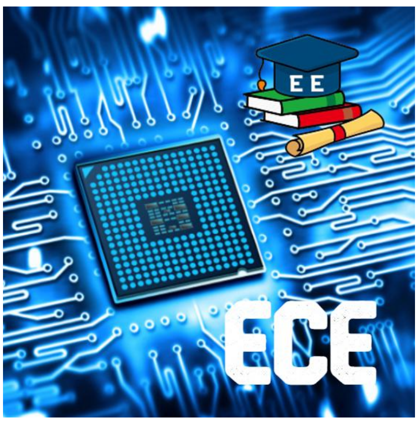
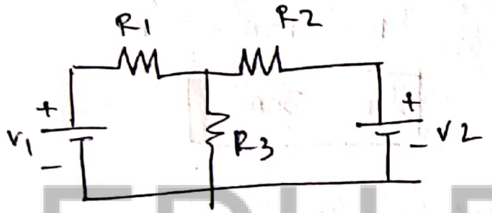


EE
ECE

Super Position Theorem:-

Super position Theorem states that the response in a circuit with multiple sources is given by the algebraic sum of responses due to individual sources acting alone.

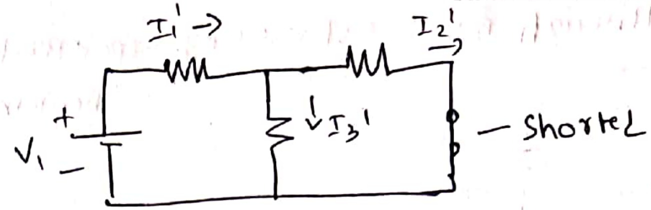


Procedure / steps:

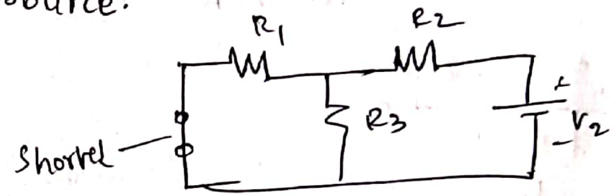
① In a circuit with multiple sources keep only one source active (V_1 - active, V_2 - short)

② Remove all the other sources (voltage sources must be short circuited, current sources must be open circuited)

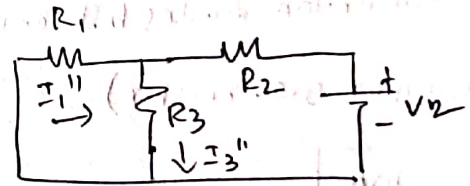
③ Find the response of the circuit for the individual sources and label the term as I_1', I_2' & I_3' etc.



④ Now keep the other source active and remove the first source.



⑤ Now ~~take~~ find the response due to the source V_2 and label the current as I_1'', I_2'' & I_3''.



(follow the same procedure if more than two sources present)

⑥ Now find the overall response of the circuit by sum up the individual responses.

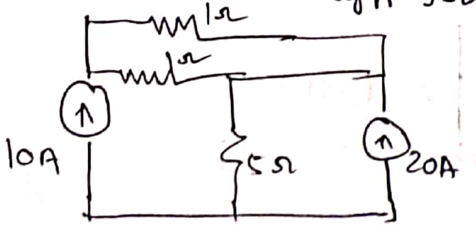
$I_1 = I_1' + I_1''$

$I_2 = I_2' + I_2''$

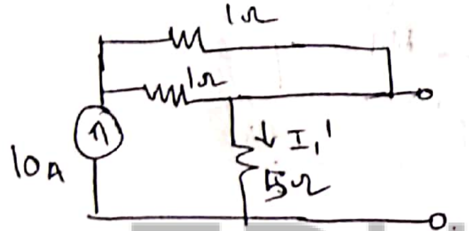
$I_3 = I_3' + I_3''$

[Note: Depending upon the direction assumed sign may vary, once current is calculated other parameters like voltage, power etc can be calculated]

(1) Find the current through 5Ω resistor using Super Position Theorem.



<u>Step1:-</u> Keep 10A Active & Remove 20A

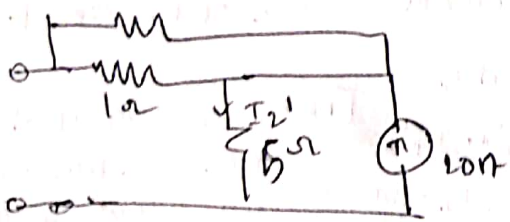


From the fig above current through 5Ω is 10A

(Even though the current 10A divides between two 1Ω it again join & enter 5Ω resistor)

$$\boxed{I_L' = 10A}$$

<u>Step2</u>
Keep 20A Active & Remove 10A



By inspecting the circuit itself we can observe, the current through 5Ω flow is 20A.

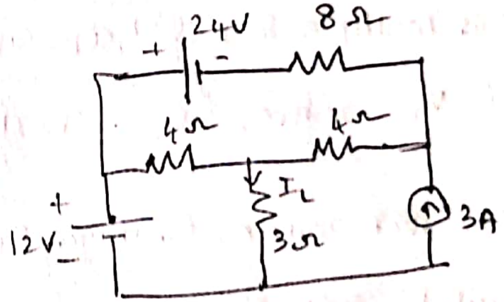
$$\boxed{I_L'' = 20A}$$

So total current through 5Ω resistor $I = I_L' + I_L''$

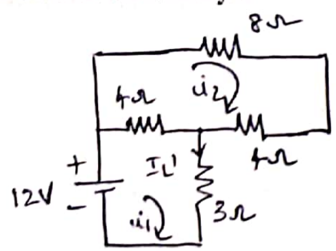
$$I_L = 10A + 20A$$

$$\boxed{I_L = 30A}$$

(2) Using Super position theorem find the current through 3Ω resistor.



Solution:- <u>Step1</u> Keep 12V source active 24V-Short, 3A-open circuited.



