BASIC ELECTRICAL

DC NETWORKS

- Ohm's Law
- KVL, KCL
- Network Reduction Theorem
  - Thevenin's
  - Norton's
- Specific quantity Theorem
  - SPT
  - Max^m Power Theorem

Ohm's Law:- "According to ohm's Law, the potential diff across any two points of the Conductor will be directly proportional to the current flowing through it".

$$\boxed{\begin{array}{c} V \propto I \\ \Rightarrow V = IR \end{array}}$$

$R \rightarrow$ ohm (Ω)

:- Kirchoff's Law :-

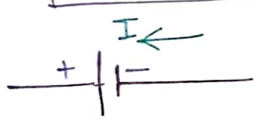
KVL:- "According to Kirchoff's Voltage Law, In any closed circuit or mesh, the algebric Sum of all the emf's and voltage drops will be Zero."

Deals with Conservation of Energy.

Net energy Supplied $\rightleftarrows$ Net energy Consumed.

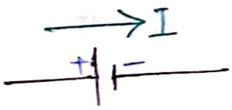
$$\boxed{\sum emf's + \sum IR = 0} \qquad \boxed{\sum IR = -\sum Emf}$$

(a)



Rise in potential (+ve)

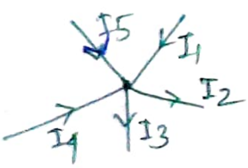
(b)



Drop in Potential or potential drop (−ve)

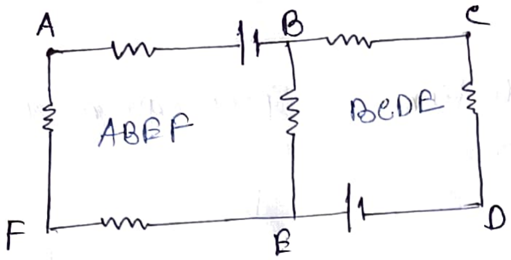
KCL:- "According to KCL, The algebric Sum of all currents meeting at a point or a junction will be Zero."

Deals with Conservation in Charge.



$\sum I = 0$.

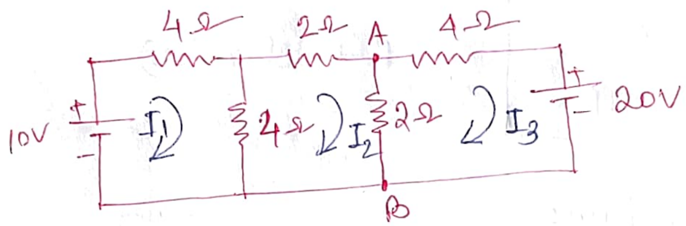
KVL:- Mesh Analysis Method :-



→ ABEF & BCDE are Mesh But ACDF not mesh.

→ ABEF, BCDE and ACDF are all Loop.

Q. Calculate the current in branch AB of 2Ω resistance for the given circuit using mesh analysis method.



$\Sigma emf + \Sigma IR = 0.$

Soln:- There are Three meshes in the given Circuit.

Applying KVL in Mesh (1),

$$+10 - I_1 \times 4 - 4(I_1 - I_2) = 0$$

$$\Rightarrow 10 - 4I_1 - 4I_1 + 4I_2 = 0$$

$$\Rightarrow -8I_1 + 4I_2 + 0I_3 = -10 \quad \text{——— (1)}$$

Mesh (2)

$$-2I_2 - 2(I_2 - I_3) - 4(I_2 - I_1) = 0$$

$$\Rightarrow 4I_1 - 8I_2 - 2I_3 = 0 \quad \text{——— (2)}$$

Mesh (3)

$$-20 - 2(I_3 - I_2) - 4I_3 = 0$$

$$\Rightarrow 0I_1 + 2I_2 - 6I_3 = 20 \quad \text{——— (3)}$$

Solving eq (I), (II), (III).

$$I_1 = 1.093\ A$$

$$I_2 = -0.312\ A$$

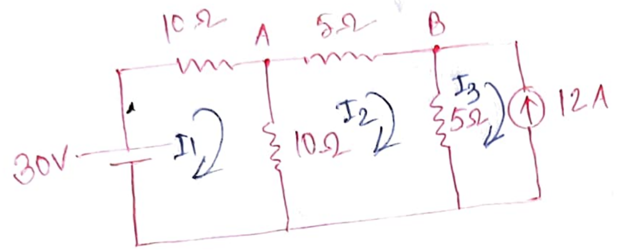
$$I_3 = -3.437\ A$$

$$I_{AB} = (I_2 - I_3)$$

$$= 0.312 + 3.437$$

$$= -3.125\ A.$$

Q. Find the current in AB Branch using mesh Analysis:-



Soln:- There are 3 meshes.

