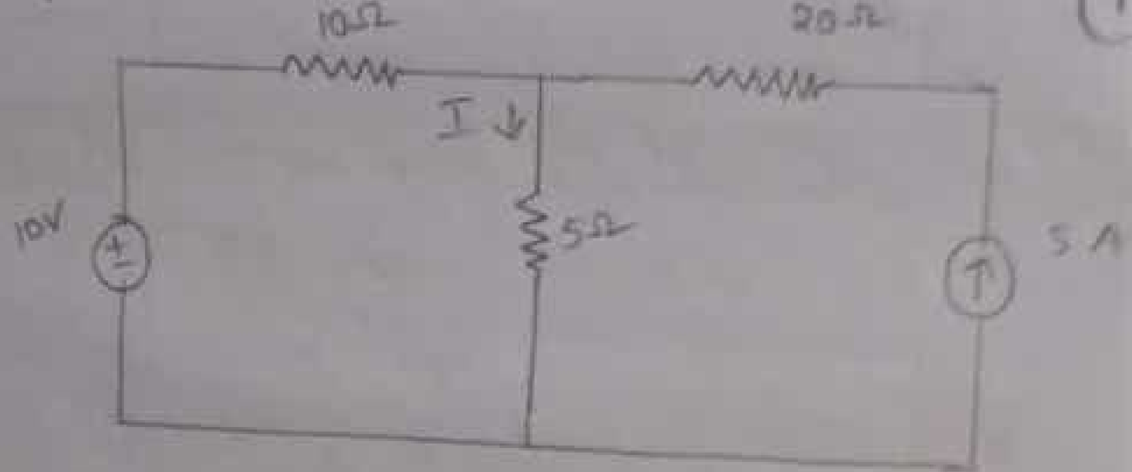
→ **Super position theorem** :- In a linear networks, with several independent sources. The response in a particular branch when all the sources acting simultaneously is equal to the algebraic sum of individual responses by taking one source at a time.

* Find the current in 5Ω by using super position theorem.

①



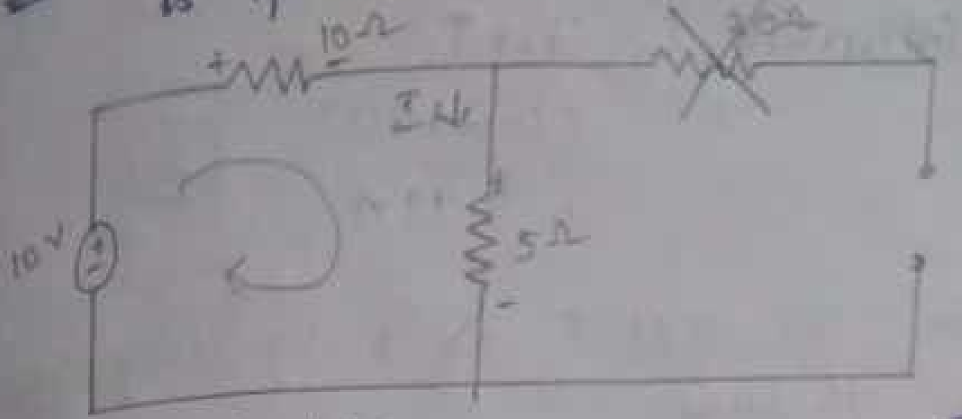

Procedure :-

→ Select a single source alone then replace all the voltage sources by a short circuit and all the current sources by a open circuit, Do not disturb dependent sources.