By KVL

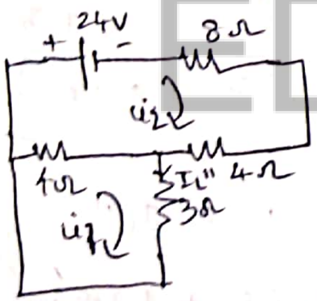
$-7i_1 + 4i_2 = -12$ -- ①

$4i_1 - 6i_2 = 0$ -- ②

$\boxed{i_1 = 2A}$ $\boxed{i_2 = 0.5A}$

So $\boxed{I_L' = 2A}$ (Since $i_1 = I_L'$ in this circuit)

Step 2: Keep 24V source active & 12V source short circuited and 3A open circuited.



let I_L'' be the current through 3Ω resistor because of the voltage source 24V

$16i_1 - 4i_1 = -24$ -- ①

$7i_1 - 4i_2 = 0$ -- ②

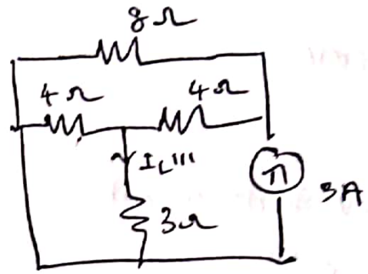
$i_2 = -1.75A$

$i_1 = -1A$

$\boxed{I_L'' = i_1 = -1A}$

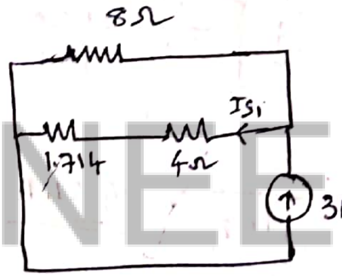
$\boxed{I_L'' = -1A}$

Step 3: Keep 12V & 24V source short circuited and 3A source - Active.



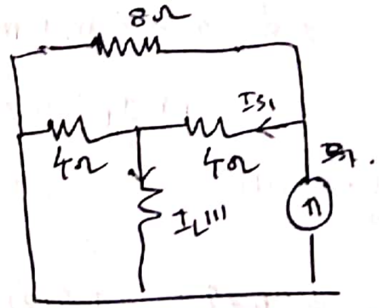
let $I_L''' = I_{3\Omega}$ due to 3A source.

$4\Omega \| 3\Omega = \frac{4\times3}{4+3} = 1.714\Omega$



$I_{S1} = \frac{3\times8}{4.714+8}$ (By current division rule)

$\boxed{I_{S1} = 1.887A}$



Current Division rule.

$I_{3\Omega} = I_L''' = \frac{1.887\times4}{4+3}$

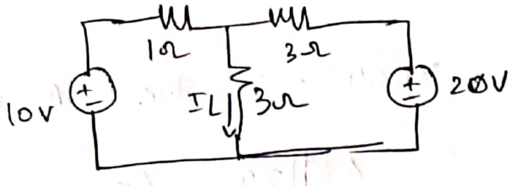
$I_L''' = 1.078A$

So $I_L = I_L' + I_L'' + I_L'''$

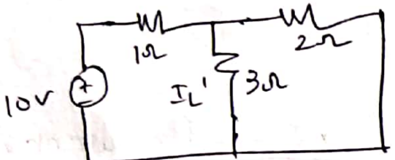
$= 2 - 1 + 1.07 = 3.07A$

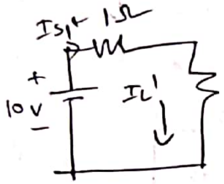
$\boxed{I_L = 3.07A}$

(3.) Find the current I_L in the circuit using super position Theorem



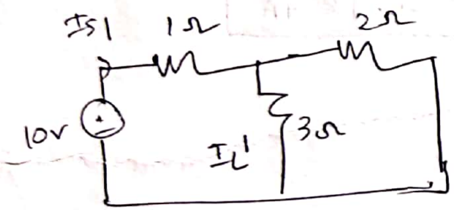
Step1: Keep 10V source Active & 20V short circuit.





$\frac{2\times3}{2+3} = 1.2\Omega$

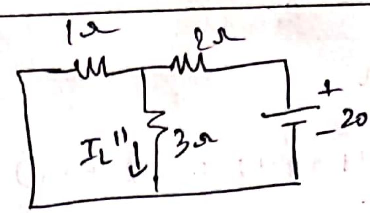
$I_{S1} = \frac{10}{1+1.2} = \underline{\underline{4.54A}}$,

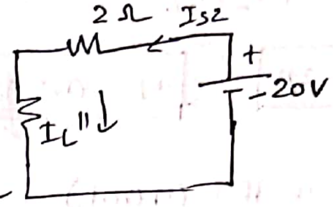


2 & 3 Ω are in parallel so current I_L' can be calculated using current division rule.

$I_L' = \frac{I_{S1}\times 2}{2+3} = \frac{4.54\times2}{2+3} = \underline{\underline{1.8182A}}$

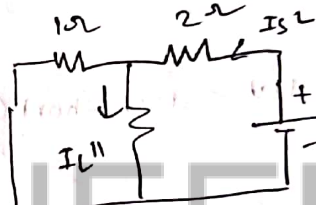
$\boxed{I_L' = 1.8182A}$





$\frac{1\times3}{1+3} = 0.75\Omega$

$I_{S2} = \frac{20}{2+0.75} = 7.27A$



$\cancel{I_{S2} = \frac{20}{2+0.75} = 7.27A}$

$\cancel{I_L'' = I_{S2}\times}$

$I_L'' = I_{S2}\times\frac{1}{1+3}$

$\boxed{I_L'' = 1.818A}$

$I_L = I_L' + I_L''$

$= 1.8182 + 1.8182$

$\boxed{I_L = 3.6364A}$

Thevenin's Theorem:-

Thevenin's Theorem states that a circuit with two terminals can be replaced with an equivalent circuit consisting of a Voltage source in series with a Resistance or impedance.

