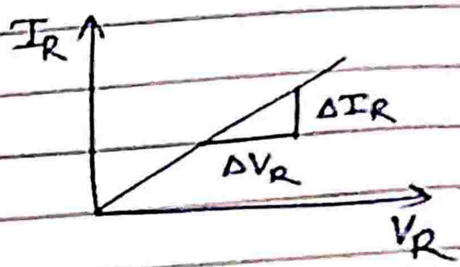
Ohm's Law

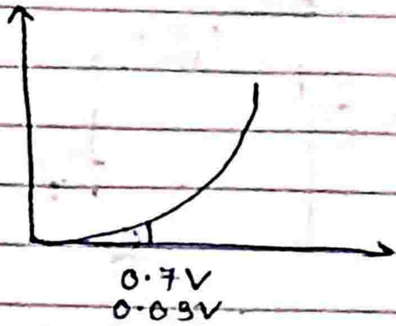
Ohm's law states that the voltage across a linear element is directly proportional to the current flowing through it.

$$V \propto I$$

$$V = IR \quad (\text{for resistive circuit})$$



$$R = \frac{\Delta V_R}{\Delta I_R}$$



Resistor $\rightarrow$ linear

diode $\rightarrow$ non linear

$$\left. V_C = \frac{1}{C}\int I_C(t)\,dt \right] \text{Capacitor}$$

$$\left. V_L = -L\frac{dI_L(t)}{dt} \right] \text{Inductor}$$

Kirchhoff's law :-

1) KCL $\rightarrow$ K. Current Law
2) KVL $\rightarrow$ K- Voltage Law

KCL

KCL states that the algebraic sum of all the currents getting into the junction is zero.

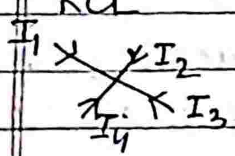
$$\boxed{\sum_{j=1}^{n} I_j = 0}$$

KVL

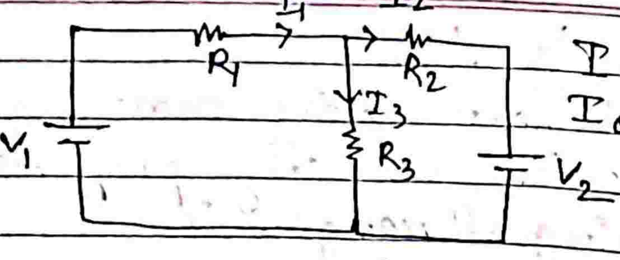
The algebraic sum of all the voltage drops around the closed loop is zero.

$$\boxed{\sum_{j=1}^{n} V_j = 0}$$

KCL



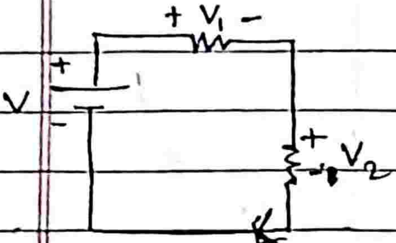
$I_1 + I_2 + I_3 + I_4 = 0$



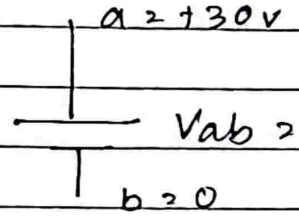
$I_{in} \rightarrow +ve$
$I_{out} \rightarrow -ve$