→ Find voltage or current in a required branch

→ Repeat the above steps for each independent source

Case(i):- Take 10 V as alone and 5A current source is open circuited. 9




According to KVL,

$$+10 - 10I_1 - 5I_1 = 0$$

$$\Rightarrow 10 - 15I_1 = 0$$

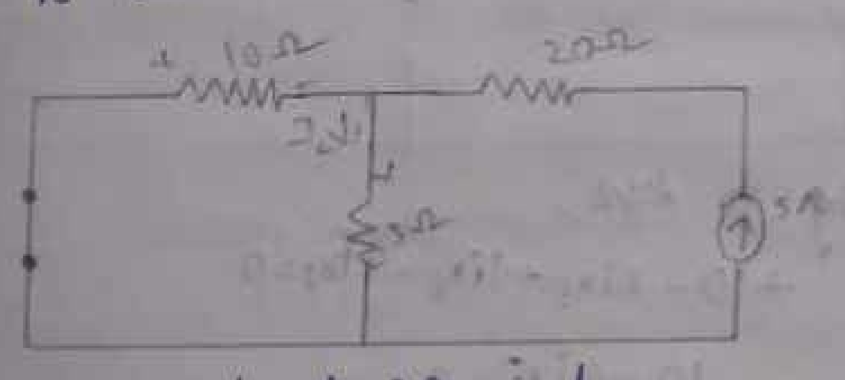
$$10 = 15I_1$$

$$I_1 = \frac{10}{15}$$

$$I_1 = 2/3$$

$$\boxed{I_1 = 0.66A}$$

Case(ii):- Take 5A as alone and 10V voltage source is short circuited.




From the current division rule,

$$I_2 = I\left(\frac{R_1}{R_1+R_2}\right)$$ Here $I = 5A$, $R_1 = 10\,\Omega$ & $R_2 = 5\,\Omega$

$$I_2 = 5\left(\frac{10}{10+5}\right)$$

$$I_2 = 5 \times \frac{\cancel{10}\,2}{\cancel{15}\,3} \Rightarrow I_2 = \frac{10}{3} = 3.3\ A$$

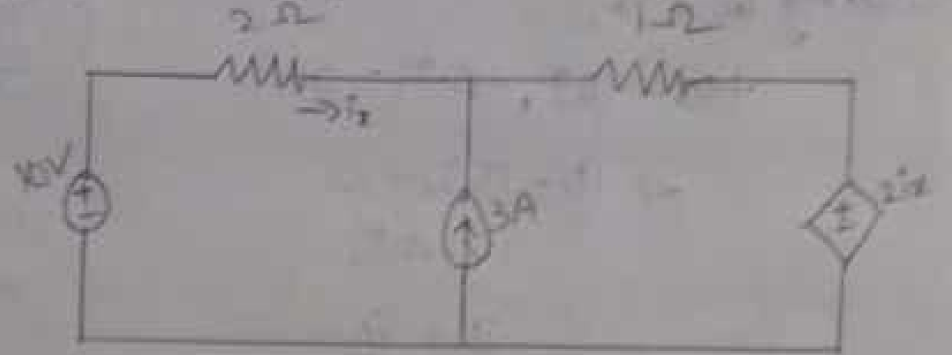
$\boxed{I_2 = 3.3\,A}$

$\therefore$ Total current $I = I_1 + I_2$

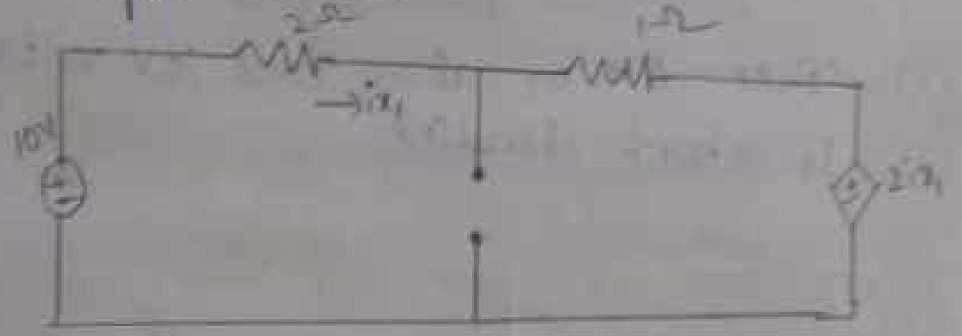
$= 0.66 + 3.33$ (3)