Applying KVL mesh ①,

$$-10I_1 - 10(I_1 - I_2) + 30 = 0$$

$$\Rightarrow -20I_1 + 10I_2 + 30 = 0$$

or, $$-20I_1 + 10I_2 = -30 \quad \text{—— (i)}$$

mesh ②

$$-5I_2 - 5(I_2 - I_3) - 10(I_2 - I_1) = 0$$

$$\Rightarrow 10I_1 - 20I_2 + 5I_3 = 0 \quad \text{—— (ii)}$$

$$I_3 = -12A.$$

Putting the value of $I_3 = -12A$,

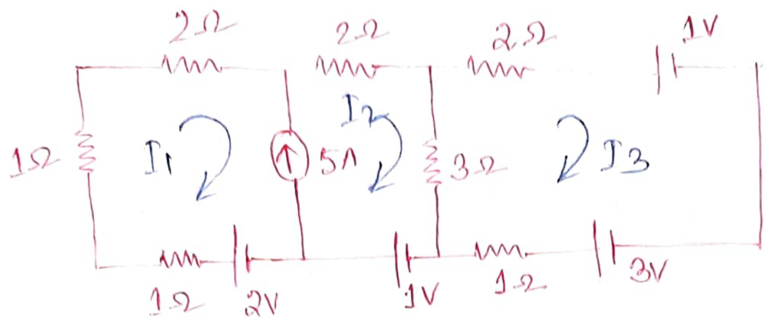
$$10I_1 - 20I_2 - 60 = 0$$

$$\Rightarrow 10I_1 - 20I_2 = 60 \quad \text{—— (ii)}$$

By solving, $I_1 = 0A$, $I_2 = -3A$, $I_3 = -12A$.

$$I_{AB} = -3A.$$

Q) Find the Voltage across 3Ω resistor using KVL. *



Solⁿ

$$I_2 - I_1 = 5$$

$$\Rightarrow -I_1 + I_2 + 0I_3 = 5 \quad \text{—— (i)}$$

Supermesh,

$$-1I_1 - 1I_1 - 2I_1 - 2I_2 - 3(I_2 - I_3) + 1 + 2 = 0$$

$$\Rightarrow -4I_1 - 5I_2 + 3I_3 + 3 = 0$$

$$\Rightarrow -4I_1 - 5I_2 + 3I_3 = -3 \quad \text{—— (ii)}$$

Applying KVL in Mesh 3,

$$-2I_3 - 1 + 3 - I_3 - 3(I_3 - I_2) = 0$$

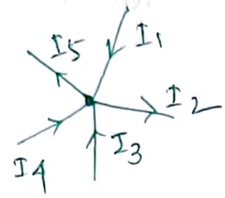
$$\Rightarrow +0I_1 + 3I_2 - 6I_3 = -2 \quad \text{—— (iii)}$$

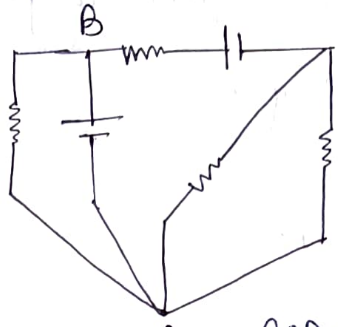
By solving, $I_1 =$ $\quad I_2 =$ $\quad I_3 =$

Kirchoff's Current Law

KCL:- According to KCL, The algebric sum of all the currents meeting at a point or junction will be zero.

> Conservation of charge





$\sum I = 0$

BCD ⇒ Node

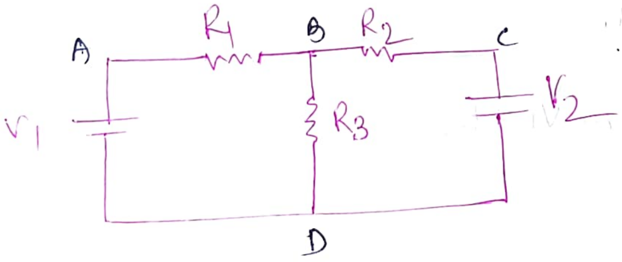
Total incoming current = Total outcoming current.