Steps:

Steps:- Calculate R_{th} (Thevenin's Equivalent resistance)

Step1: Remove the load resistor

Step2: Remove all the voltage sources (short circuit)

Step3: Remove all the current sources (open circuit)

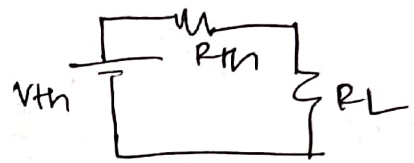
Step4: measure the Resistance across the load terminals, which is the thevenin's resistance. (R_{th})

Steps to calculate V_{th} (Thevenin's Equivalent Voltage) (V_{th})

Step1:- Remove the load resistor and then measure the voltage drop across the load terminal, which gives the open circuit voltage also called thevenin's voltage

Step3: To calculate the current through load resistance use the formula.

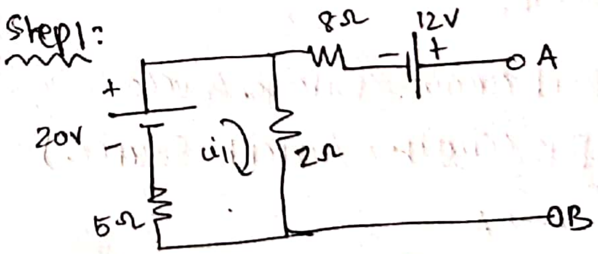
$$\boxed{I_L = V_{th}/R_{th}+R_L}$$



Redraw the circuit as shown above & find I_L.

Problems: Determine the current I_L using Thevenin's theorem.

Step1:



$2i_1 + 5i_2 = 20$

$i_1 = 20/7 = 2.857A$

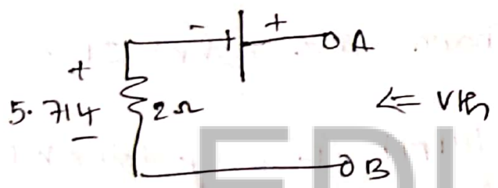
Voltage across 2Ω resistor

$V_{2\Omega} = I_{2\Omega} \times R$

$= 2.857 \times 2$

$\boxed{V_{2\Omega} = 5.714V}$

12 V voltage source is added



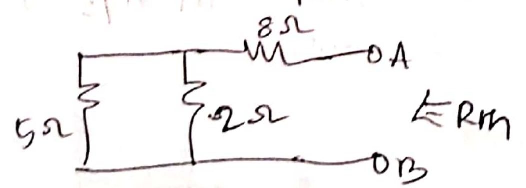
$V_{th} = 12 + V_{2\Omega} = 12V + 5.714\ V$

$\boxed{V_{th} = 17.714V}$

Step2 To calculate R_{th}

Remove load, short circuit - voltage source

open circuit - current source)



$R_{th} = 8 + \frac{5 \times 2}{5+2} = 8 + 1.428 = 9.428\Omega$

$\boxed{R_{th} = 9.428\Omega}$

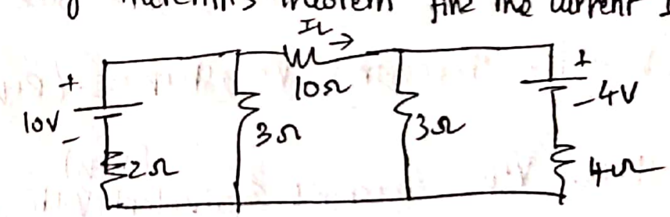
Step3. To calculate load current I_L

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

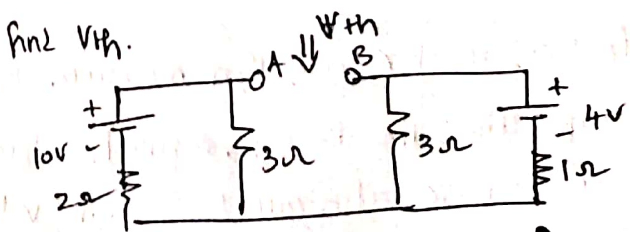
$I_L = \frac{17.714}{9.428 + 10} = 0.9118A$

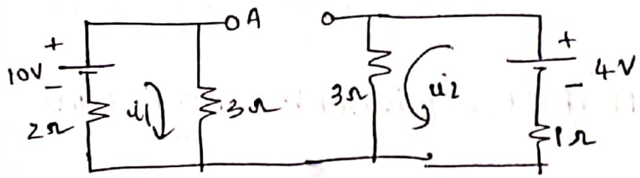
$\boxed{I_L = 0.9118A}$

② Using Thevenin's Theorem find the current I_L in the circuit.



To find V_{th}.





loop1

$3i_1 + 2i_1 = 10$

$5i_1 = 10$

$\boxed{i_1 = 2A}$

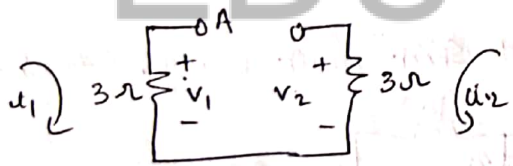
loop2

$3i_2 + 1i_2 = 4$

$4i_2 = 4$

$\boxed{i_2 = 1A}$

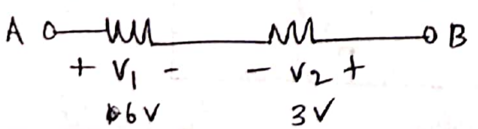
To find voltage drop across A & B, we need to find voltage drop across both the 3Ω resistors.



