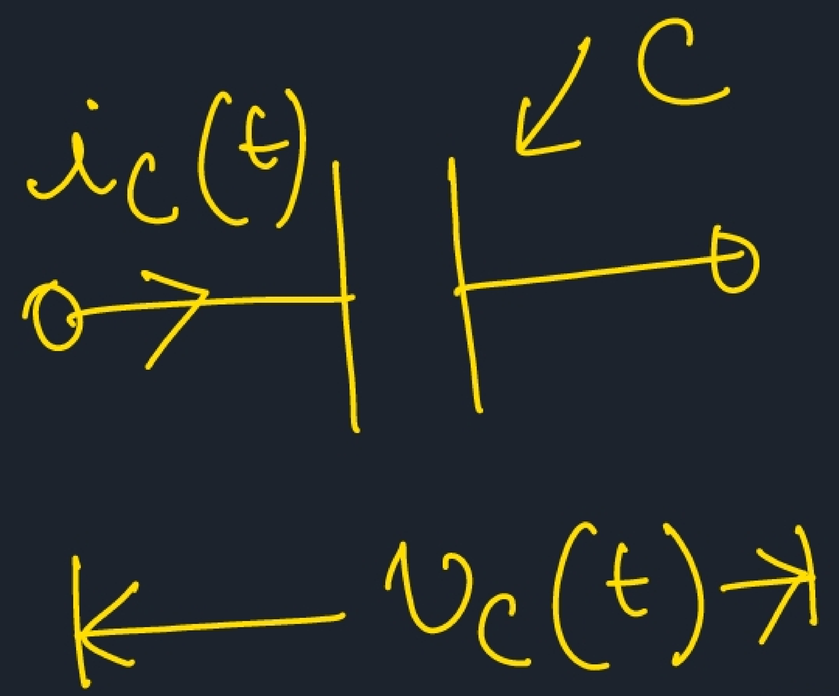
$$= L_1 \frac{di_L(t)}{dt} + L_2 \frac{di_L(t)}{dt} + \cdots + L_n \frac{di_L(t)}{dt}$$

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

$$v_{L_m} = \frac{L_m}{\sum_{j=1}^{n} L_j} v_L(t)$$

$$L_{eq}^{P} = \frac{1}{1/L_1 + 1/L_2 + \cdots + 1/L_n}$$

Capacitor :-



$$\boxed{i_c(t) = C\,\frac{dv_c(t)}{dt}}$$

$$\boxed{v_c(t) = V_c(0) + \frac{1}{C}\int_0^t i_c(t)\,dt}$$

$$v_c(t) = \frac{1}{C}\int_{-\infty}^{t} \underbrace{i_c(t)\,dt}_{\text{Amp-Sec.}} = \underbrace{\frac{1}{C}\int_{-\infty}^{0} i_c(t)\,dt}_{V_c(0)} + \frac{1}{C}\int_0^t i_c(t)\,dt$$

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

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

$$\boxed{v_R(t) = R\, i_R(t)}$$

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

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

Linear & Nonlinear Element.

$y = mx$

1. Additivity
2. Homogeneity

$\Rightarrow$ Superposition.

$y = f(x)$

$y_1 = f(x_1)$

$y_2 = f(x_2)$

$y_1 + y_2 = f(x_1 + x_2)$

$ay = f(ax)$

$i_{R_1}(t) \rightarrow v_{R_1}(t)$

$i_{R_2}(t) \rightarrow v_{R_2}(t)$

$a\, i_R(t) \rightarrow a\, v_R(t)$

$$y = mx + c \xrightarrow{} 0$$

Non linear

x_1, x_2

ax_1

ay_1

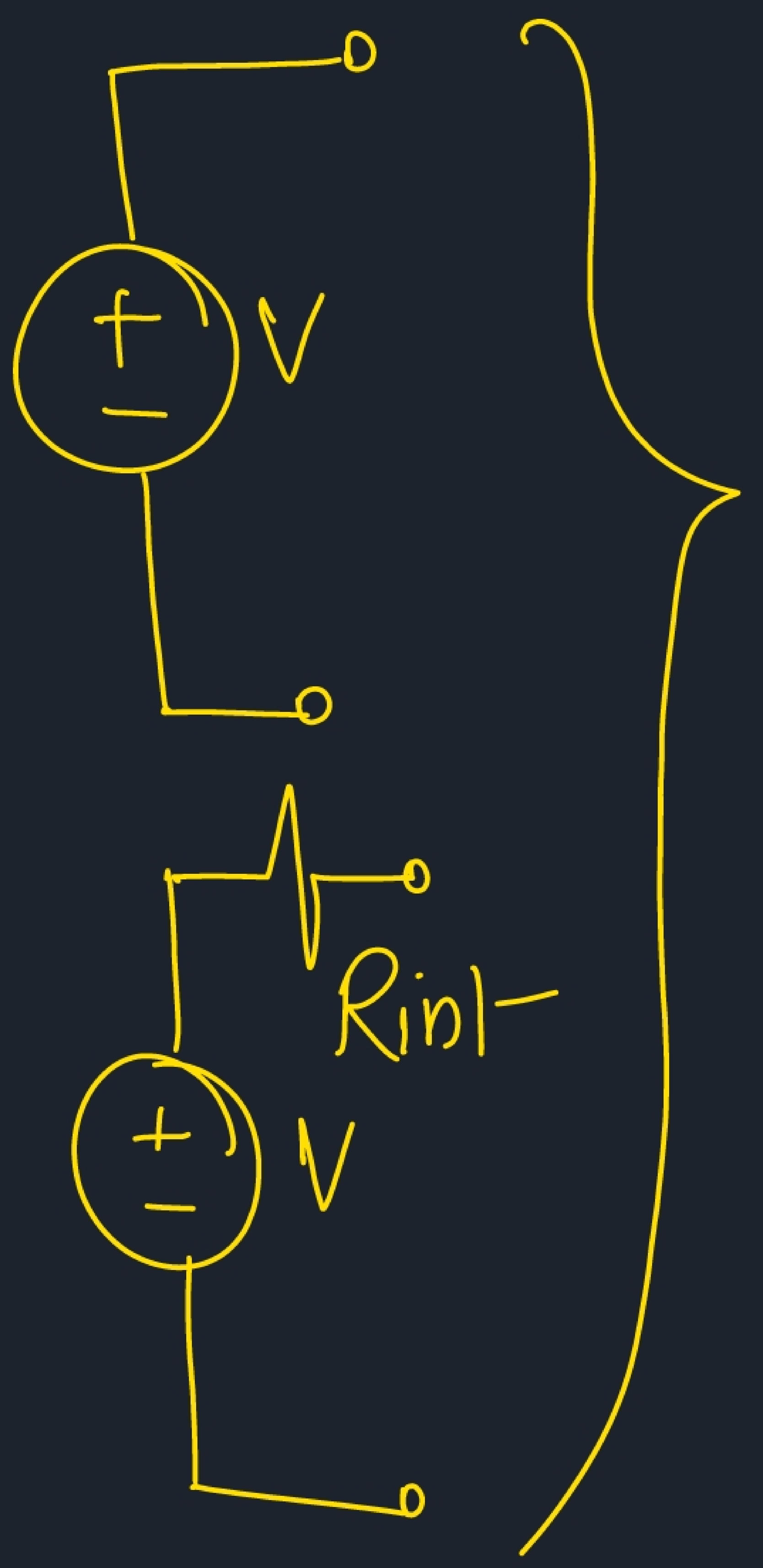
$$\boxed{v_L(t) = L\frac{di_L(t)}{dt}}$$