Q What is the diff b/w Node & Junction?

→ Node:- It is the point in a circuit at which at least two elements (active or passive) are joined.

Junction:- It is the point in a circuit at which at least three elements (active or passive) are joined.

"A junction must be a node but a node may or may not be a junction."



(A, C → Node
B, D → Junc^n.) ✓

KCL:- Steps for Solving numericals using nodal Analysis:-

① Identify the principal nodes or Junction present in the network.

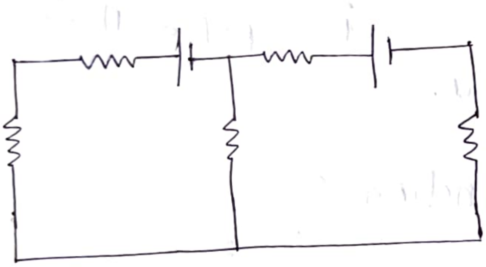
② Assign a junction potential on each junction with respect to the assign reference junction having value $V_0 = 0\,V$

3) Assuming all the currents in outgoing direction from each junction form KCL equation.

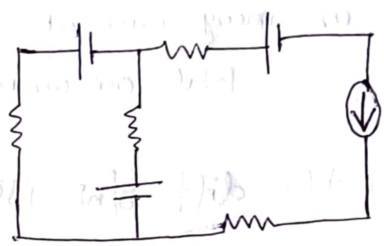
4) Solve the equation to calculate the value of junction potentials.

5) Using individual junction potential find the value of required electrical quantity.

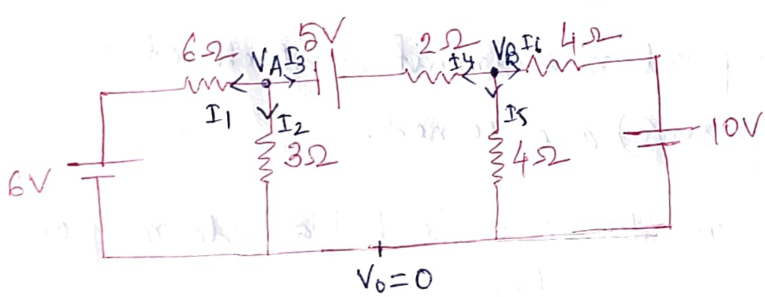
Type-1

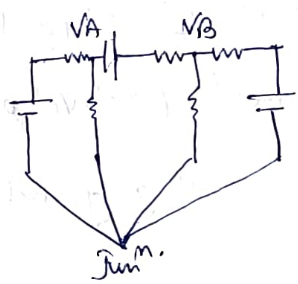


Type-2



Q) Find the current in 3Ω resistor using KCL ......





→ Applying KCL at junction A,

$$\frac{V_A - V_0 - 6}{6} + \frac{V_A - V_0}{3} + \frac{V_A - V_B + 5}{2} = 0$$

$$\Rightarrow 6V_A - 3V_B = -9 \quad \text{—(1)}$$

$$\frac{V_B - V_A - 5}{2} + \frac{V_B - V_0}{4} + \frac{V_B - 10 - V_0}{4} = 0$$

$$\Rightarrow -2V_A + 4V_B = 20 \quad \text{—(II)}$$

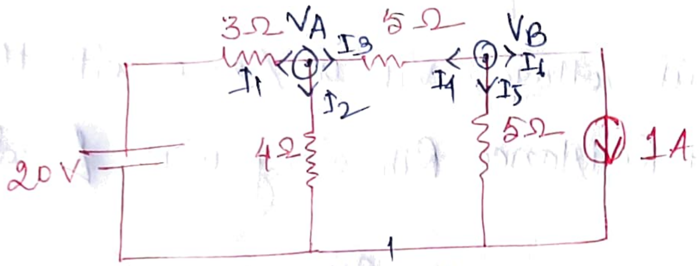
$V_A = 1.333V$

$V_B = 5.666 V$

$\therefore$ Current Through 3Ω Resistor (I_2) $= \dfrac{V_A - V_o}{3} = \dfrac{1.333-0}{3} = 0.444A$

Q Using Nodal Analysis, Find the Current in 4Ω Branch.