$I_1 - I_2 - I_3 = 0$

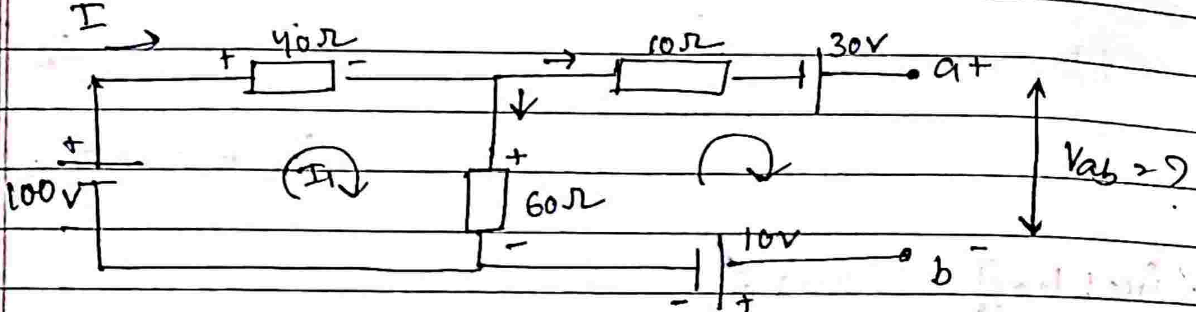
KVL



$V + V_1 + V_2 = 0$



$V_{ab} = +30V$



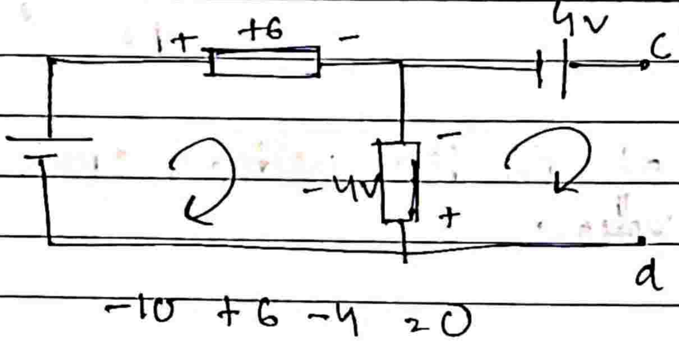
$-100 + 40I + 60I = 0$

$I = 1A$

$10 - 60 - 30 + V_{ab} = 0$

| no current; voltage drop = 0 in 10Ω resistor

$V_{ab} = 80$



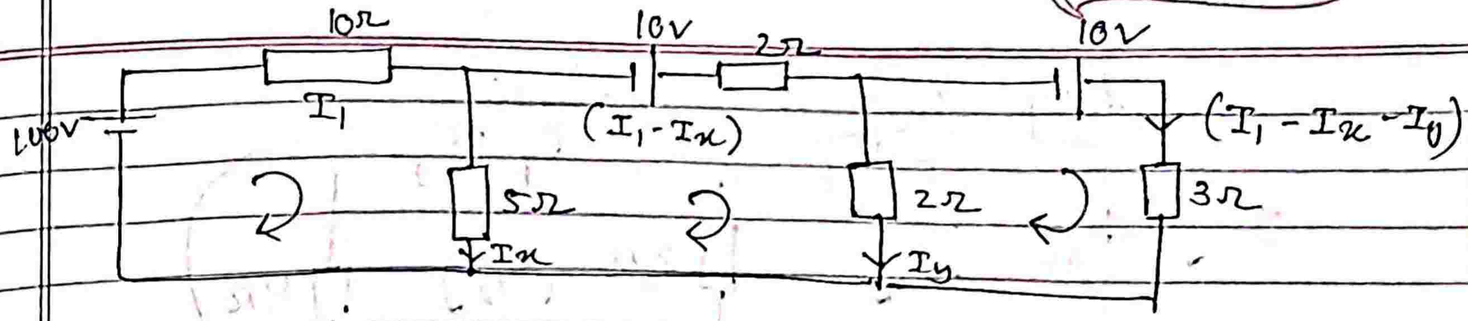
$-10 + 6 - 4 = 0$

$-4 - 4 - V_x = 0$

$V_x = -8V$

$-6V + 4V + V_{cd} = 0$

$V_c = +2V$



$-100 + 10I + 5I_x = 0$

$\Rightarrow 2I + I_x = 20$

$-10 + 2(I_1 - I_x) - 2I_y - 5I_x = 0$

$-10 + 2I_1 - 2I_x - 2I_y - 5I_x = 0$

$2I_1 + 7I_x + 2I_y = 10$

$-10 + 3(I_1 - I_x + I_y) + 2I_y = 0$

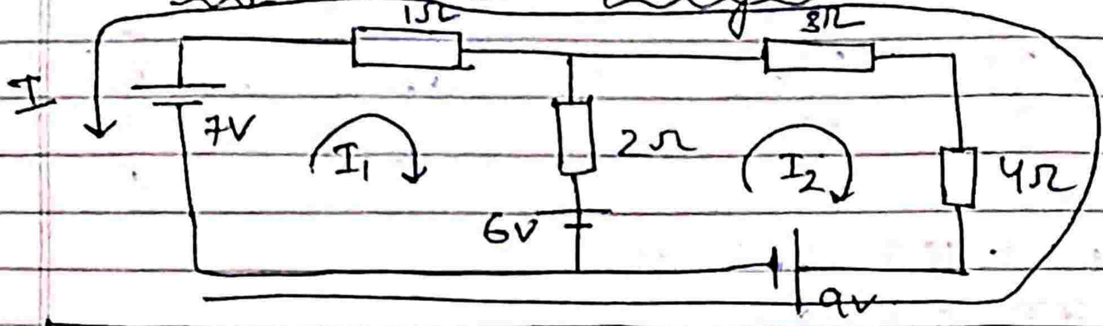
$3I_1 - 3I_x + 3I_y + 2I_y = 10$

$3I_1 - 3I_x + 5I_y = 10$

using Cramer rule:

$$\begin{bmatrix} 10 & 5 & 0 \\ -2 & 7 & 2 \\ 3 & -3 & 5 \end{bmatrix} \begin{bmatrix} I_1 \\ I_x \\ I_y \end{bmatrix} = \begin{bmatrix} 100 \\ -10 \\ 10 \end{bmatrix}$$