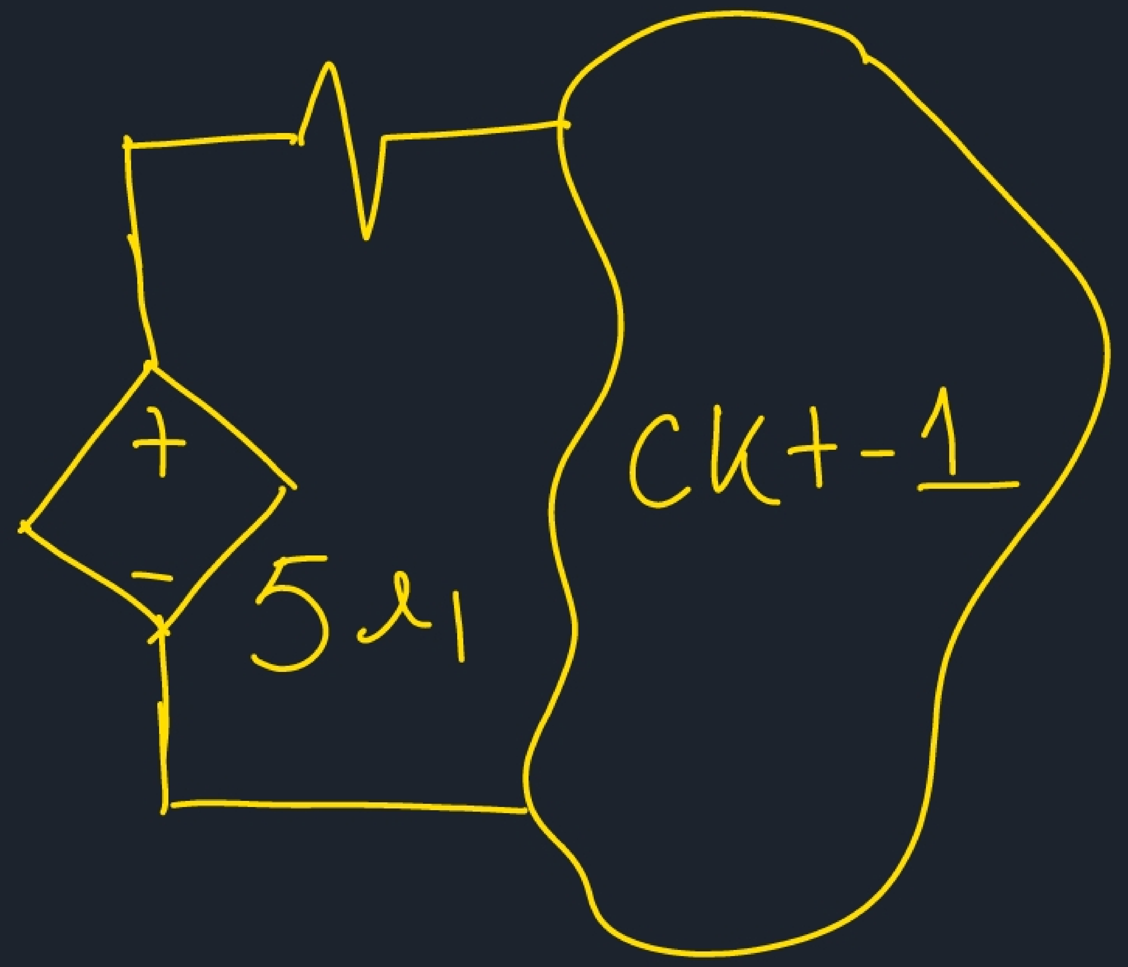
$$i_L(t) = I_0 + \int_0^t v_L(t)\,dt$$

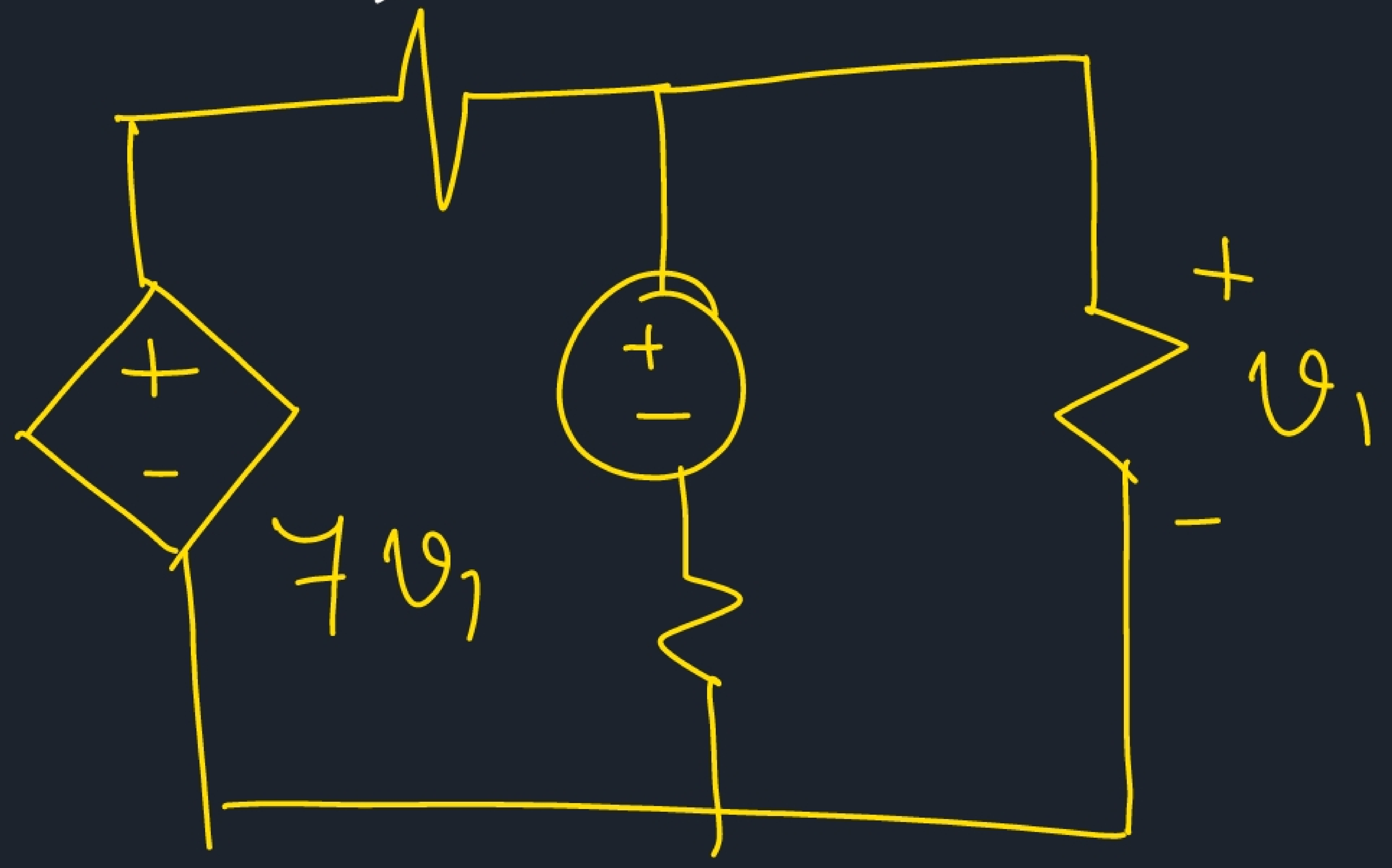
$$v_L(t) = L\frac{d\{i_L + k\}}{dt}$$

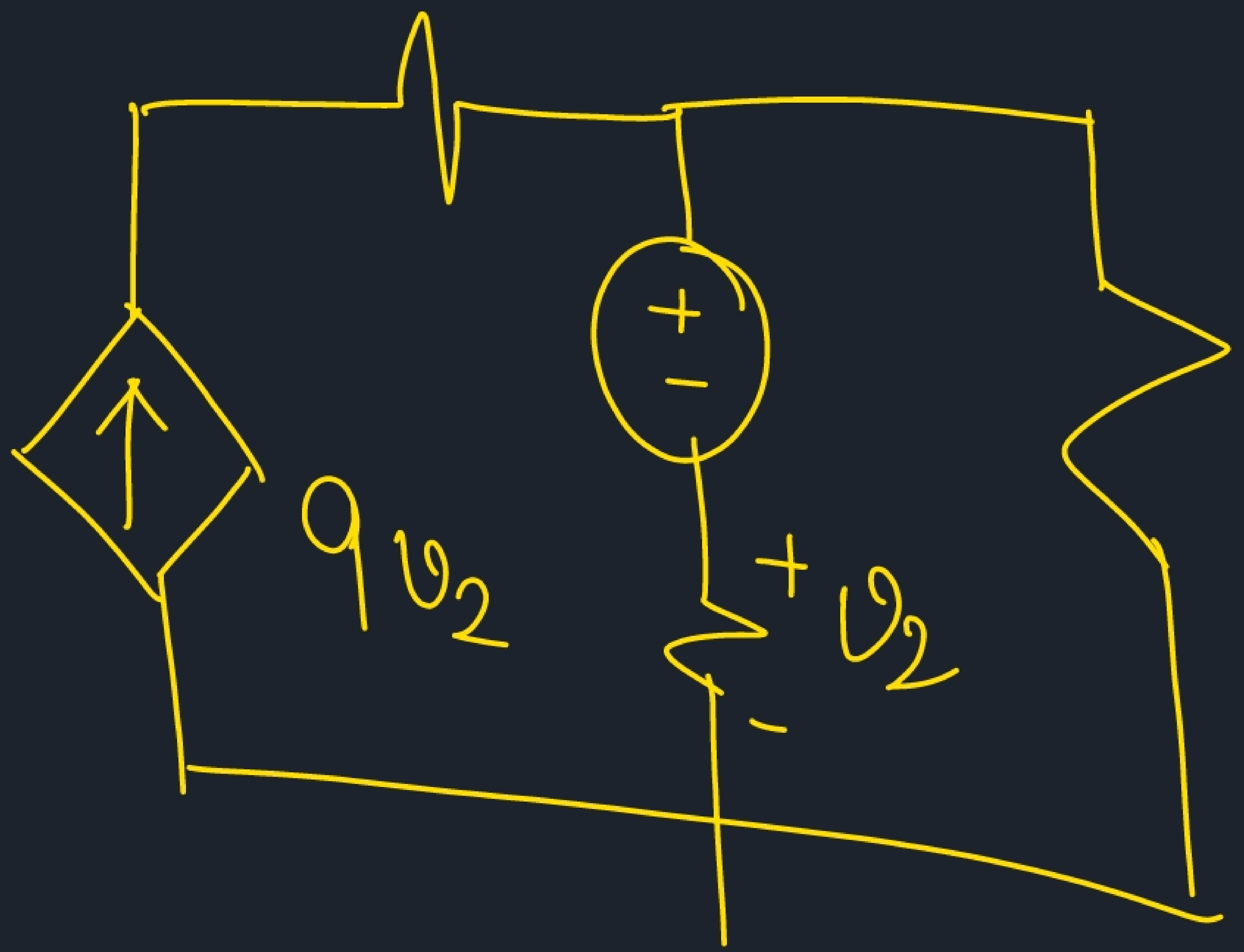
$$i_c(t) = C\frac{dv_c(t)}{dt}$$

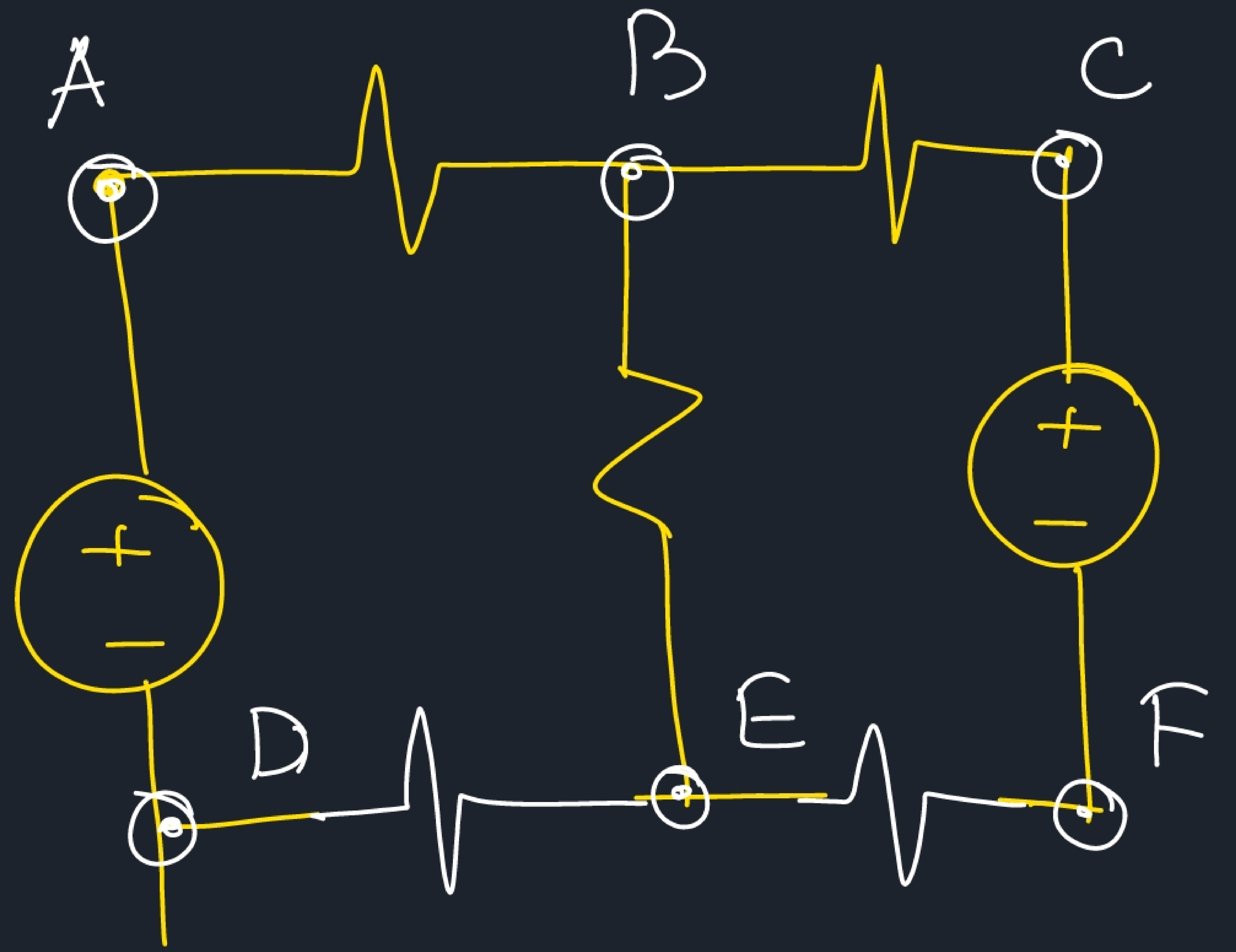
Dependent & Independent :- (Sources)











NODE

JUNCTION $\Rightarrow$ B, E

BRANCH $\Rightarrow$

LOOP $\Rightarrow$

MESH $\Rightarrow$

NETWORK ANALYSIS.

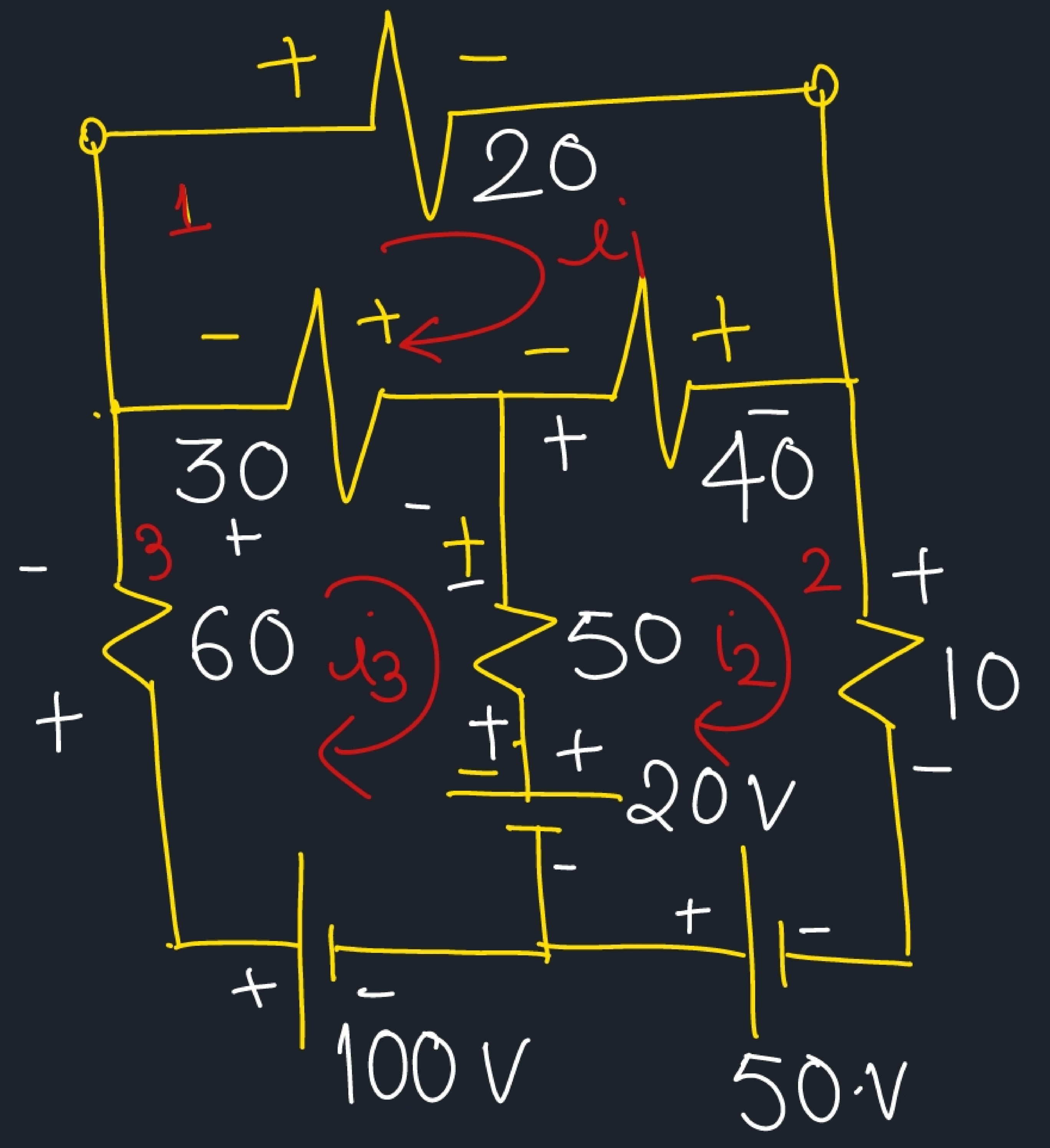
DIRECT

- MESH ANALYSIS
- NODAL "
- SUPERPOSITION

INDIRECT

- THEVENIN'S
- NORTON'S
- Y-Δ Transform.

MESH ANALYSIS:-



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

MESH-1.

$$-20i_1 - 40(i_1 - i_2) - 30(i_1 - i_3) = 0 \quad \text{....(i)}$$

$$\Rightarrow i_1(20+40+30) - i_2(40) - i_3(30) = 0 \quad \text{....(iv)}$$

MESH-2

$$-40(i_2 - i_1) - 10i_2 + 50 + 20 - 50(i_2 - i_3) = 0 \quad \text{....(ii)}$$

$$\Rightarrow -40i_1 + i_2(50+40+10) - 50i_3 = 50+20 \quad \text{....(v)}$$

MESH-3.