$= 3.99\,A$

* Determine the current ~~Ix~~ $i_x$ by using super position theorem




<u>case (i)</u>:- Taking 10V source as alone and 3A is open-circuited




According to KVL,

$$+10 - 2i_{x_1} - 1i_{x_1} - 2i_{x_1} = 0$$

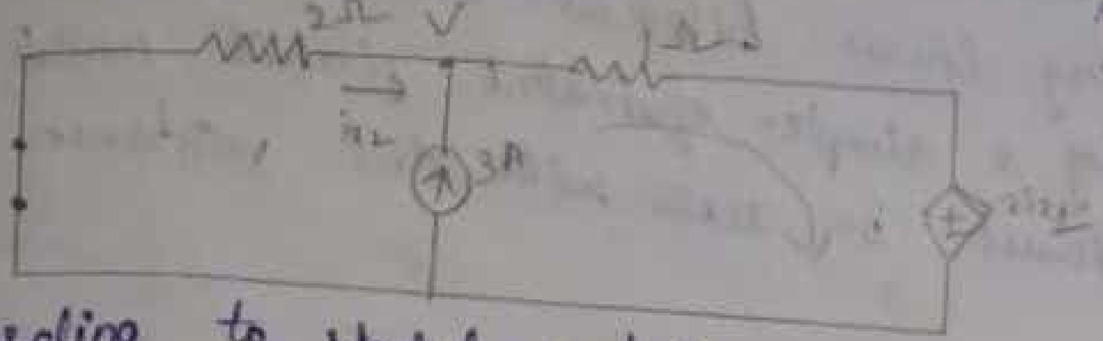
$$10 - 5i_{x_1} = 0$$

$$10 = 5i_{x_1}$$

$$i_{x_1} = \frac{10}{5}$$

$$\boxed{i_{x_1} = 2\,A}$$

Case(II): Take 3A is as alone, 10 V voltage source is short circuited.




According to Nodal analysis.

$$i_{x_2}+3 = \frac{V-2i_{x_2}}{1}$$

$$\Rightarrow i_{x_2}+3 = V-2i_{x_2}$$

$$\Rightarrow V = 3i_{x_2}+3$$

$$V = 3(i_{x_2}+1) \rightarrow (1)$$

Here, Appling KVL,

$$2i_{x_2}+V=0$$

$$\Rightarrow \boxed{V=-2i_{x_2}} \rightarrow (2)$$

Substitute eqn (2) in eqn (1)

$$-2i_{x_2} = 3(i_{x_2}+1)$$

$$-2i_{x_2} = 3i_{x_2}+3 \Rightarrow -5i_{x_2} = 3$$

$$\boxed{i_{x_2} = -\frac{3}{5}} \Rightarrow i_{x_2} = -0.6A$$

Total current $= i_{x_1}+i_{x_2}$

$= 2-0.6$

$= 1.4A$

→ Thevinin's theorem:- Thevinin's theorem states that any linear bilateral network can be replaced by a simple equivalent circuit consists of voltage source in series with the resistance.

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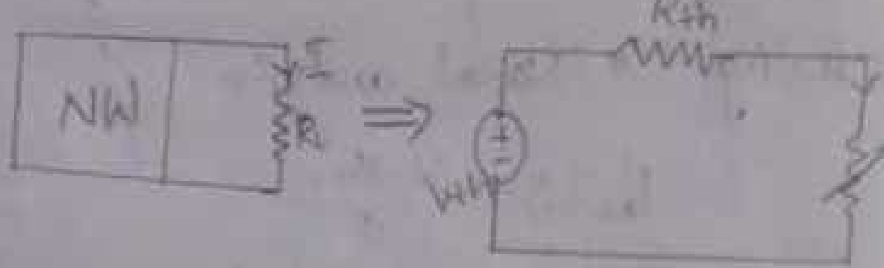