Loop Current Analysis



$$\boxed{\begin{aligned}&\Sigma \text{ Voltage drop across resistors} \\ &= \Sigma \text{ (+ or -) Voltage sources in the loop}\end{aligned}}$$

$$1I_1 + 2(I_1 - I_2) = +7 - 6 \Rightarrow 3I_1 - 2I_2 = 1$$

$$\Rightarrow 3I_1 = 1 + 2I_2$$

$$\Rightarrow I_1 = \frac{1+2I_2}{3}$$

$$(I_2 - I_1)2 + I_2 3 + I_2 4 = -9 + 6$$

$$2I_2 - 2I_1 + 7I_2 = -3$$

$$9I_2 - 2I_1 = -3$$

$$9I_2 - 2\left(\frac{1+2I_2}{3}\right) = -3$$

$$9I_2 - \frac{2}{3} - \frac{4I_2}{3} = -3$$

$-3 + \frac{2}{3}$

$-9 + 2$

$$\begin{array}{r} 23 \\ -14 \\ \hline 9 \end{array}$$

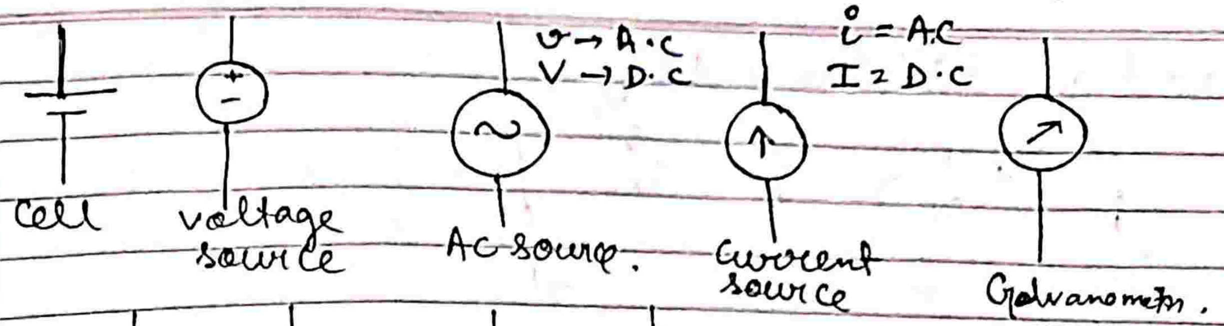
$$\frac{23}{\cancel{3}} I_2 = \frac{-7}{\cancel{3}}$$

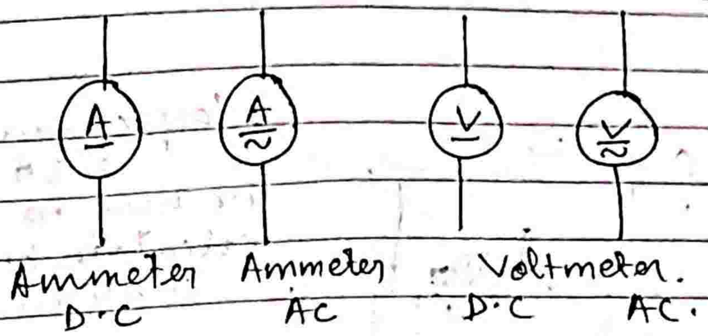
$$I_2 = -7/23 = -0.304$$

$$I_1 = \frac{1 - 14/23}{3} = \frac{\cancel{9}\,3}{23 \times \cancel{3}} = \frac{3}{23} = 0.13$$

Outer loop (consider I and I_1)

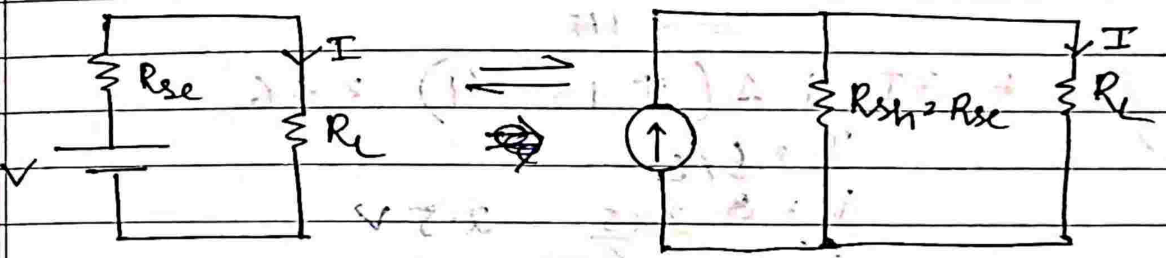
$$7I + 1(I - I_1) = -7 + 9$$





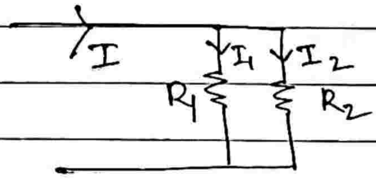
Voltage source in series.
Current source in parallel.