$$-60i_3 - 30(i_3 - i_1) - 50(i_3 - i_2) - 20 + 100 = 0 \quad \text{....(iii)}$$

$$\Rightarrow -30i_1 - 50i_2 + i_3(60+30+50) = 100-20 \quad \text{....(vi)}$$

$$\mathbb{A}\,\mathbb{I} = \mathbb{C}$$

$$\boxed{\mathbb{I} = \mathbb{A}^{-1}\mathbb{C}}$$

$i_1 = 1.49$ A

$i_2 = 2.12$ A

$i_3 = 1.65$ A

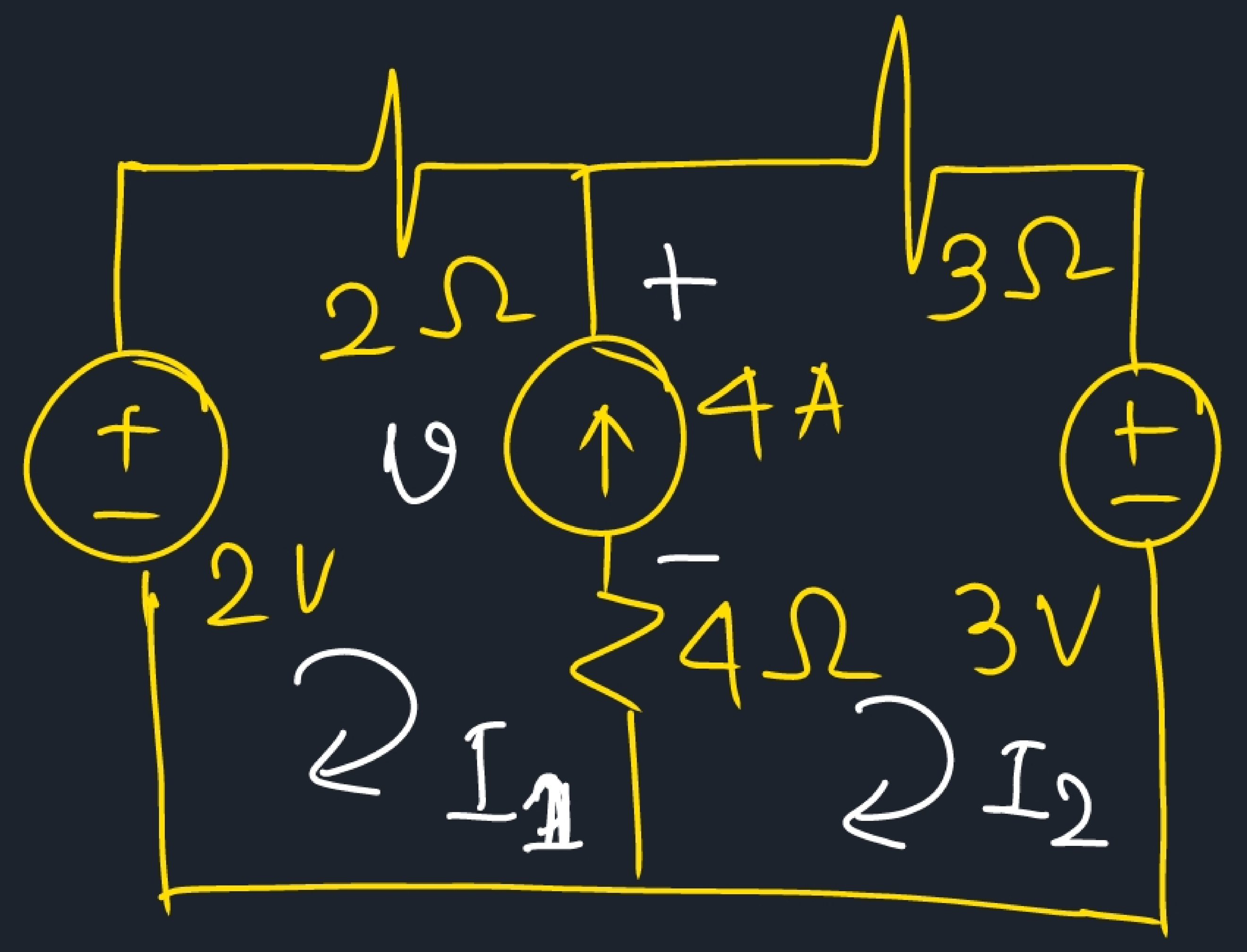
$$\underbrace{\begin{bmatrix} 90 & -40 & -30 \\ -40 & 100 & -50 \\ -30 & -50 & +140 \end{bmatrix}}_{\mathbb{A}} \underbrace{\begin{bmatrix} i_1 \\ i_2 \\ i_3 \end{bmatrix}}_{\mathbb{I}} = \underbrace{\begin{bmatrix} 0 \\ 50+20 \\ 100-20 \end{bmatrix}}_{\mathbb{C}}$$

CRAMER'S RULE :-

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

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

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

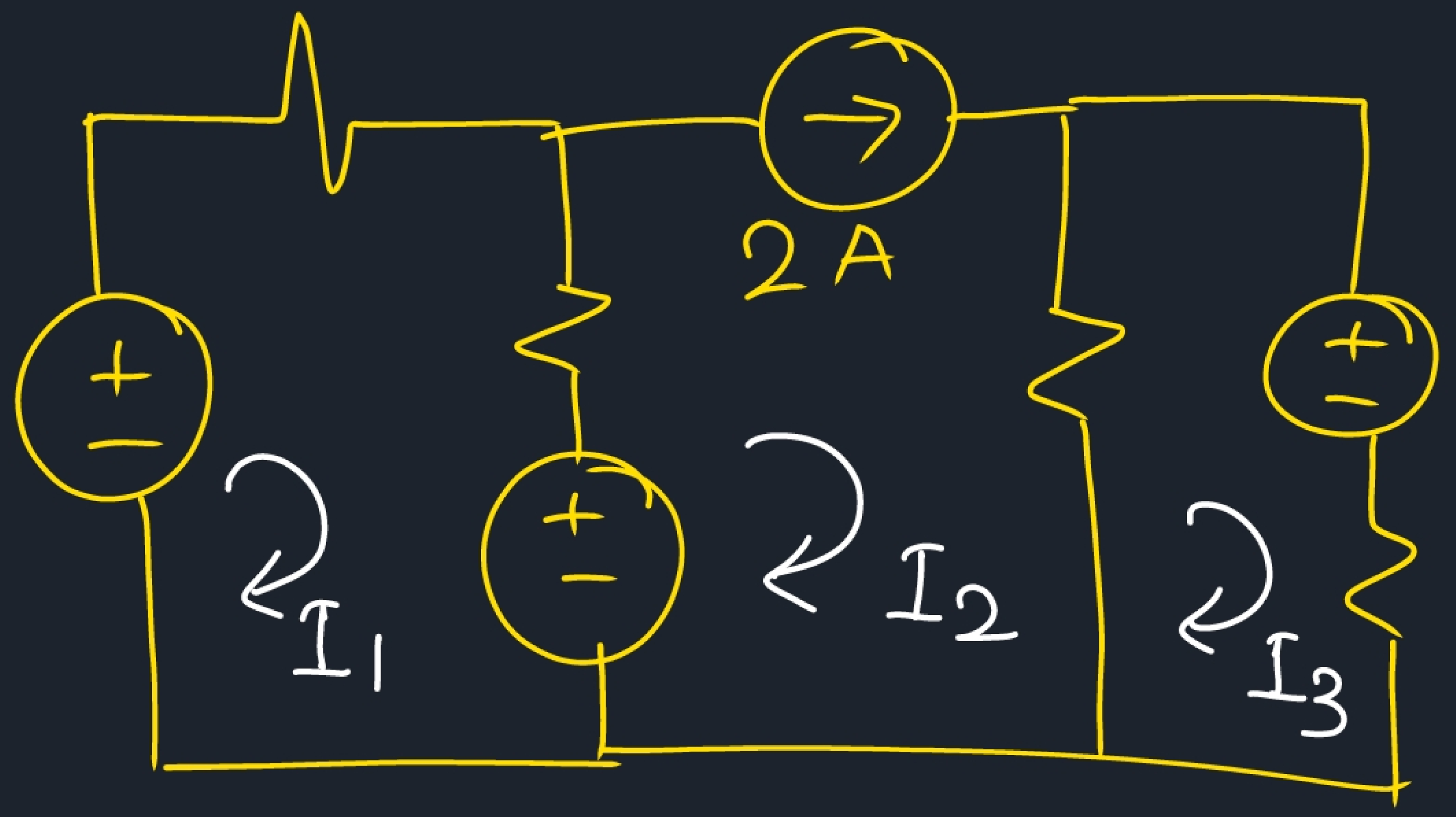


(II)

$$I_2 - I_1 = 4 \quad \text{- - (i)}$$

$$2 - 2I_1 - v - 4(I_1 - I_2) = 0 \quad \text{- - (ii)}$$

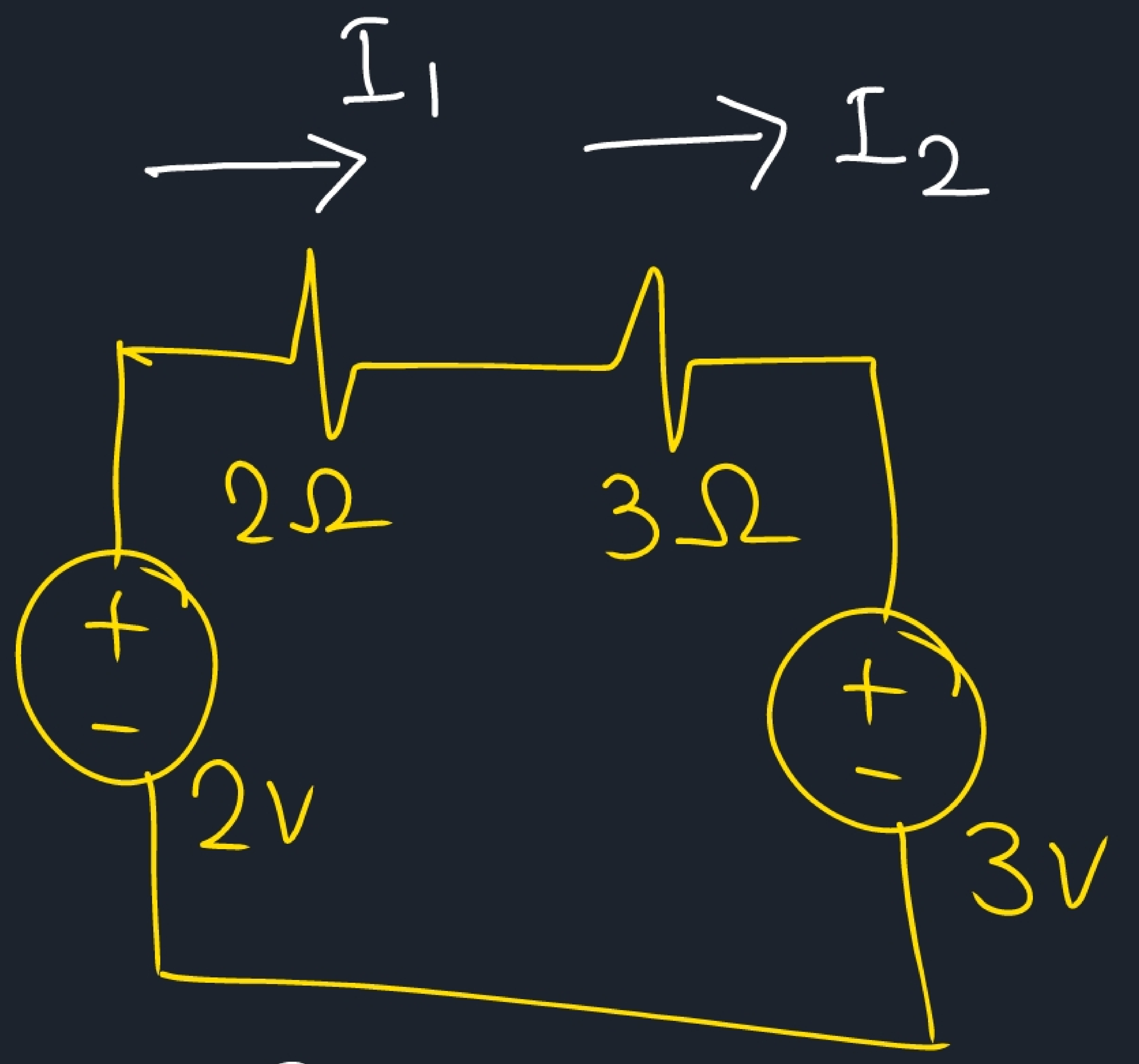
$$-4(I_2 - I_1) + v - 3I_2 - 3 = 0 \quad \text{- - (iii)}$$