Procedure:-

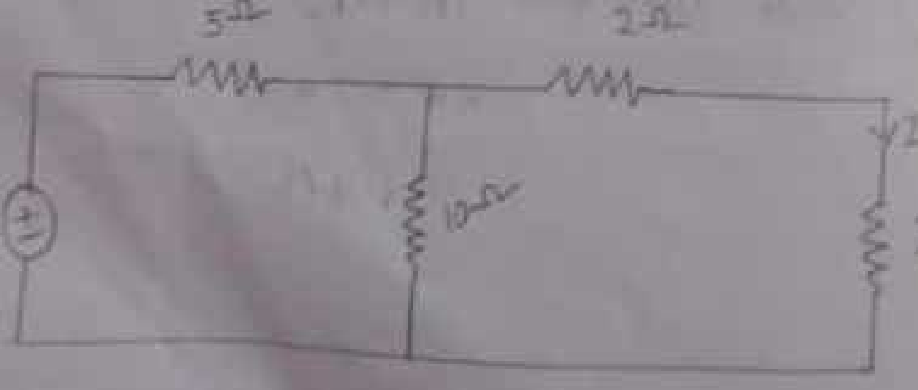
→ Remove the resistance through which desired current flows.

→ Find the open circuit voltage between two terminals that is called Thevinin's voltage

→ Find the thevinin's equivalent resistance by considering the all voltage sources are short circuited and current sources are open circuited.

→ Draw the equivalent thevinin's circuit.

* Find the current in 3 Ω resistor using thevinin's theorem



After removing the desired current flows in the resistor i.e., 3Ω

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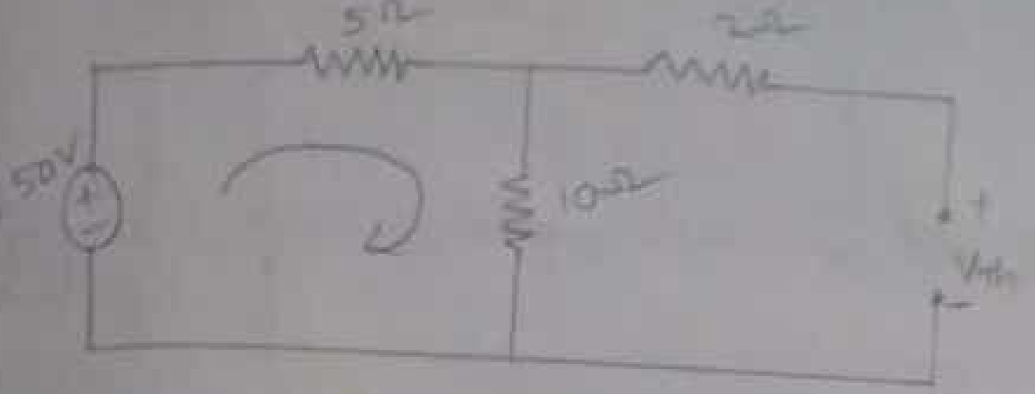



(6)