$V_o \to$ Reference Junc.



→ There are Two Junction.

Applying KCL at Junction A,

$$\frac{V_A - 20 - V_o}{3} + \frac{V_A - V_o}{4} + \frac{V_A - V_B}{5} = 0$$

$\Rightarrow 47 V_A - 12 V_B = 400$ —— ①

Applying KCL at Junction B,

$I_6 = 1A$.

$$\frac{V_B - V_A}{5} + \frac{V_B - V_o}{5} + 1 = 0$$

$\Rightarrow -1V_A + 2V_B = -5$ —— ②

$V_A = 9.02$ V

$V_B = 2.012 V$.

$\therefore$ Current Through 4Ω Branch

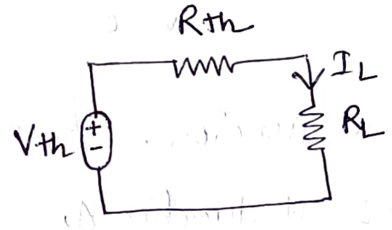
$$I_2 = \frac{V_A - V_o}{4} = \frac{9.02}{4} = 2.255A$$

Network Reduction Theorem

THEVENIN'S THEOREM

"According to the Thevenin's Theorem, Any Linear bilateral network irrespective of its complexities can be reduced into a Thevenin's equivalent circuit having the Thevenin's Open Circuit Voltage 'V_{th}' in series with the Thevenin's equivalent Resistance R_{th} along with Load Resistor R_L"?

$$\boxed{I_L = \frac{V_{th}}{R_{th}+R_L}}$$



Steps for solving:

① Identify the Load Resistor R_L

② Remove the Load Resistor and calculate the open circuit potential across two open ends. This will be the Thevenin's equivalent Voltage V_{th}.

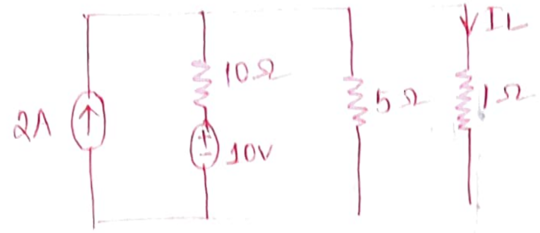
③ Again Remove the Load Resistor and Replace all the active sources by their internal Resistance.

④ Calculate the equivalent Resistance across the open ends. This will be the Thevenin's equivalent resistance R_{th}.

⑤ Draw the equivalent (Thevenin's) for given network.

⑥ Calculate the load current I_L by using the identity.

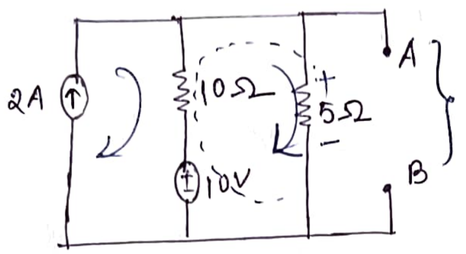
Find the current through 1 Ω Resistor in the given circuit using Thevenin's Theorem.



[Jisko across data pucha Jayega O hi R_L hain. $R_L = 1\Omega$.]

→ $R_L = 1\Omega$

Removing R_L.



mesh 1

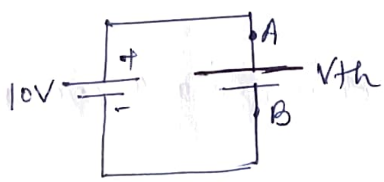
$I_1 = 2A$

mesh 2

$10 - 10(I_2 - I_1) - 5I_2 = 0$

$\Rightarrow 10 - 10(I_2 - 2) - 5I_2 = 0$

$\Rightarrow I_2 = 2A$.