(I)

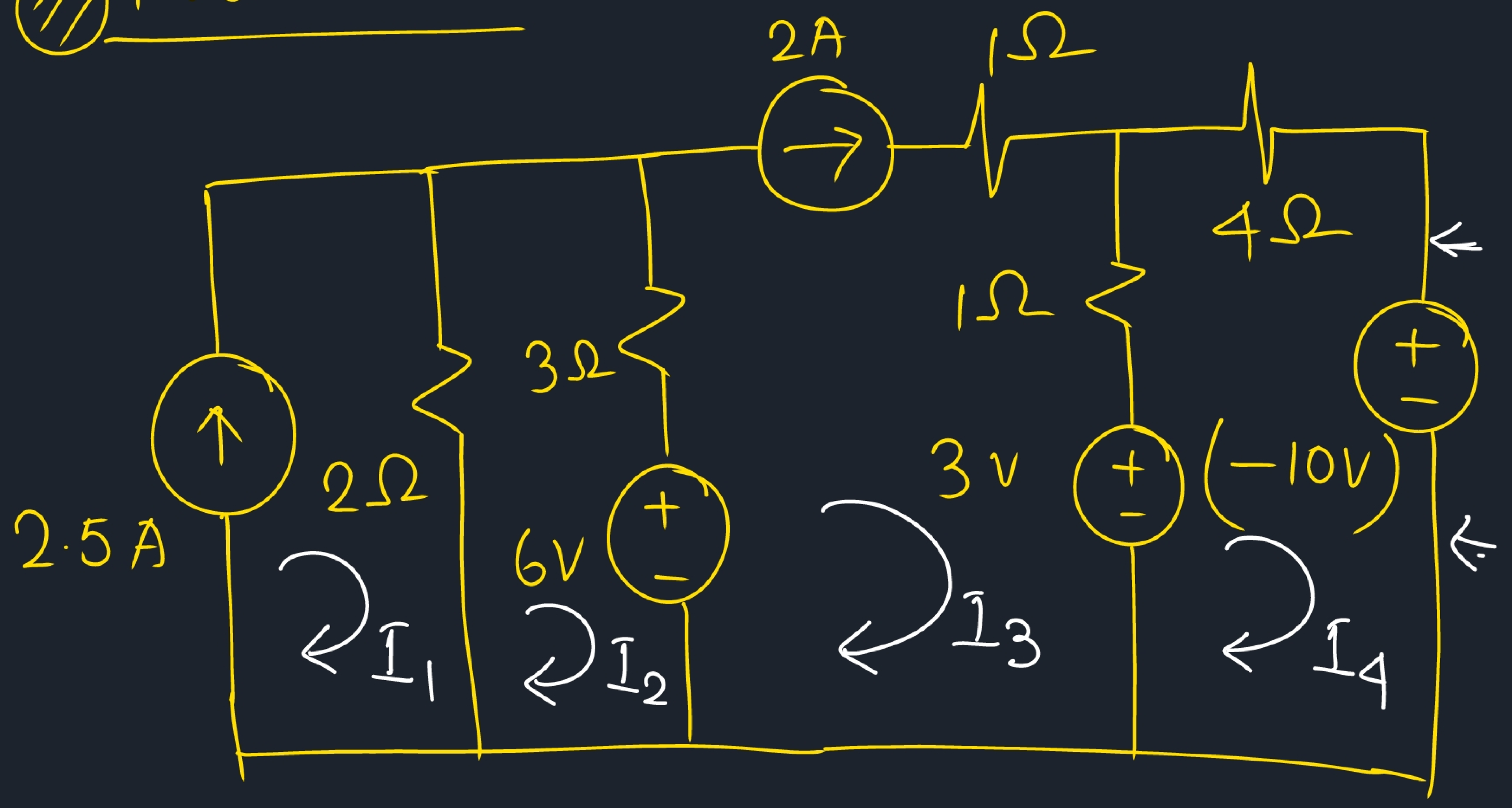
(i) + (ii)

$$2 - 2I_1 - 3I_2 - 3 = 0 \quad \text{- - - (iv)}$$



SUPERMESH.

Problem:-



$I_1 = 2.5$ Amps.
$I_3 = 2$ Amps

MESH-2 :-

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

$I_2 = ?$ 1 Amps.