Voltage $V_1 = i_1 \times 3 = 2 \times 3 = \underline{\underline{6V}}$

$V_2 = i_2 \times 3 = 1 \times 3 = \underline{\underline{3V}}$

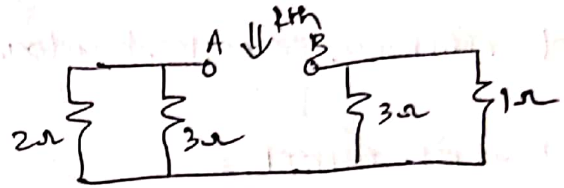
Redraw the circuit for better understanding



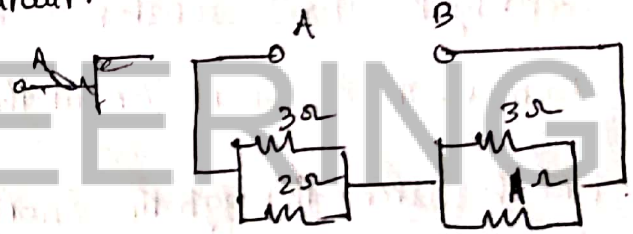
So $V_{AB} = V_{th} = 6V - 3V = 3V$

$\boxed{V_{th} = 3V}$

To find Thevenin's Resistance R_{th}



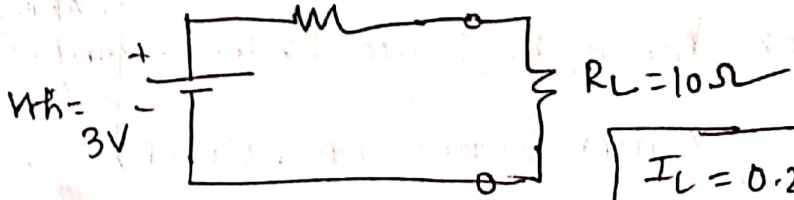
Redraw the circuit.



$R_{th} = \left(\frac{3 \times 2}{3+2}\right) + \left(\frac{3 \times 1}{3+1}\right)$

$\boxed{R_{th} = 1.95Ω}$

Thevenin's circuit:



$\boxed{I_L = 0.251A}$

$I_L = \frac{V_{th}}{R_{th} + R_L} = \frac{3}{1.95 + 10} = 0.251A$

Norton's Theorem:

States that It is possible to simplify any linear circuit to an equivalent circuit with Just a single current source and parallel resistance connected to a load.

Steps: To calculate Norton's current:-

Step1: Identify the load resistor.

Step2: Remove it & Short circuit the terminal.

Step3: find the current through the short circuit terminal which is the Norton's current (I_N).

Steps: To calculate Rth or RN (Norton's Resistance)

Step1: Remove the load resistor (R_L) & label the terminal as A&B

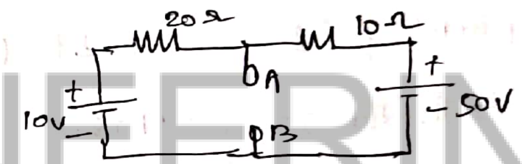
Step 2: Remove the Source (voltage source - Short circuit, current source - open circuit)

Step3: measure the resistance across the terminals A&B, which gives the Norton's resistance RN

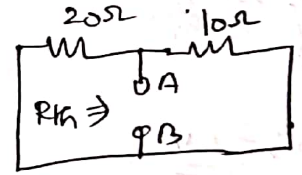
Step3: Draw the Norton's Equivalent circuit & use the formula

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

Problem:- ① find the thevenin's & Norton's equivalents of the circuit with respect to terminal A&B.

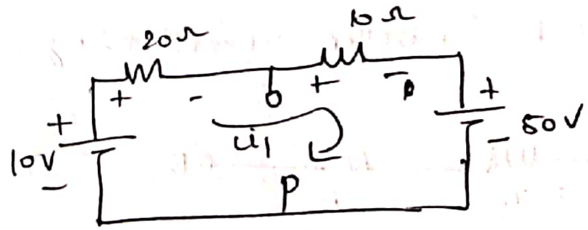


Solution:-
Step1. To find Rth Short circuit voltage sources.



$R_{th} = \frac{20 \times 10}{20+10} = \underline{\underline{6.667\Omega}}$.

Step2 To find Vth



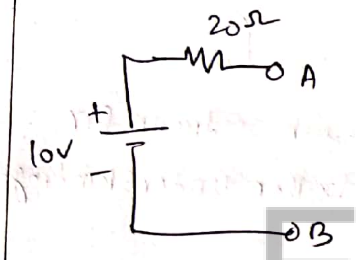
$20i_1 + 10i_1 + 50 - 10 = 0$

$30i_1 = -40$

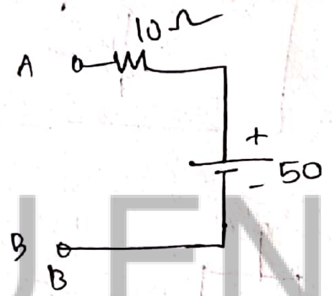
$i_1 = -40/30 = -1.33A$

$\boxed{i_1 = -1.33A}$

Voltage across A & B is either



(or)



We select LHS

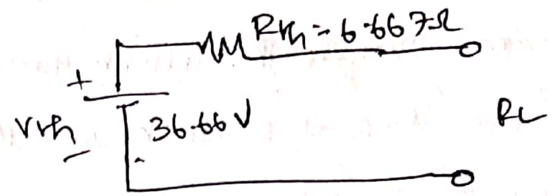
$V_{AB} = 10V$ - voltage across 20Ω

$V_{20\Omega} = i_1 \times 20 = -26.66V$

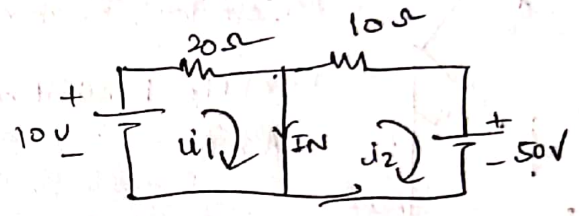
$V_{th} = V_{AB} = 10 - (-26.66V)$

$\boxed{V_{th} = 36.66V}$

Thevenin's Circuit:-



for Norton's Theorem:



loop1

$20i_1 = 10$

$\boxed{i_1 = 0.5A}$

loop2

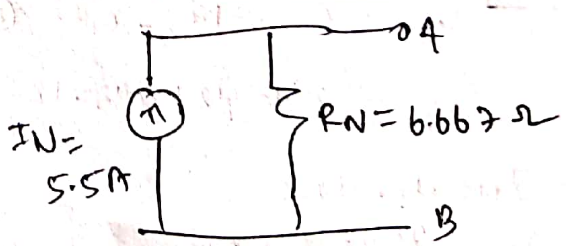
$10i_2 + 50 = 0$

$\boxed{i_2 = -5A}$

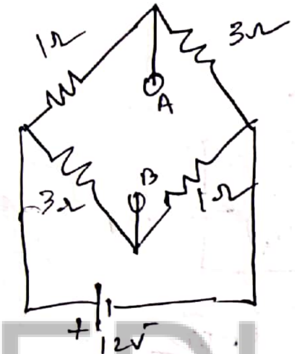
$I_N = i_1 - i_2$

$= 0.5 - (-5) = \boxed{I_N = 5.5A}$

Norton's Equivalent ckt:

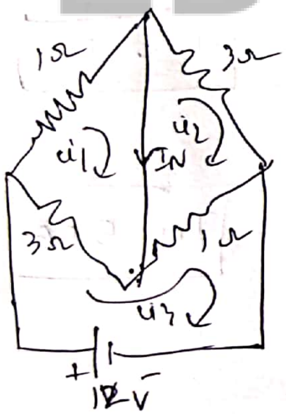


(2) Using Norton's theorem, Determine the current through an ammeter connected across A & B of the circuit, take the resistance of the ammeter as 0.5 Ω



1. Remove load Resistor & label the terminal as A & B.

2. Short circuit the terminal A & B and find the current through it



$i_1 + 3i_1 - 3i_3 = 0$

$4i_1 - 3i_3 = 0$ — (1)

$4i_2 - 1i_3 = 0$ — (2)

$-3i_1 - i_2 + 4i_3 = 12$ — (3)

$i_1 = 6A$

$i_2 = 2A$

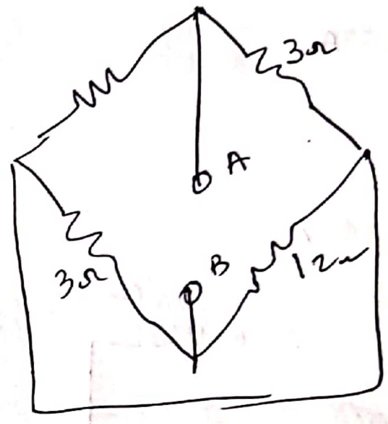
$i_3 = 8A$

$I_N = i_1 - i_2$

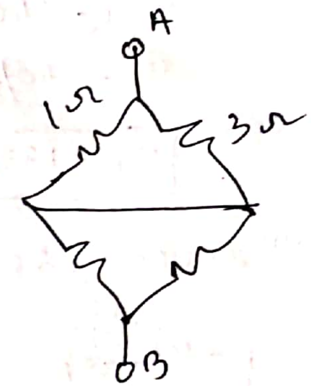
$= 6 - 2 = 4A$

$\boxed{I_N = 4A}$

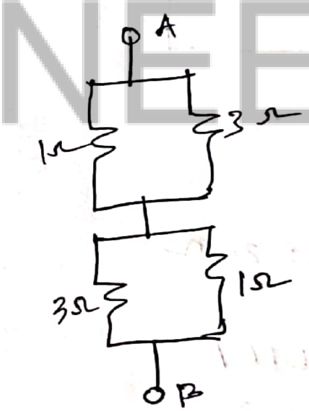
To find R_{th} or R_N



⇒



Circuit redrawn for better understanding



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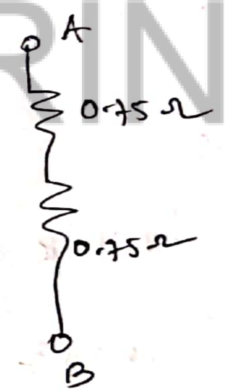
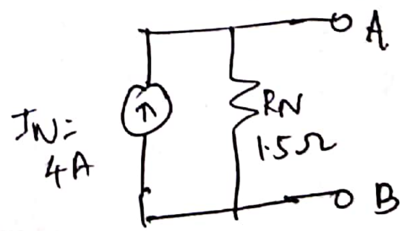


$\boxed{R_N = 1.5\,\Omega}$

Norton's Equivalent Circuit:



Maximum Power Transfer Theorem (MPTT)

MPTT states that maximum power will be delievered to the load when the load impedance and source impedance are equal.

Steps:

(1.) Find R_{th} (Remove voltage source; current source & load resistance) & label the terminal as A & B)

(2.) Find the V_{th} (Thevenin's equivalent voltage)

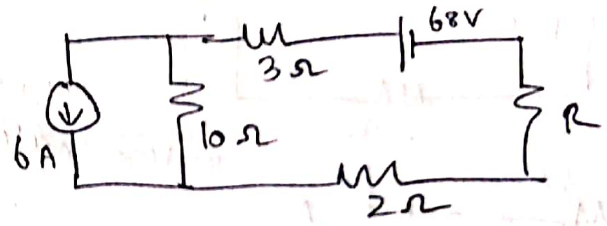
i.e. the voltage across the terminal A & B.

(3) Find maximum power using the formula.

$$\boxed{P_{max} = \frac{V_{th}^2}{4R_{th}}}$$

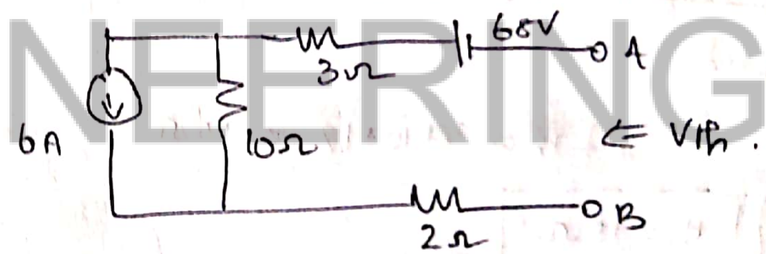
Problems:

(1) Find the value of 'R' for maximum power transfer and calculate the maximum power.