Source Transformation



$$\frac{V}{R_{se}} = I$$

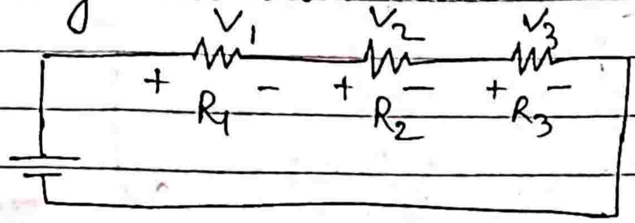
Current Division Rule



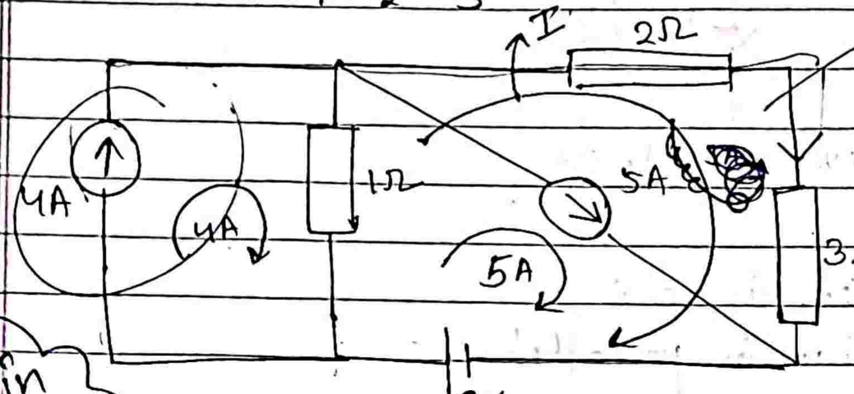
$$I_1 = \frac{R_2}{R_1+R_2} \times I$$

$$I_2 = \frac{R_1}{R_1+R_2} \times I$$

Voltage division rule.



$$V_1 = V \times \frac{R_1}{R_1+R_2+R_3}$$

Q. 

Loop current = 5A
we have to calculate branch current.

3Ω $V = ?$

Current in any 1 loop can be 5 A or total in both loop can be 5A

3+0
or 5+0

~~4x1.~~ $\cancel{2I + 3I + 1I = 6}$

$\cancel{I = 1A}$.

$$2I + 3I + 1(I+5-4) = +6$$

$$I = 5/6$$

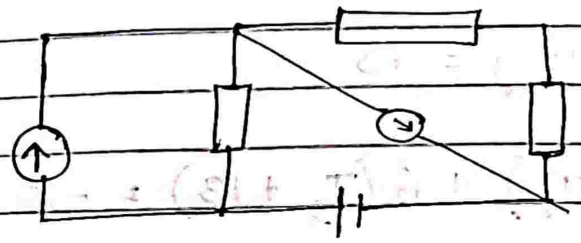
$$V = 3 \times \frac{5}{6} = 2.5\,V$$

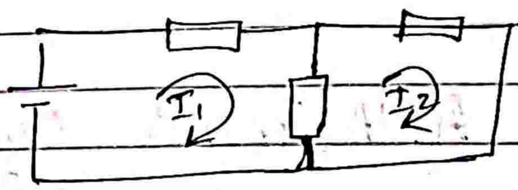
Dependent and Independent loop

An independent loop is a loop, the current of which doesn't depend on the current of any other loop.

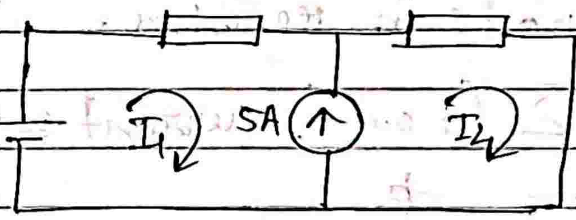
To identify the independent loop, one has to replace the sources in the electrical circuit with their equivalent resistance.

Voltage source with closed circuit.
Current source with open circuit.



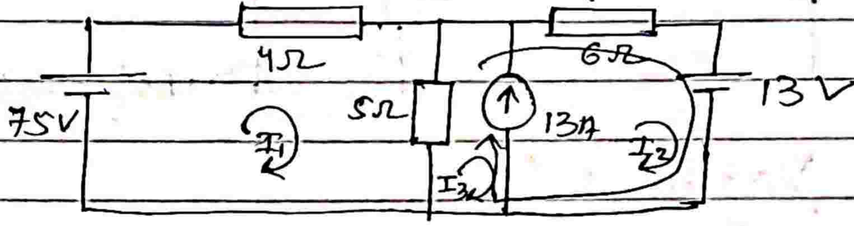


I_1 & I_2 are indepent
→ independent loop.



$|I_1 - I_2| = 5A$
→ dependent loop.

Mesh Analysis



A mesh is the smallest loop in a electreical circuit.

A mesh can also be considered as a loop, but a loop may not always be a mesh.

To handel current source, the concept of super mesh has been developed.