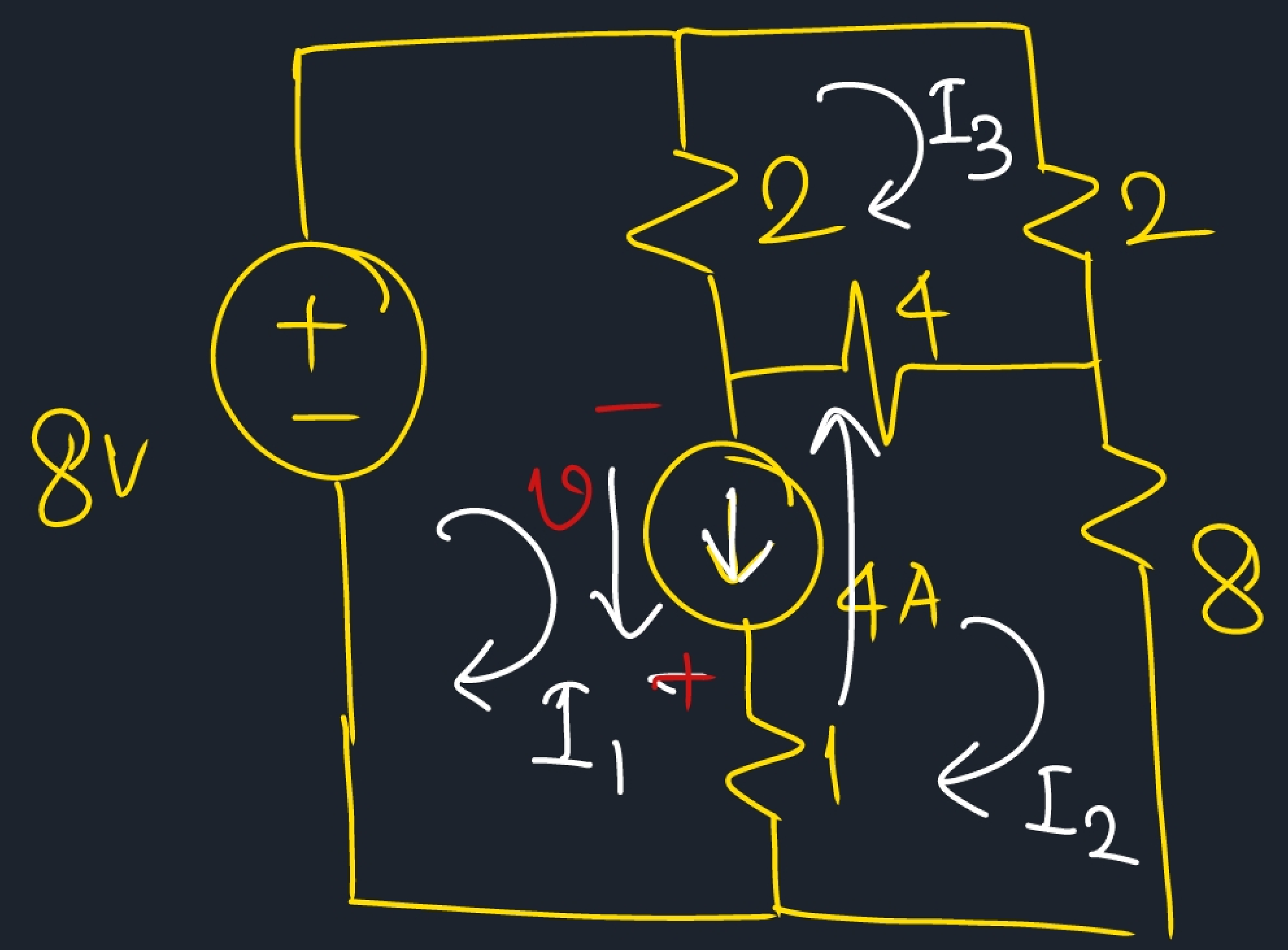
MESH-4 :-

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

$I_4 = ?$ 3 Amps

Problem :-

$I_1, I_2, I_3 = ?$



$I_1 = 4.632$ A

$I_2 = 0.632$ A

$I_3 = 1.4736$ A

MESH-3

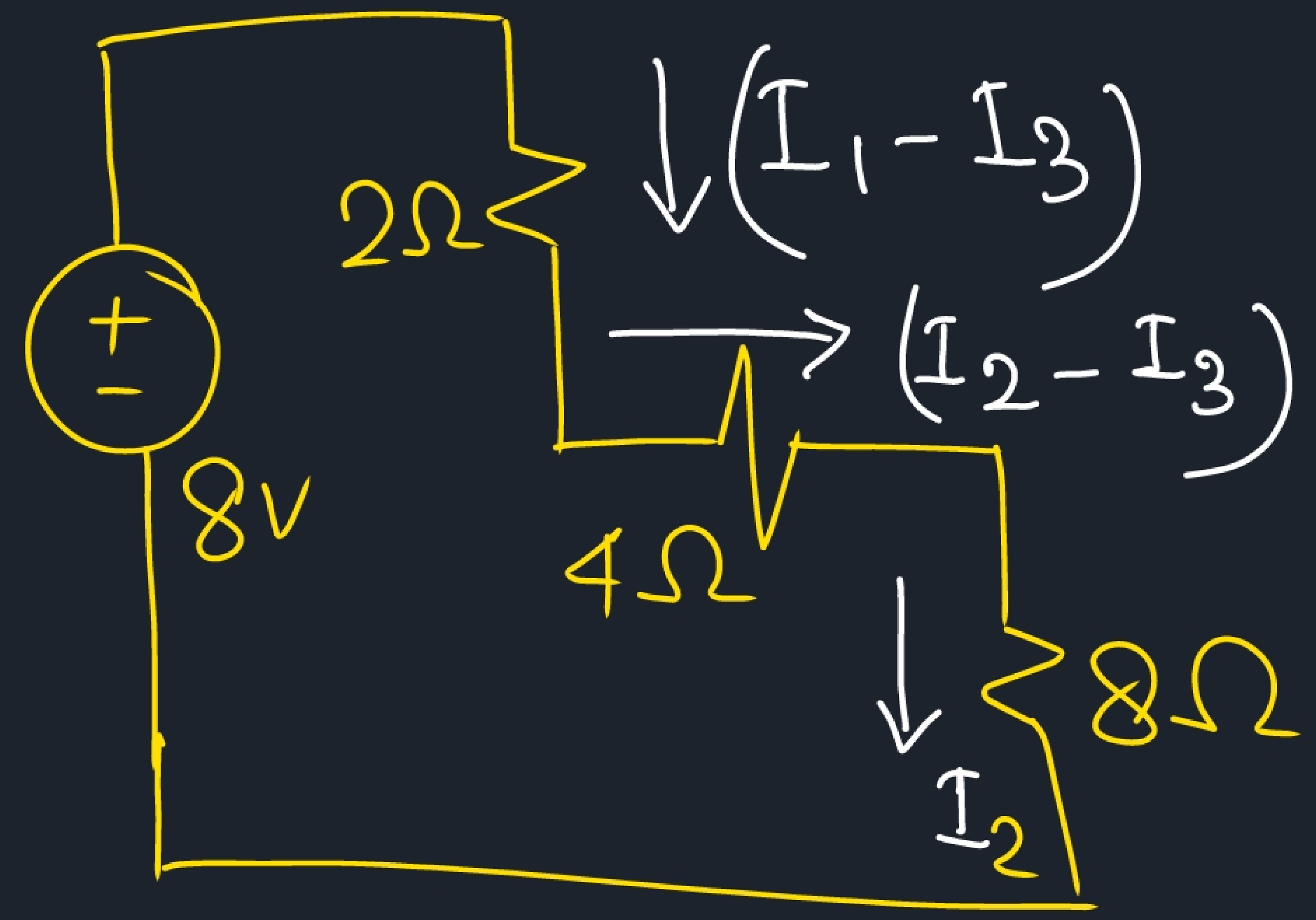
$$-2I_1 - 4I_2 + 8I_3 = 0 \quad \dots (i)$$

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

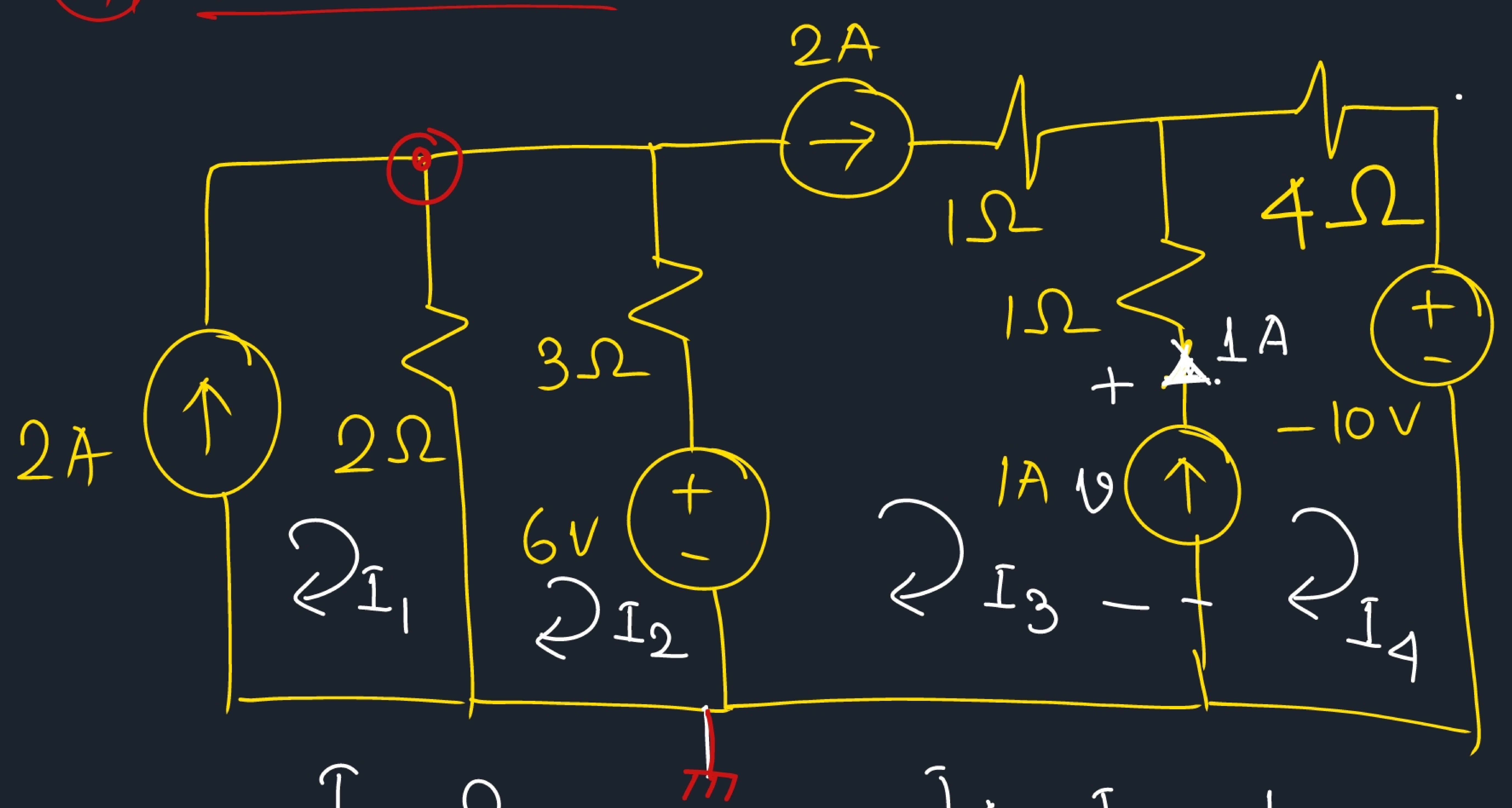
$$8 = 2(I_1 - I_3) + 4(I_2 - I_3) + 8I_2 \quad \dots (iii)$$

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

$v = ?$



(///) Problem:-



$I_1 = 2$

$I_4 - I_3 = 1$

$\downarrow$

2A

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

$\boxed{v = 3V}$

Power Delivered = 3W

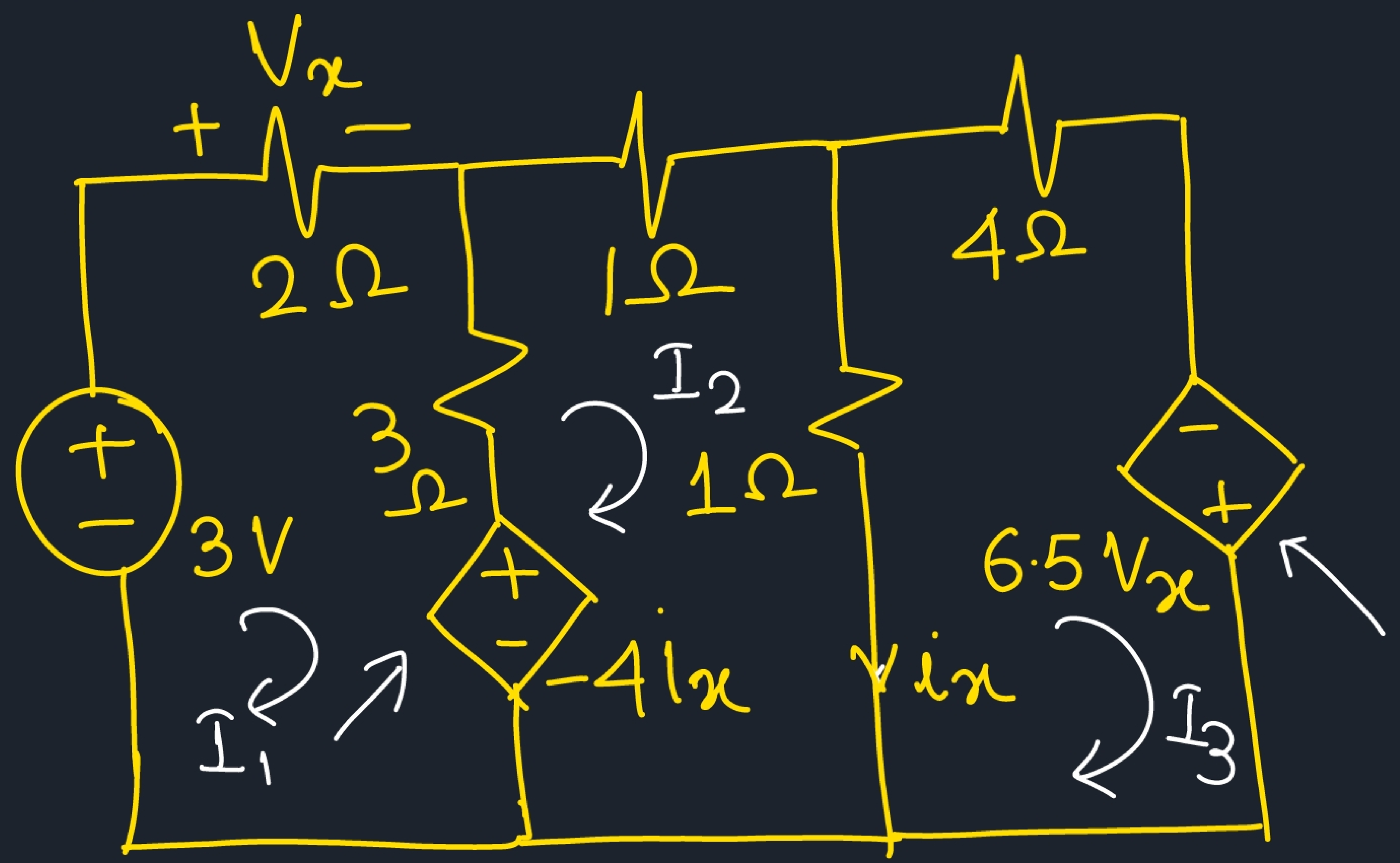
$I_4 - I_3 = 1$

$I_4 = 3$ Amps.