$V = I_2 R = 2 \times 5 = 10V$

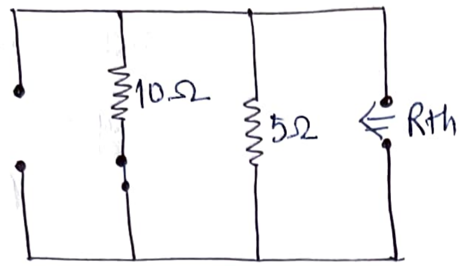
$-V_{th} + 10 = 0$

$\boxed{\Rightarrow V_{th} = 10V}$

Voltage source: Always has a internal Resistance of 0 Ω $\xrightarrow{\text{Replace by}}$ Short Circuit

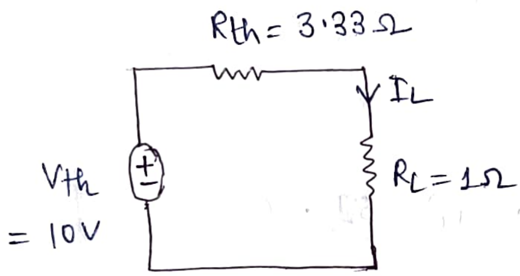
Current Source: ∞ internal Impedence/(Resistance) $\xrightarrow{\text{Replaced by}}$ Open Circuit Branch.

Removing R_L and Replacing all the active sources by their internal Resistance.



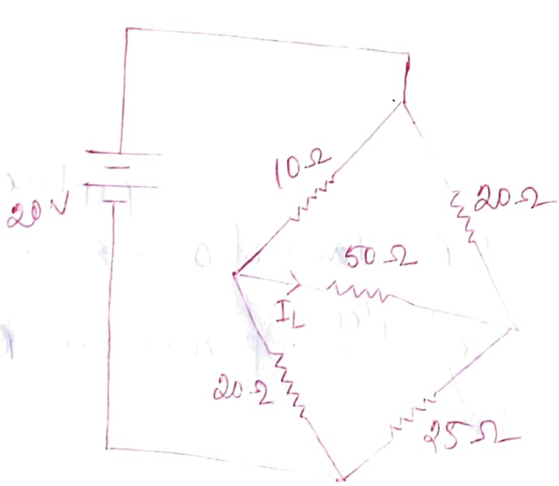
$$R_{th} = \frac{10 \times 5}{10+5} = \frac{50}{15} = 10/3\ \Omega = 3.33\ \Omega$$

$$\boxed{R_{th} = 3.33\ \Omega}$$



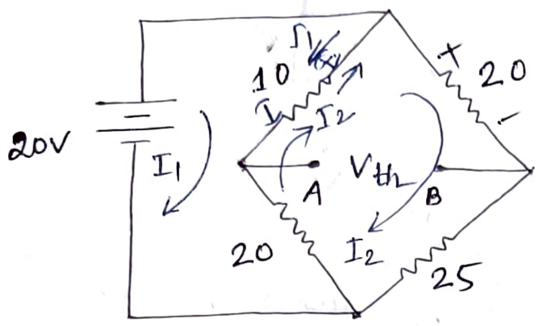
$$I_L = \frac{V_{th}}{R_{th}+R_L} = \frac{10}{3.33+1} = \frac{10}{4.33} = 2.31\ A.$$

2). Find the Current through 50 Ω Resistor using Thevenin's Theorem.



$\rightarrow R_L = 50\,\Omega$.

Removing R_L to calculate V_{th}.