If the current source is common to two different meshes then both mesh can be combined to form a super mesh

Mesh ~~Loop~~ 1 :- $4I_1 + 5(I_1 - I_3) = 75$

Super mesh $\quad 5(I_3 - I_1) + 6(I_3 + 13) = -13$

Pre-define step $\quad I_2 - I_3 = 13$

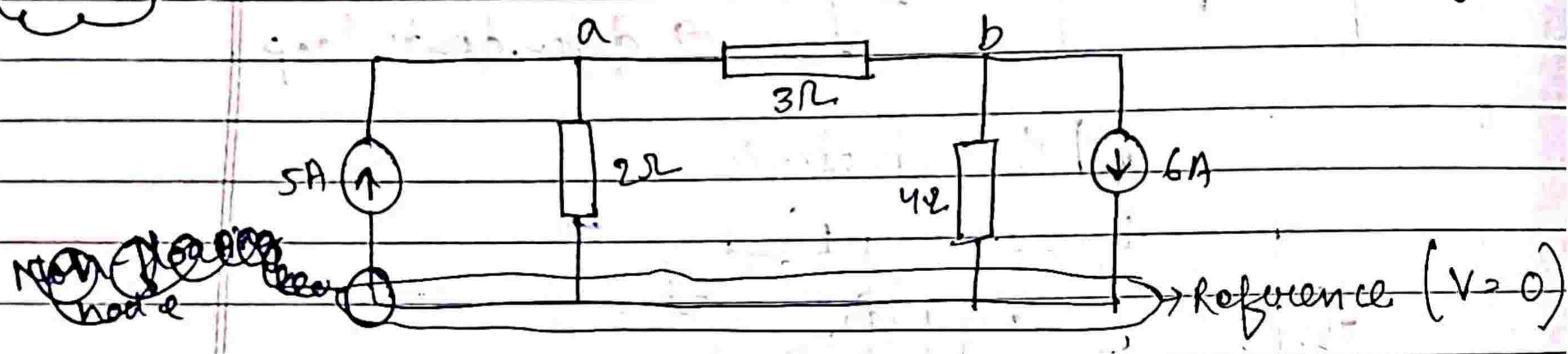
Always considere current leaves from a node

NODE VOLTAGE ANALYSIS

use when current source is given

$\sum$ current leaving the node in resistor.

$= \sum$ (+ or -) current entering the node



Node a $\quad \dfrac{V_a - 0}{2} + \dfrac{V_a - V_b}{3} = 5$

Node b $\quad \dfrac{V_b - 0}{4} + \dfrac{V_b - V_a}{3} = -6$

$$5 - \frac{V_a}{2} = 6 + \frac{V_b}{4}$$

$$-\frac{V_b}{4} - \frac{V_a}{2} = 6 - 5$$

$$-\left(\frac{2V_b - V_a}{2}\right) = 1.$$

$$V_a - 2V_b = -2$$

$$V_a = 2V_b - 2$$

$$\cancel{\frac{V_a}{2} \quad 2V_b - 2}$$

$$\frac{V_b}{4} + \frac{V_b - 2V_b + 2}{3} = -6$$

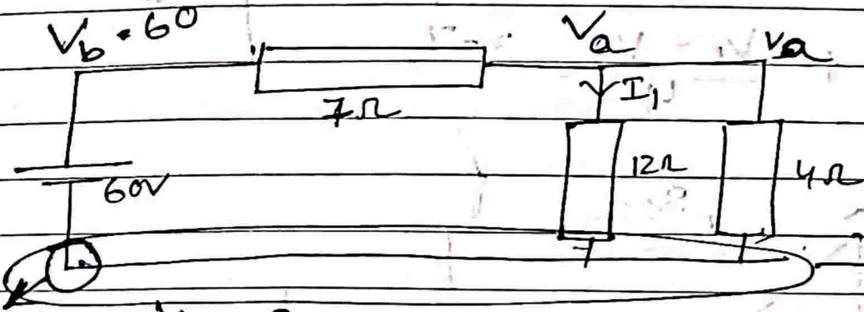
$$\frac{3V_b - 4V_b + 8}{12} = -6$$

$$8 - V_b = -12\times 6$$

$$V_b = 72 + 8$$
$$= 80$$

$$V_a = 160 - 2$$
$$= 158$$

$V_a = 9.5V \qquad V_b = -8.88V$



$I_1 = ?$

reference node.

Non floating voltage (voltage source connected to the reference node source)

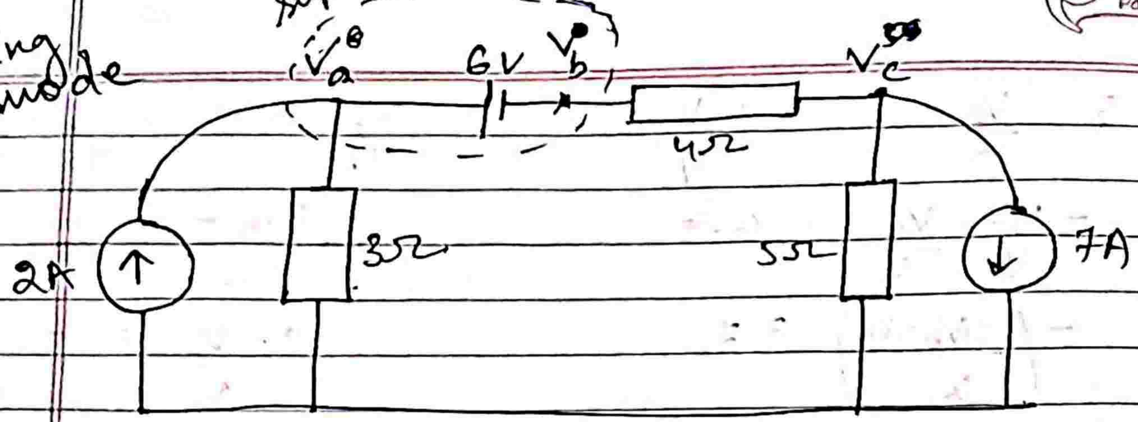
$$\cancel{\frac{V_a - 0}{12} + \frac{V_a - 60}{7} = I_1}$$