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

$\boxed{I_2 = 0.8}$

Problem:-



$V_x = 2I_1$

$i_x = I_2 - I_3$

MESH-1 :-

$$3 - 2I_1 - 3(I_1 - I_2) - (-4(I_2 - I_3)) = 0 \quad \text{------(i)}$$

MESH-2 :-

$$-4(I_2 - I_3) - 3(I_2 - I_1) - 1 \times I_2 - 1(I_2 - I_3) = 0 \quad \text{------(ii)}$$

MESH-3 :-

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

$I_1 = ?$ 1 A

$I_2 = ?$ 2A

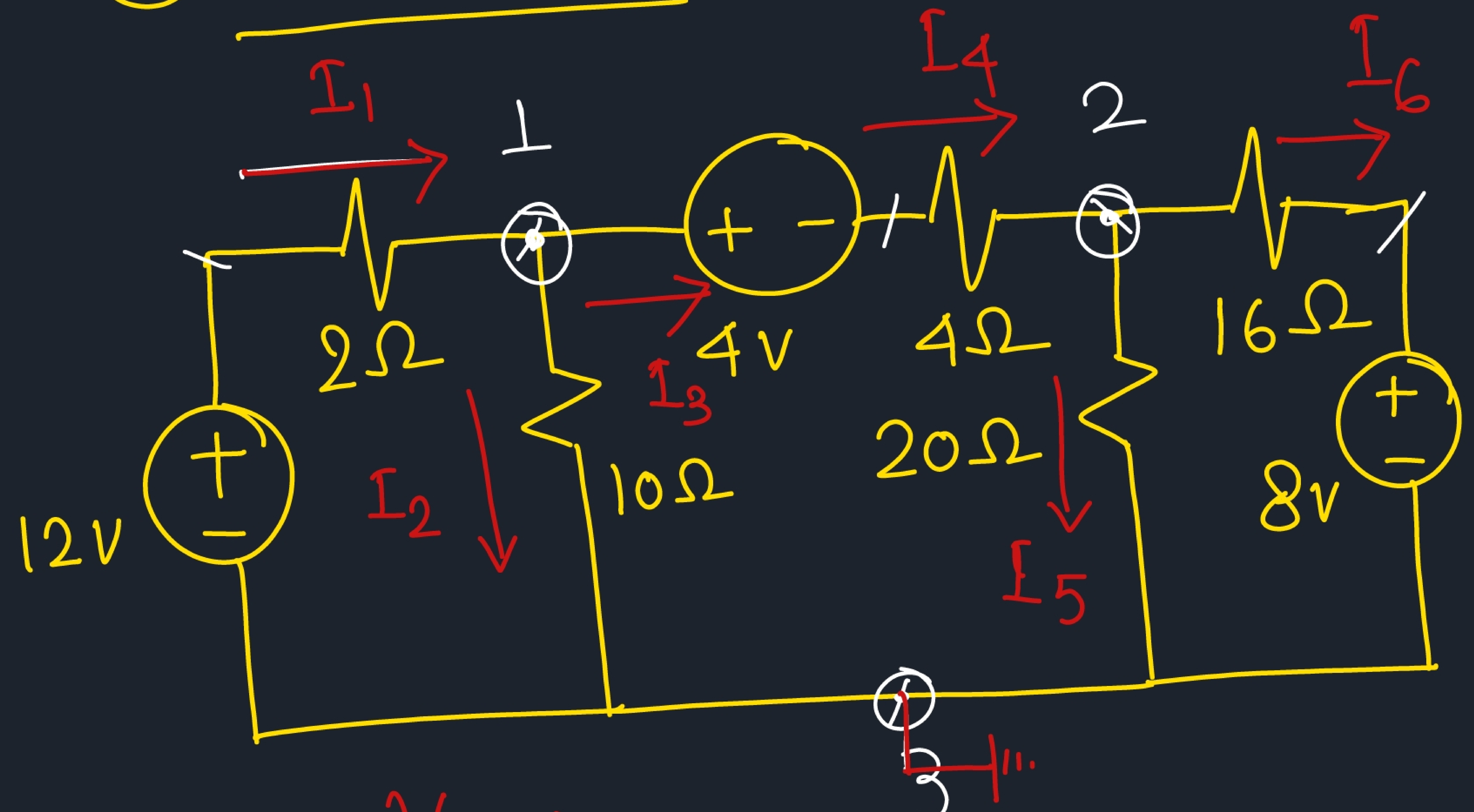
$I_3 = ?$ 3A

$V_x = ?$ 2 Volts

$i_x = ?$ −1 Amps.

MESH ANALYSIS	NODAL ANALYSIS
1. Identify MESH -	1. Identify nodes.
2. Assume Random Mesh currents	2. Assume the node voltages.
3. Write KVL & Solve	3. Write KCL & solve.
4. Get actual values of branch currents.	4. . . . . node voltage.

(3) Problem :-



$V_3 = 0$

$V_1 = ?$ 9.82 V

$V_2 = ?$ 5.39 V

NODE-1 :-

$I_1 = I_2 + I_3$

$$\Rightarrow \frac{12 - V_1}{2} = \frac{V_1}{10} + \frac{V_1 - V_2 - 4}{4} \quad \text{----- (i)}$$

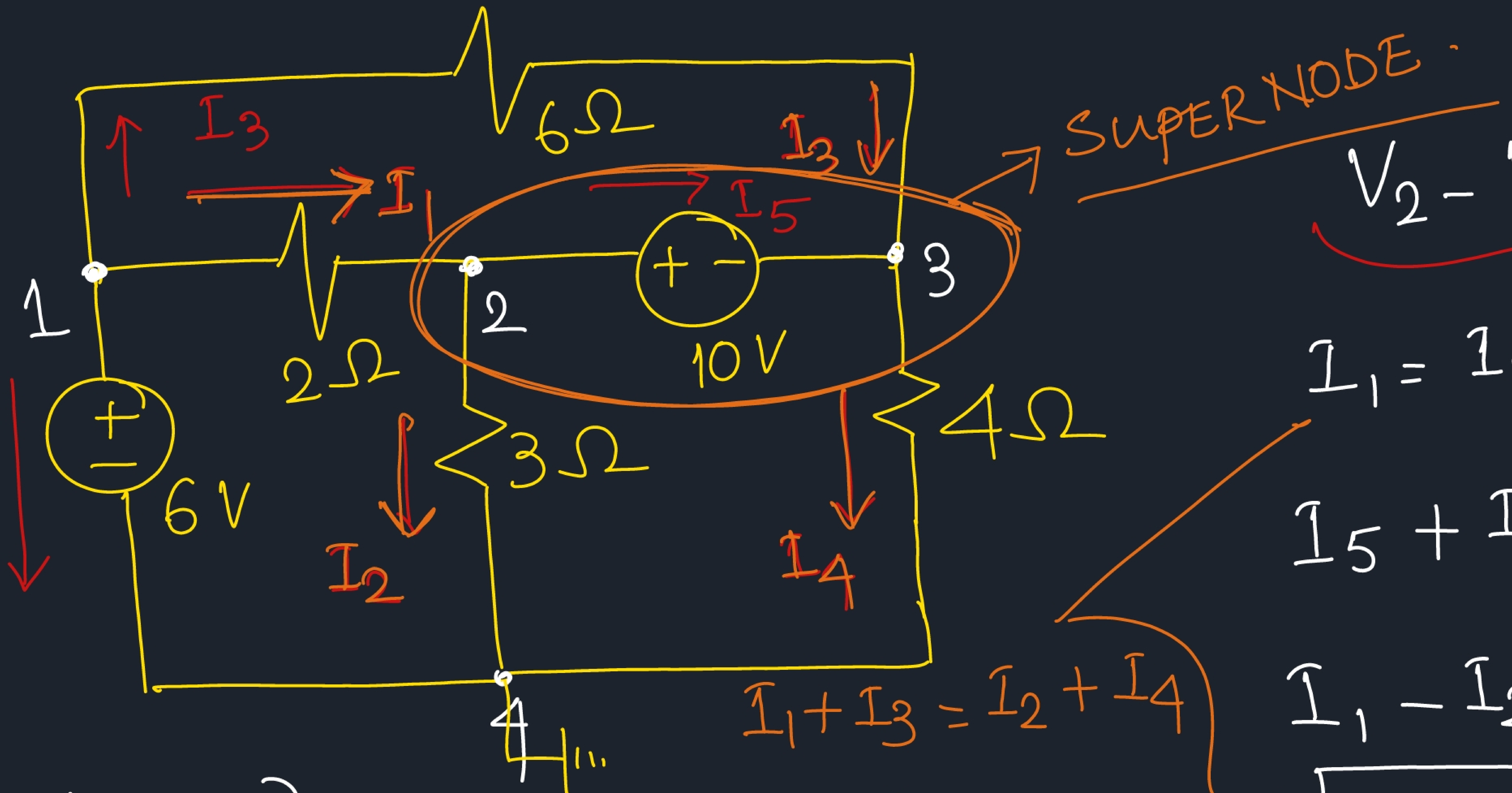
$$V_1\left(\tfrac{1}{2} + \tfrac{1}{10} + \tfrac{1}{4}\right) - V_2\left(\tfrac{1}{4}\right) = \frac{12}{2} \quad \text{--- (i)}$$