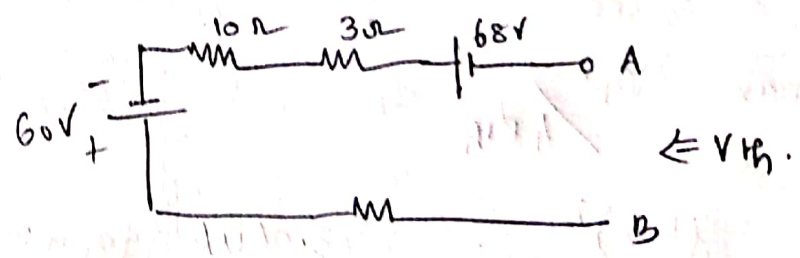


Soln

Step1:- Find R_{th} (Remove R_L)



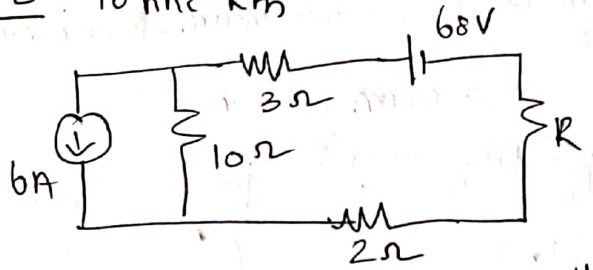
V = IR (By source transformation formula)

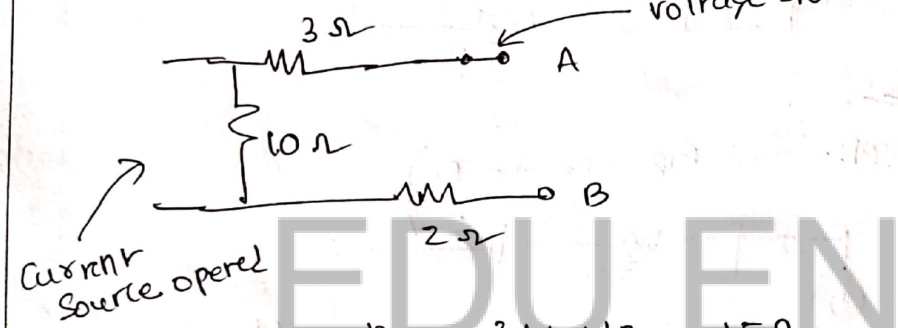


68V & 60V are in series

So $\boxed{V_{th} = 128V}$

Step 2 To find R_{th}





$R_{th} = 3+10+12 = 15\Omega$

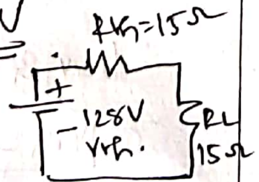
$\boxed{R_{th} = 15\Omega}$

Maximum power P_{max}

$P_{max} = V_{th}^2 / 4R_{th}$

$= \frac{(128)^2}{4 \times 15} = 273.06W$

$\boxed{P_{max} = 273.06W}$ $\boxed{R_{th} = R_L = 15\Omega}$



Reciprocity Theorem:

The Reciprocity theorem states that in a linear bilateral, single source circuit, the ratio of excitation to response is constant, when the position of the excitation and response are interchanged.

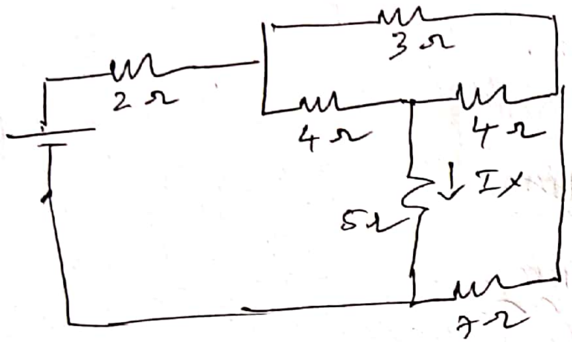
Steps:-

1. Interchange the position of source & response.
   [voltage - short
   current - open]

2. Find the Response at the particular Branch.

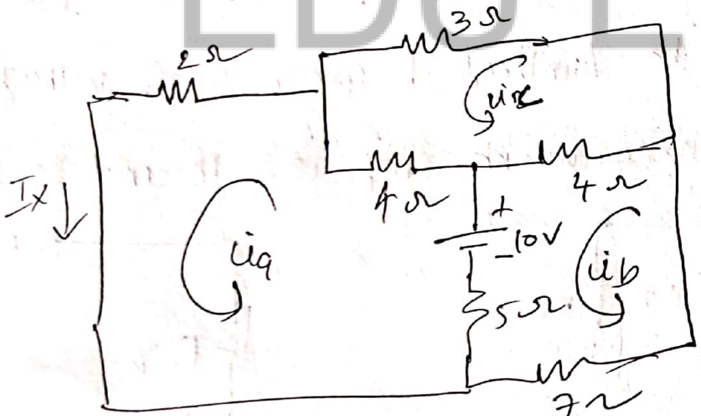
3. Compare it with the response that you got before interchanging.