By Appling KVL, we get

$$50 - 5I_1 - 10I_1 = 0$$

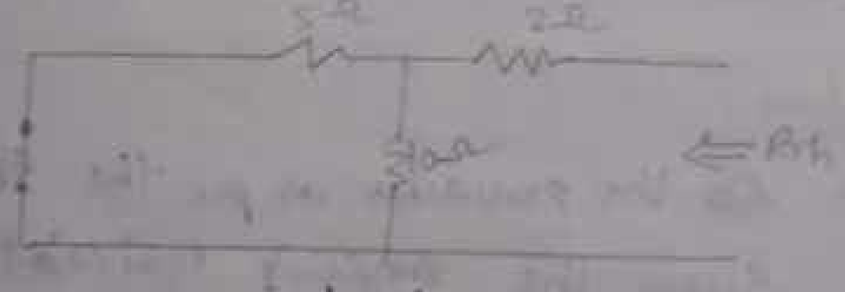
$$\Rightarrow 50 - 15I_1 = 0$$

$$15I_1 = 50$$

$$I_1 = \frac{50}{15} = \frac{10}{3}$$

$$\boxed{I_1 = 3.33A}$$

$$V_{th} = V_{10\Omega} = 3.33 \times 10 = 33.3\ V$$




$$R_{th} = \frac{1}{5} + \frac{1}{10}$$

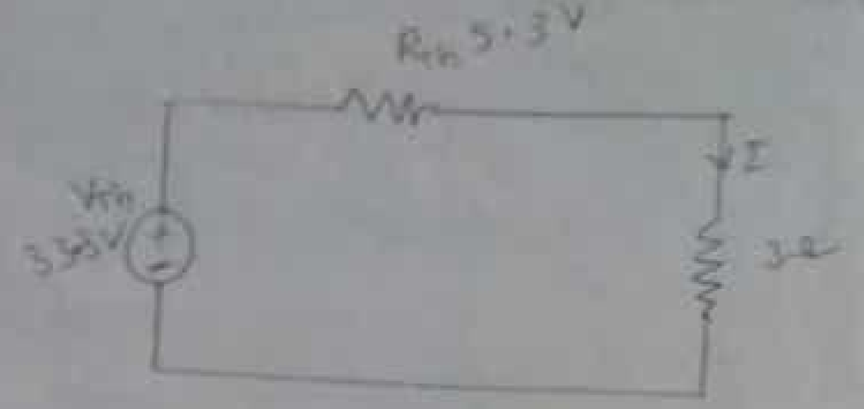
$$= \frac{50}{15} + 2$$

$$= 3.33 + 2$$

$$R_{th} = 5.3\ \Omega$$

Equivalent thevinin's circuit:-



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$$I = \frac{V}{R} = \frac{33.3}{5.3+3} = \frac{33.3}{8.3}$$

$$\boxed{I = 4.01\,A}$$

→ Norton's theorem:- Any linear bi-lateral network can be replaced by a simple equivalent circuit consisting of a single current source in parallel with the resistance. Norton's is a converse of thevinin's theorem.

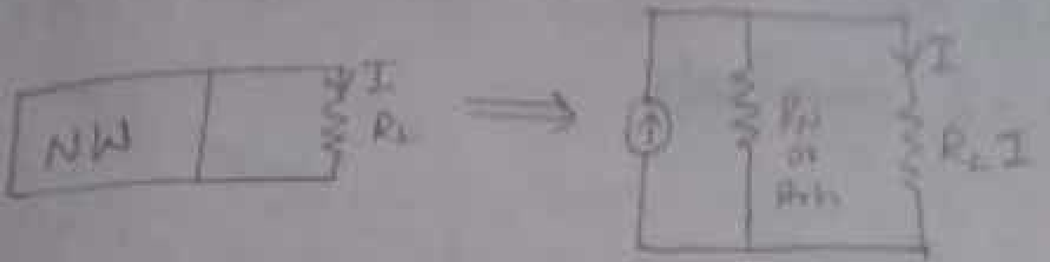
Procedure :-

→ Do the procedure as per the thevinin's theorem

→ Draw the thevinin's equivalent circuit.

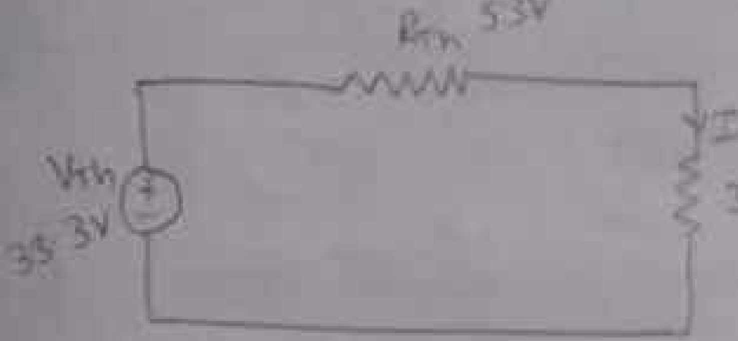
→ By using source transformation convert $V_{th}$ to $I_{sc}$ (or) $I_N$ and $R_{th}$ to $R_N$

→ Now draw Norton's equivalence circuit.