where Current enter = +

where Current leave = -

Applying KVL in Mesh 1,

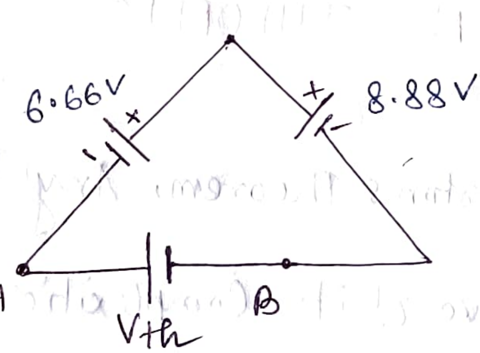
$$-30I_1 + 30I_2 + 20 = 0$$

$$\Rightarrow -30I_1 + 30I_2 = -20 \quad \text{—(1)}$$

$$30I_1 - 75I_2 = 0 \quad \text{—(2)}$$

$$\boxed{\begin{aligned} I_1 &= 1.11\,A \\ I_2 &= 0.44\,A. \end{aligned}}$$

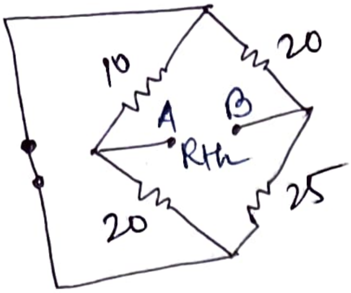
$I' = I_1 - I_2 = 0.66\,A$

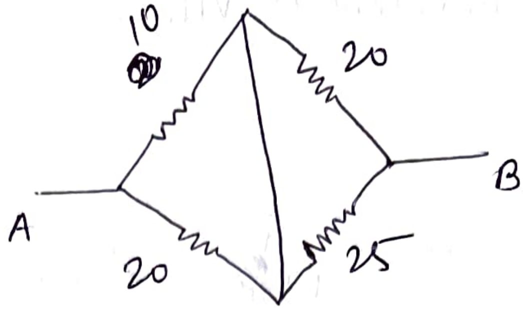


$$V_{th} + 6.66 - 8.88 = 0$$

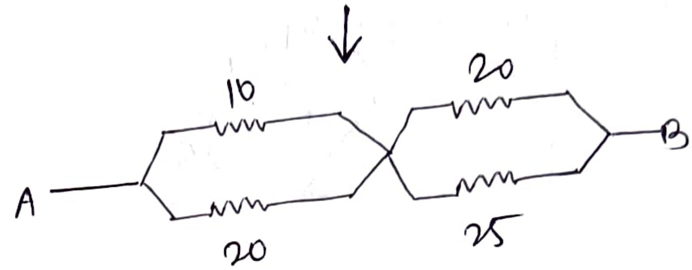
$$\Rightarrow V_{th} = 2.22\,V$$

Again Removing R_L and replacing all the active Sources by their internal Resistances.





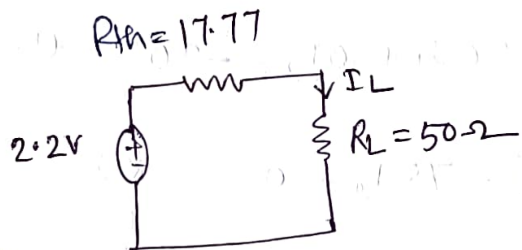
$\cancel{R_{th} = \frac{30 \times 45}{75} = 18\,\Omega}$



$R_{th} = (10 \parallel 20) + (20 \parallel 25)$

$= 6.66 + 11.11$

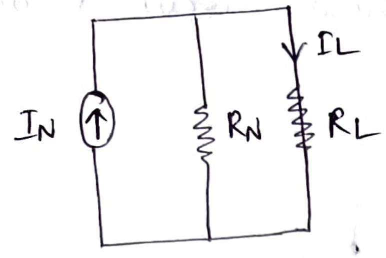
$= 17.77\,\Omega$



$I_L = \frac{2.2}{17.77 + 50} = 0.032\,A.$

NORTON'S THEOREM

— "According to Norton's Theorem, Any Linear bilateral Network irrespective of its Complexities Can be reduced in to a Norton's equivalent Circuit having a Norton's Short Circuit Current 'I_N' in parallel with Norton's equivalent resistance R_N in parallel with Load Resistor R_L"



$$\boxed{I_L = \frac{I_N R_N}{R_N + R_L}}$$

Steps for solving:

① Identify the Load Resistor R_L.

② Replace R_L with a short circuit Branch.

③ The Current Flowing through this short circuit Branch will be the Norton's Current I_N.

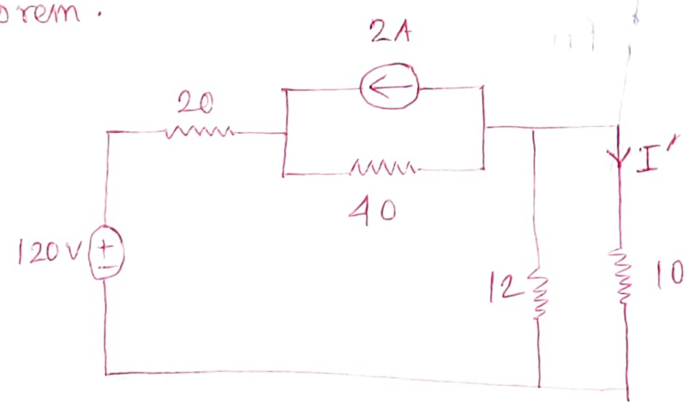
④ Remove R_L and replace all the active sources by their internal Resistance.

⑤ ~~the~~ equivalent Resistance across the ~~two~~ two

⑥ Draw the Norton's equivalent Circuit.