1. Calculate I_x & prove the reciprocity theorem by Interchanging the position of 10V source & I_x.



Soln:

Interchanging source & response.



$$\begin{bmatrix} 2+4+5 & -5 & -4 \\ -5 & 5+4+7 & -4 \\ -4 & -4 & 3+4+4 \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} = \begin{bmatrix} 10 \\ -11 \\ 0 \end{bmatrix}$$

$\Delta = 1069$

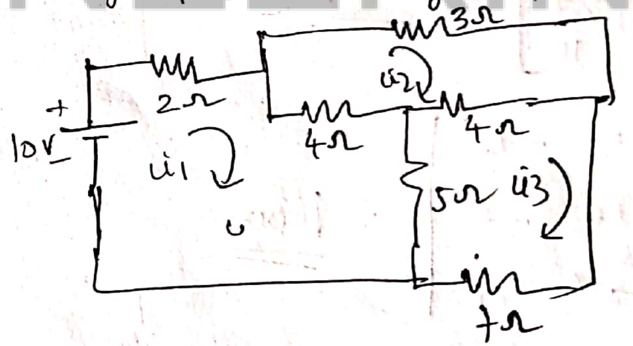
$$\Delta a = \begin{bmatrix} 10 & -5 & -4 \\ -10 & 16 & -4 \\ 0 & -4 & 11 \end{bmatrix} = 890$$

$$I_x = I_a = \frac{\Delta a}{\Delta} = \frac{890}{1069}$$

$$I_x = I_a = \frac{\Delta a}{\Delta} = \frac{890}{1069} = 0.8326A$$

$$\boxed{I_x = I_a = 0.8326A}$$

for original circuit (original position of the voltage source)

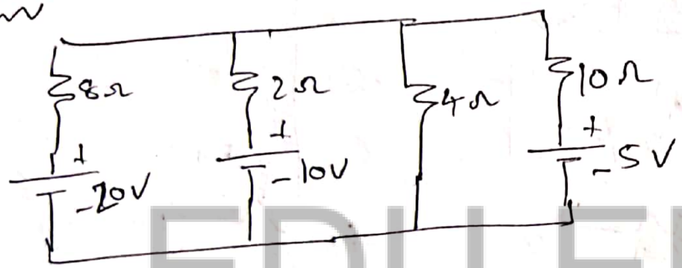


$I_x = I_1 - I_2$

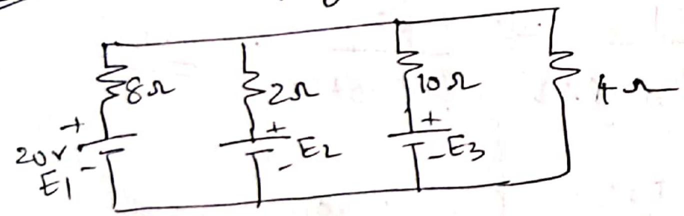
$$Z_{eq} = \frac{1}{\frac{1}{Z_1} + \frac{1}{Z_2} + \dots \frac{1}{Z_n}}$$

$$E_{eq} = \left[\frac{E_1}{Z_1} + \frac{E_2}{Z_2} + \frac{E_3}{Z_3} \dots \frac{E_n}{Z_n} \right] Z_{eq}$$

Problem:-



Soln Re-arranging the Circuit.



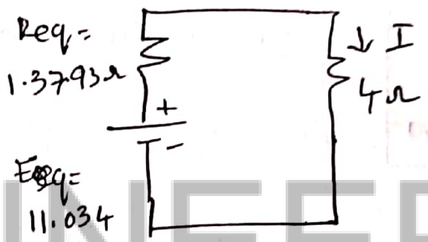
$$R_{eq} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}} = \frac{1}{\frac{1}{8} + \frac{1}{2} + \frac{1}{10}}$$

$$\boxed{R_{eq} = 1.3793\,\Omega}$$

$$E_{eq} = \left[E_1/R_1 + E_2/R_2 + E_3/R_3 \right] \cdot R_{eq}$$

$$= \left[\frac{20}{8} + \frac{10}{2} + \frac{5}{10} \right] \times 1.3793$$

$$\boxed{E_{eq} = 11.0344\ V}$$



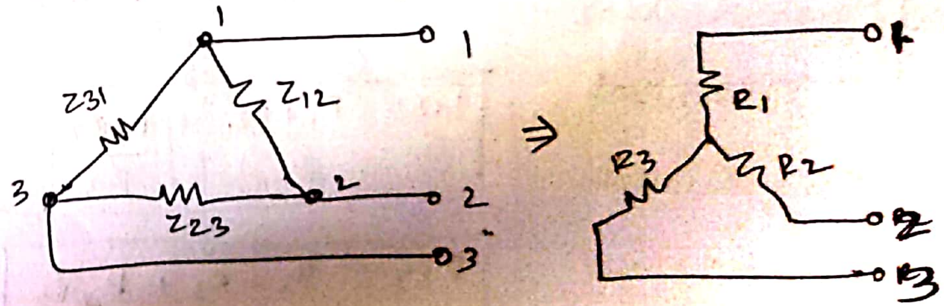
$V = IR$

$I = V/R$

$= \frac{11.0344}{(1.3793 + 4)}$

$$\boxed{I = 2.0513A}$$

Impedance in Star to Delta ($\lambda \to \Delta$) & Delta to Star

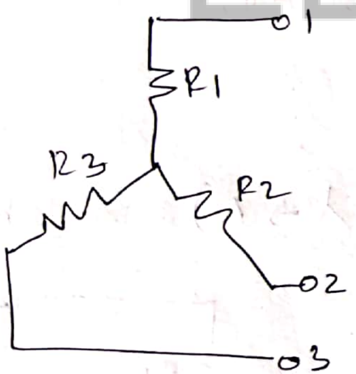


$$R_1 = \frac{R_{12} R_{31}}{R_{12} + R_{23} + R_{31}}$$

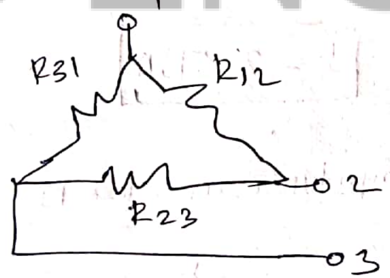
$$R_2 = \frac{R_{12} R_{23}}{R_{12} + R_{23} + R_{31}}$$

$$R_3 = \frac{R_{23} R_{31}}{R_{12} + R_{23} + R_{31}}$$

Star to Delta:



$\Rightarrow$

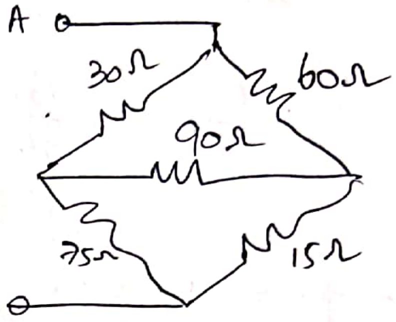


$$R_{12} = R_1 + R_2 + \frac{R_1 R_2}{R_3}$$

$$R_{23} = R_2 + R_3 + \frac{R_2 R_3}{R_1}$$

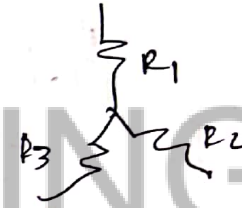
$$R_{31} = R_3 + R_1 + \frac{R_3 R_1}{R_2}$$

Problem: Find the Equivalent resistance of the network.



Soln

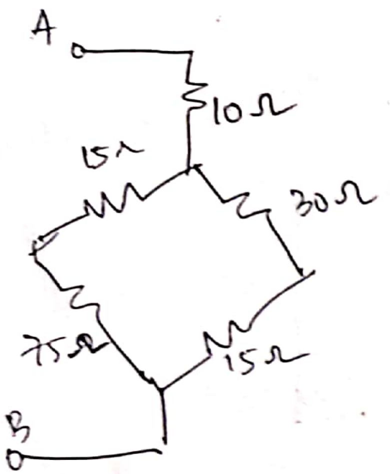
=



$$R_1 = \frac{R_{12} R_{31}}{R_{12} + R_{31} + R_{23}} = \frac{60 \times 30}{30 + 90 + 60} = \underline{\underline{10\Omega}}$$

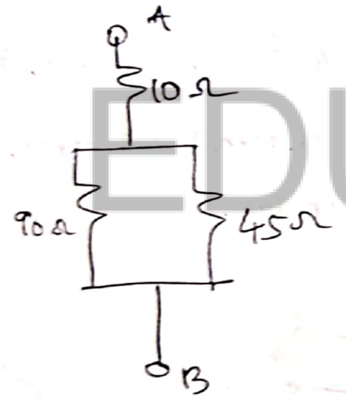
$$R_2 = \frac{R_{12} R_{23}}{R_{12} + R_{23} + R_{31}} = \frac{60 \times 90}{30 + 90 + 60} = \underline{\underline{30\Omega}}$$

$$R_3 = \frac{R_{31} R_{23}}{R_{12} + R_{23} + R_{31}} = \frac{30 \times 90}{30 + 90 + 60} = \underline{\underline{15\Omega}}$$



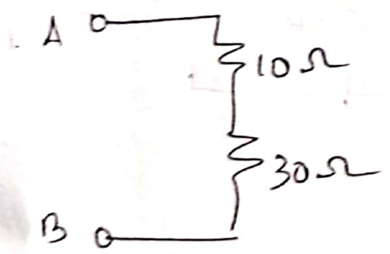
15Ω & 75Ω are in series

30Ω & 15Ω are is series



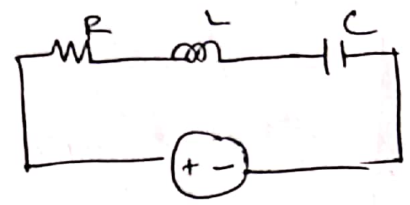
90 & 45 are in Parallel.

$90 \| 45 = \underline{\underline{30\Omega}}$

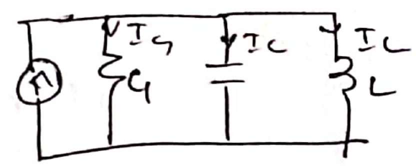


$\boxed{R_{AB} = 40\Omega}$

Duality:



Original network



Dual Network

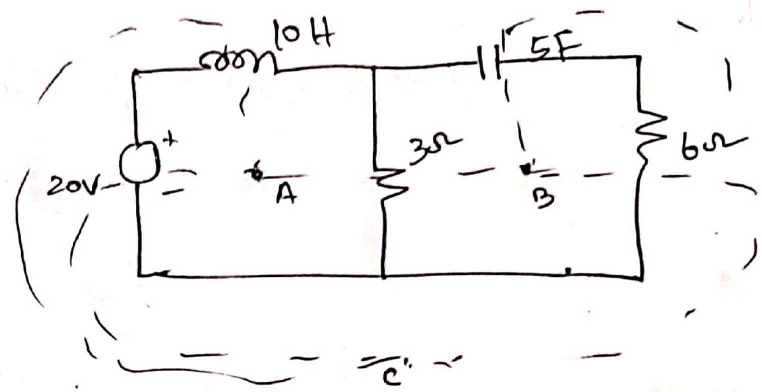
* In an Electrical network, electrical terms are associated in to pairs called as duals.
* A dual of a expression is formed by interchanging voltage & current in the expressions

Dual Elements.

Original	Dual.
Resistance	Conductance
Capacitance	Inductance
Inductance	Capacitance.
Voltage Source	Current Source.

Original	Dual
Current Source	Voltage Source.
Series Branch	Parallel Branch
Mesh equation	Node equation
KCL	KVL
Switch closed at t=0	Switch opened at t=0.
Open circuit	Short circuit
Short circuit	Open circuit
Impedance	Admittance.
Reactance	Susceptance.

Draw the dual of the network shown.



(1) Label A & B inside loops & Place reference 'C' node outside

(2). Draw a dotted line from each node to reference node through all the available branches.

(3) Draw its Dual.