For the above problem; Thevinin's equivalent circuit is:

(8)



Find the thevinin's equivalent circuit between A & B terminals.

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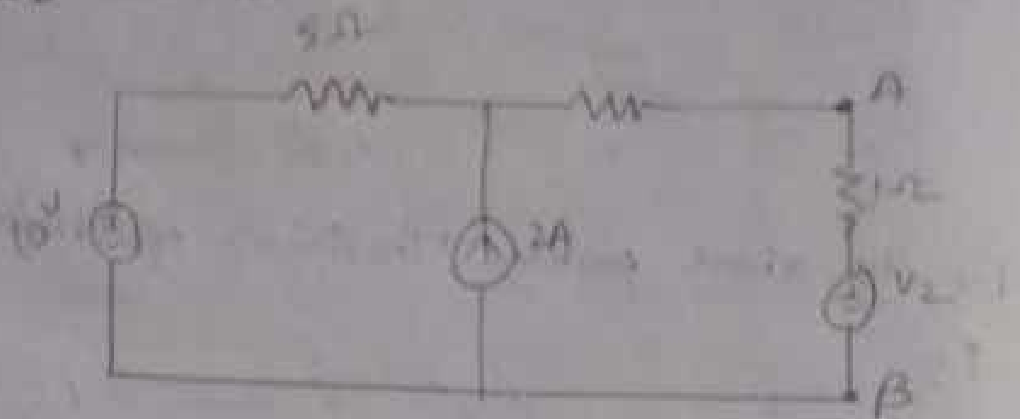
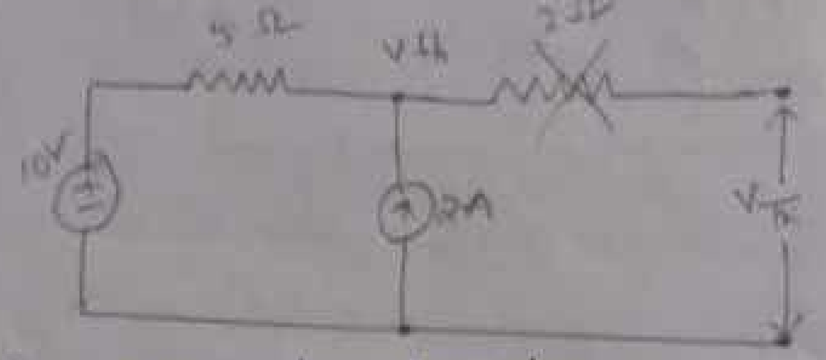
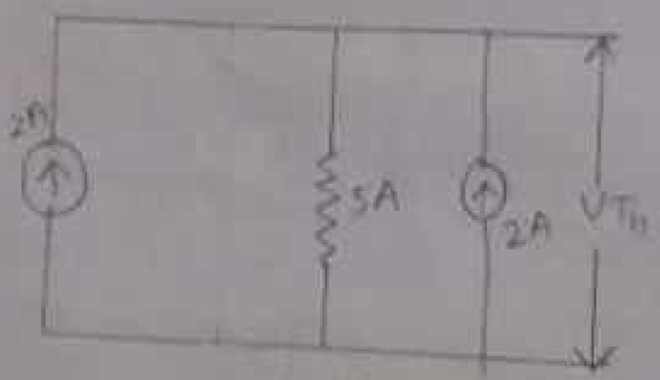