$$\cancel{\frac{7V_a + 12V_a - 12\times 60}{84} = I_1}$$

$$\frac{V_a}{12} + \frac{V_a}{4} + \frac{V_a - 60}{7} = 0$$

floating node

super node · $V_b - V_a = -6$



$\left.\begin{matrix} V_a \\ V_b \\ V_c \end{matrix}\right\} = ??$

$$\frac{V_a}{3} + \frac{V_b - V_c}{4} = 2$$

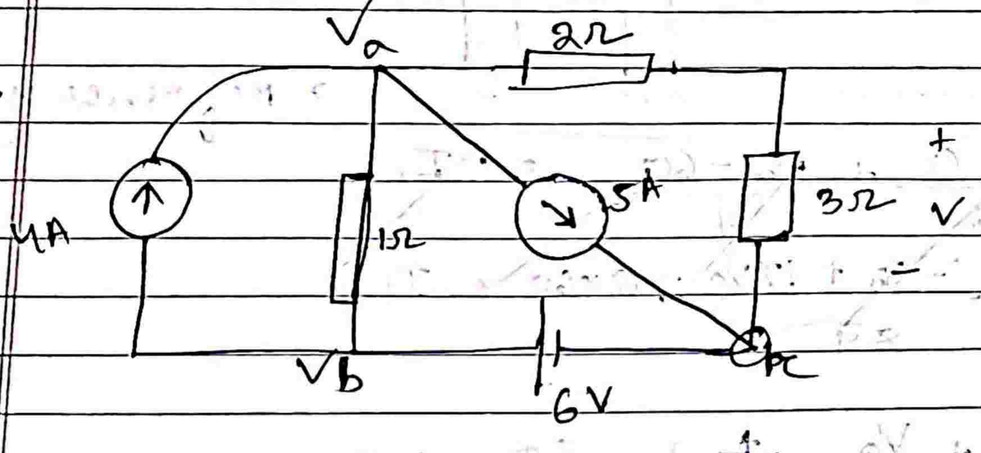
$$\frac{V_c}{5} + \frac{V_c - V_b}{4} = -7$$

$V_a = -2.75$

$V_b = -8.77$

$V_c = -20.43$

Q.



$$\frac{V_a - 6}{1} + \frac{V_a}{5} = 4 - 5$$

$V_a = 4.17$ V.

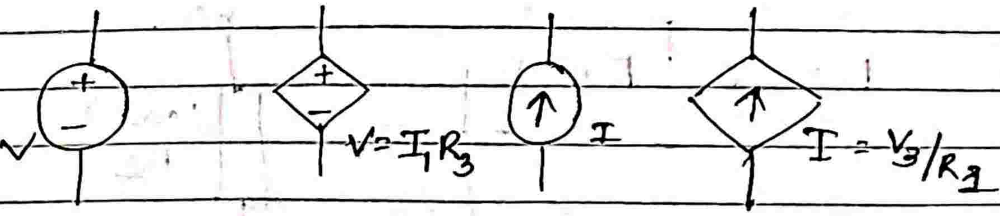
$$\frac{4.17 \times 3}{5} = 2.4A$$

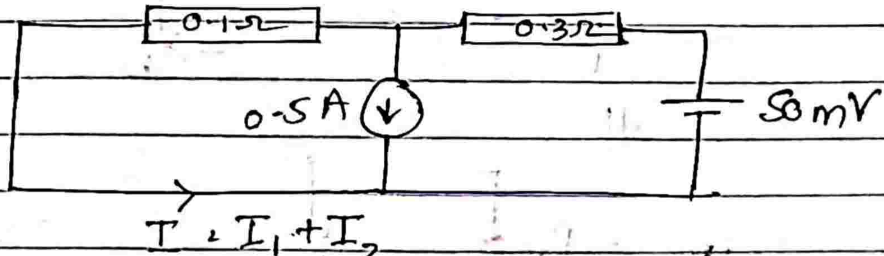
Network Theorems

Superposition Theorem.

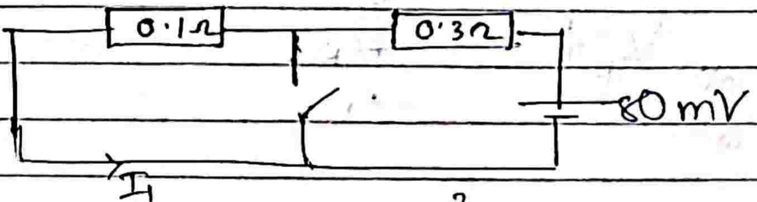
The response in a linear circuit at any point due to multiple sources can be calucated by suming the effects of each source considered separetly, or all other sources being made inoperative (open circuit for current source, short circuit for voltage source.)