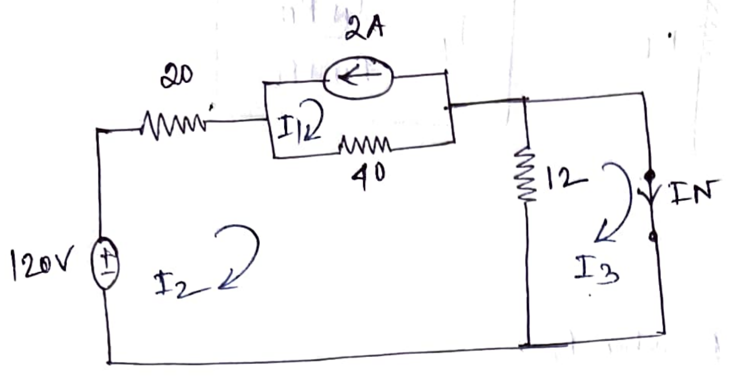
⑦ Calculate I_L using the Identity. $\boxed{I_L = \frac{I_N R_N}{R_N + R_L}}$

2 Find the current I' in the given circuit using Norton's Theorem.



→ Load Resistance = 10 Ω.

Replacing the Load Resistor with a Short Circuit Branch.



$I_1 = -2A$

Mesh 2

$$40I_1 - 72I_2 + 12I_3 = -120$$

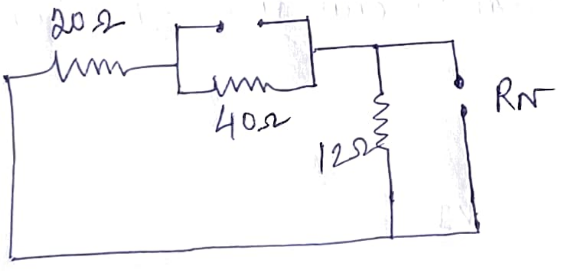
$$\Rightarrow -72I_2 + 12I_3 = -40 \quad \text{—(I)}$$

Mesh 3

$$-12I_3 + 12I_2 = 0 \quad \text{—(II)}$$

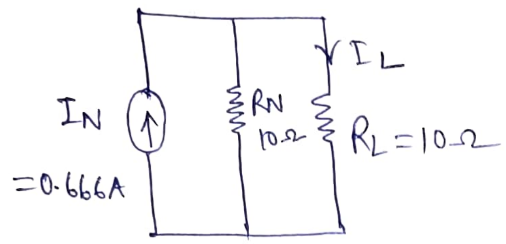
$I_2 = 0.666A$ $\quad$ $I_N = I_2 = 0.666A$.

Removing the Load Resistant R_L and replacing all the active Sources by their internal Resistances.



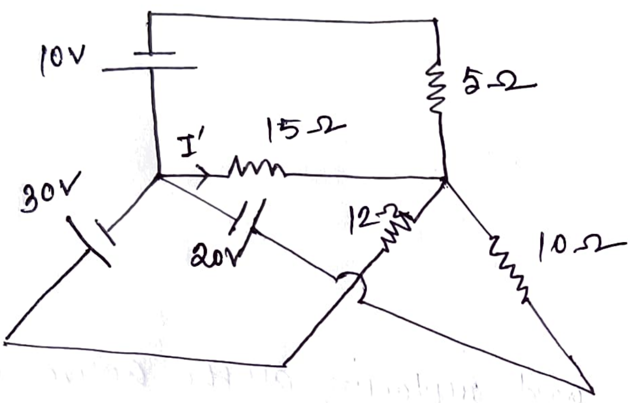
$$R_N = (20+40) \parallel 12$$

$$R_N = \frac{60 \times 12}{60+12} = 10\Omega.$$



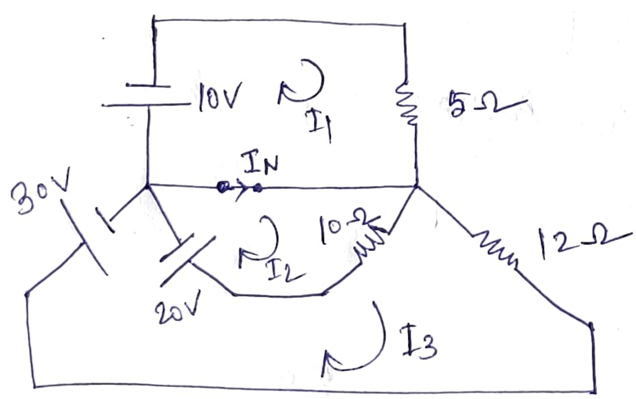
$$I_L = \frac{I_N R_N}{R_N + R_L} = 0.333\ A.$$

Q Find the current I' in the given circuit using Norton's Theorem.