NODE-2 :-

$I_4 = I_5 + I_6$

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

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



$V_2 - V_3 = 10\,V$ - - - (iv)

$I_1 = I_2 + I_5 \Rightarrow I_5 = I_1 - I_2$ - - - (ii)

$I_5 + I_3 = I_4 \Rightarrow I_5 = I_4 - I_3$ - - - (iii)

$I_1 - I_2 = I_4 - I_3$

$I_1 + I_3 = I_2 + I_4$

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

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

$V_1 = ?$

$V_2 = ?$

$V_3 = ?$

$V_1 = 6\,V$ - - - (i)

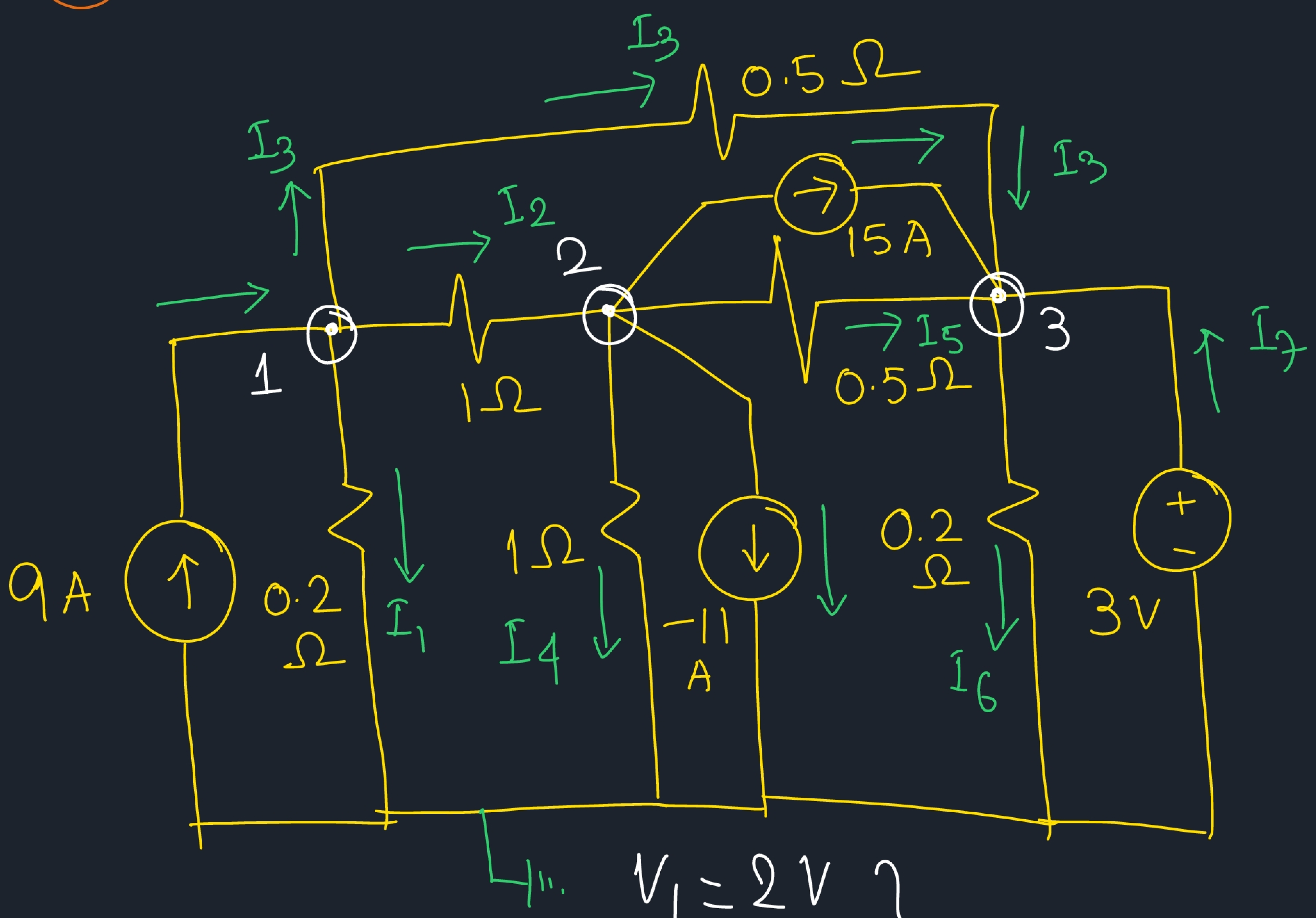
$\Rightarrow \underbrace{V_1\left(\frac{1}{2}+\frac{1}{6}\right) - V_2\left(\frac{1}{2}+\frac{1}{3}\right) - V_3\left(\frac{1}{6}+\frac{1}{4}\right) = 0}$ - - - (vi)

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

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

$-1.644\,A$

Problem:-



$$\left.\begin{aligned} V_1 &= 2V \\ V_2 &= 1V \end{aligned}\right\}$$

NODE-1 :-

$$I_1 + I_2 + I_3 = 9$$

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

NODE-2 :-

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

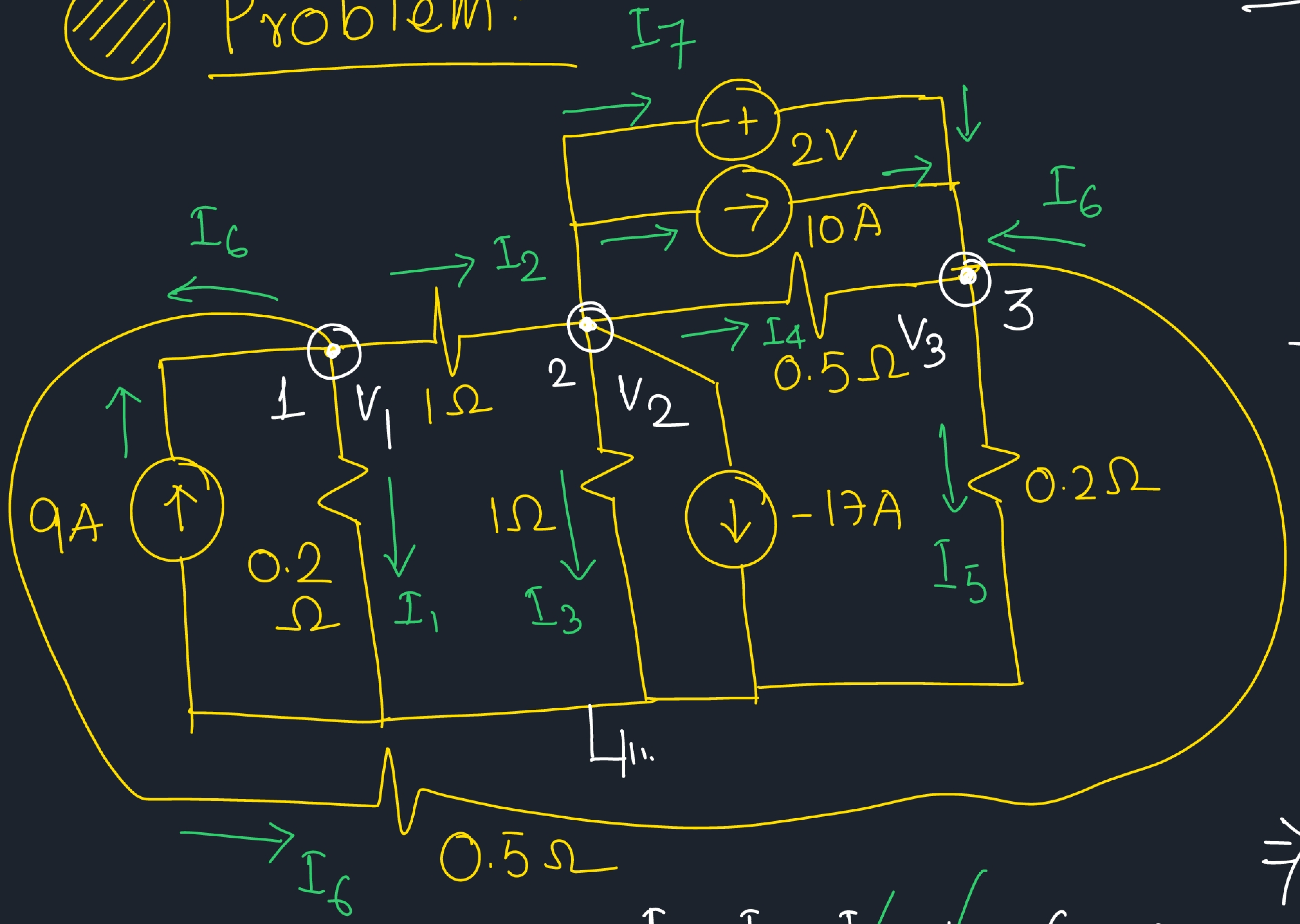
$$\Rightarrow I_2 - I_4 - I_5 = 4$$

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

NODE-3

$$V_3 = 3V \quad \text{...(iii)}$$

Problem:-



$I_2 - I_3 - \cancel{I_4} - \cancel{10} - (-17)$
$= I_5 - \cancel{I_4} - I_6 - \cancel{10}$

NODE-1

$$9 = I_1 + I_2 + I_6$$

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

NODE-2

$$I_2 = I_3 + I_4 + 10 - 17 + I_7$$

$$I_7 = I_2 - I_3 - I_4 - 10 - (-17) \quad \text{--} (ii)$$

NODE-3

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

$$\Rightarrow I_7 = I_5 - I_4 - I_6 - 10 \quad \text{---} (iii)$$

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