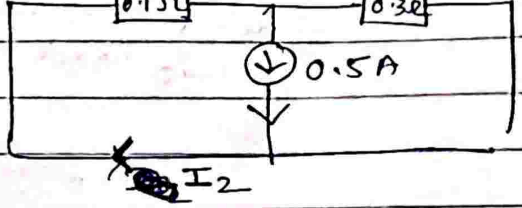
Dependent Source





$I = I_1 + I_2$





$I_1 = \frac{80 \times 10^{-3}}{0 \cdot 4}$

$= 0 \cdot 2A$

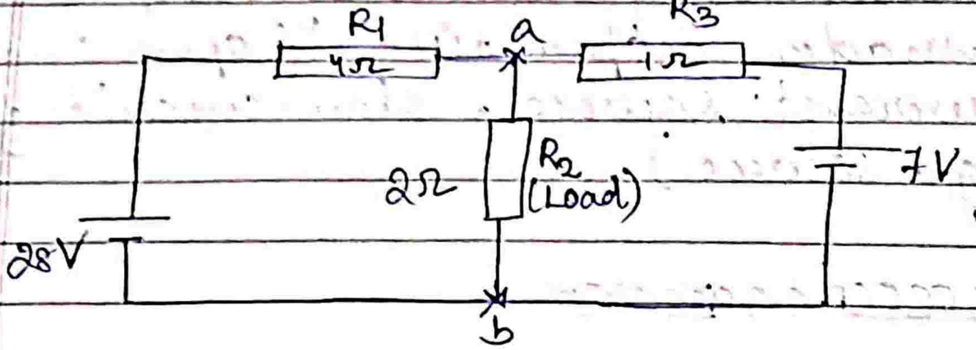
$I_2 = \frac{0 \cdot 5 \times 0 \cdot 3}{0 \cdot 4}$

$= \frac{1.5}{4} = 0 \cdot 37$

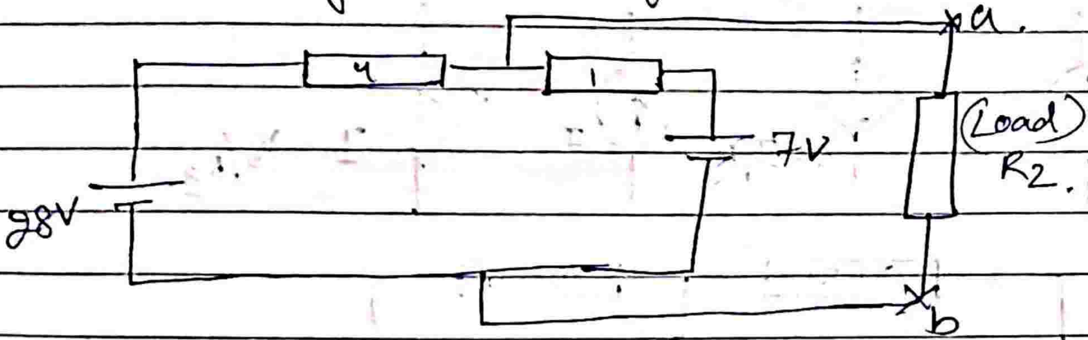
$I = 0 \cdot 2 - 0 \cdot 037 = -0.17$

Thevenin's Theorem

Thevenin's Theorem ~~to~~ states that it is possible to simplify any linear circuit containing dependent & independent source, to an equivalent circuit with a voltage source (V_{Th}) in series with a resistance (R_{Th}) between any 2 terminals or pts in the circuit