→ $R_L = 15\Omega$.

Replacing R_L with Short Circuit Branch.



Applying KVL in mesh 1,

$$-5I_1 = 10$$

$$\Rightarrow I_1 = -2\ A.$$

Applying KVL in mesh (2),

$$-10I_2 + 10I_3 = 20 \quad \text{—— (I)}$$

Apply KVL in mesh (3),

$$10I_2 - 22I_3 - 30 + 20 = 0$$

$$\Rightarrow 10I_2 - 22I_3 = 10 \quad \text{—— (II)}$$

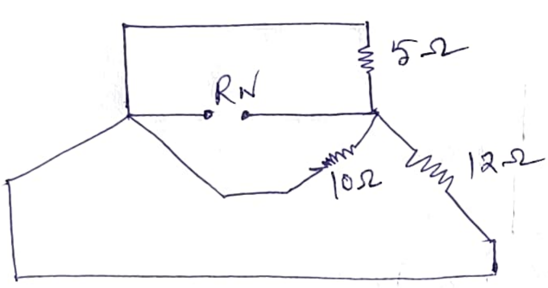
$$\boxed{\begin{array}{l} I_2 = -4.5A \\ I_3 = -2.5A \end{array}}$$

$$I_N = I_2 - I_1$$

$$\Rightarrow I_N = 2.5A.$$

For

R_N, Removing R_L and replacing all the active sources by their internal Resistances,



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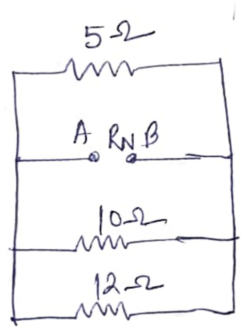

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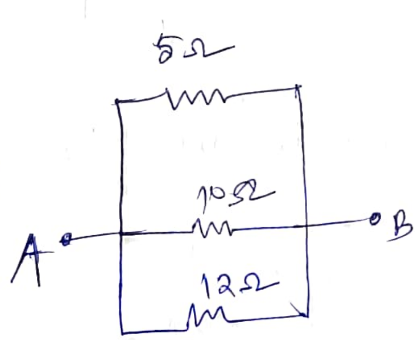
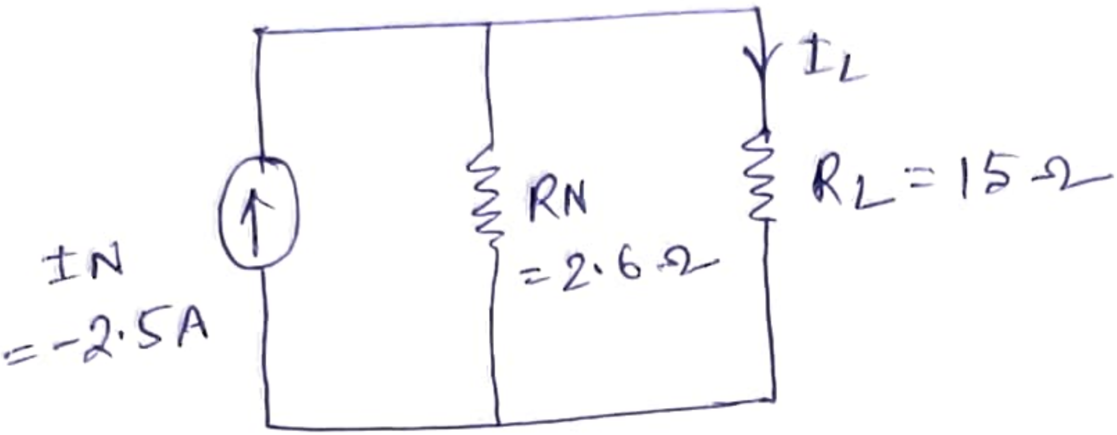


$$R_N = 5 \parallel 10 \parallel 12$$

$$\Rightarrow R_N = 2.6\,\Omega$$



$$I_L = \frac{I_N R_N}{R_N + R_L} = -0.37 \text{ A}.$$

Answer