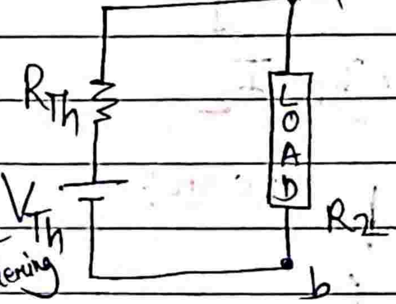


Circuit obeys the law of superposition – linear circuit

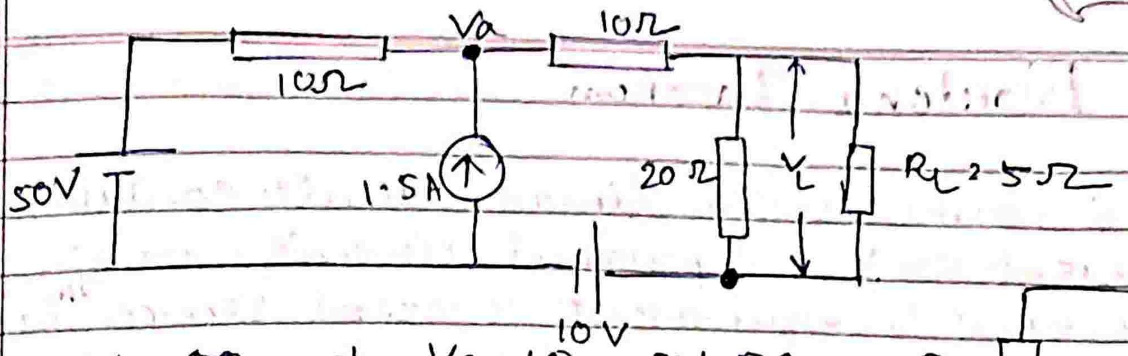


⇓

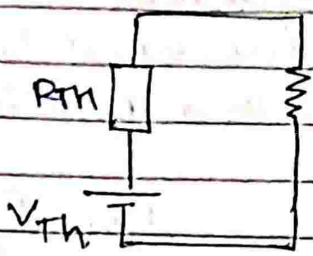
(net resistance w/o Load) 4/5 = R_{Th}



(calculate voltage without considering load)



$$\frac{V_a - 50}{10} + \frac{V_a - 10}{30} = 1.5A.$$



$$\frac{3V_a - 150 + V_a - 10}{30} = 1.5$$

$$4V_a - 160 = 45$$

$$V_a = 51.25$$

$$V \text{ across } 20\Omega = V \times \frac{20}{30}$$

$$= (51.25 - 10) \times \frac{2}{3}$$

$$= 41.25 \times \frac{2}{3} = 27.5$$

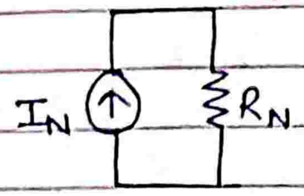
$V_{TH} = 27.5$

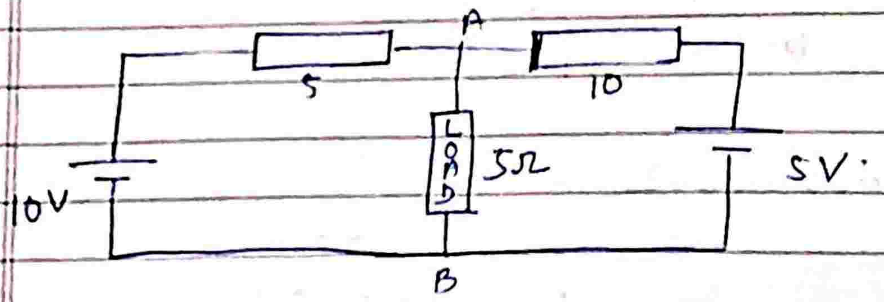
Norton's Theorem

Any 2 terminal of a linear circuit containing dependent and independent circuit can be converted to equivalent current source (I_N) in parallel with a resistance (R_N)

$R_N = R_{Th}$

$I_N = \frac{V_{Th}}{R_{Th}}$





$R_N =$ ~~1/5 + 1/10~~ $\quad RN = \frac{10 \times \cancel{5}}{\cancel{15}\,3} = 10/3$

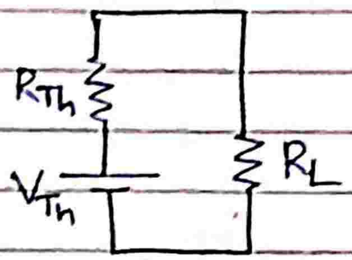
$I_N = \frac{\cancel{5}}{2\,\cancel{10}/3} = \frac{3}{2} = 2.5$

Maximum Power Transfer

Maximum power is absorbed from a network when the load resistance is equal to the output resistance of the network as seen from the load side

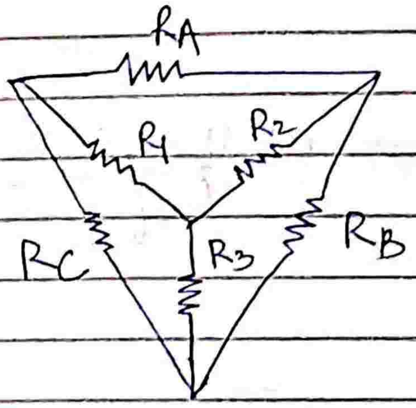
$$P = I^2 R_L$$

$$P = \left(\frac{V_{Th}}{R_{Th}+R_L}\right)^2 R_L$$



$$\frac{dP}{dR_L} = 0 \Big|_{\underbrace{R_{Th} = R_L}_{\text{Impendance Matching}}}$$

Star-Delta Transformation



$\nabla \rightarrow Y$

$$R_1 = \frac{R_A R_C}{R_A+R_B+R_C}$$

$$R_2 = \frac{R_A R_B}{R_A+R_B+R_C}$$

$$R_3 = \frac{R_B R_C}{R_A+R_B+R_C}$$

$Y \rightarrow \Delta$

$$R_A = \frac{R_1R_2+R_2R_3+R_3R_1}{R_3}$$

$$R_B = \frac{R_1R_2+R_2R_3+R_3R_1}{R_1}$$

$$R_C = \frac{R_1R_2+R_2R_3+R_3R_1}{R_2}$$