Step-1

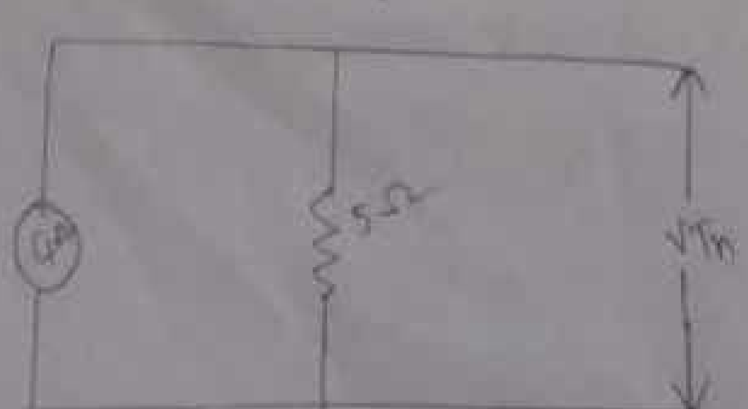
9




By using source transformation



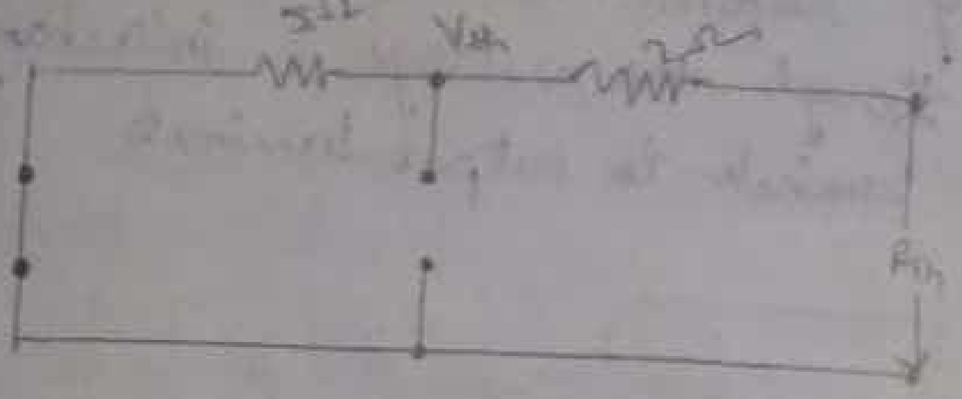

Here, in the above circuit 2A & 2A current sources are in parallel. So it will be 4A.



$\therefore \quad V_{Th} = 4 \times 5 = 20\,V$



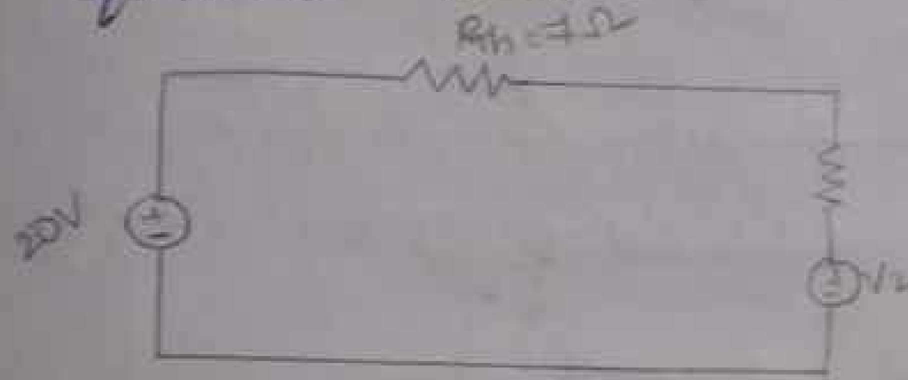
Step 2






$R_{Th} = 5\Omega + 2\Omega = 7\Omega$

$\therefore$ Equivalent Thevinin's circuit is




Draw the norton's equivalent circuit for the above problem

## Reciprocity theorem :-

In any linear bilateral network the ratio of response to excitation is constant even though the voltage is interchanged from input terminals to output terminals

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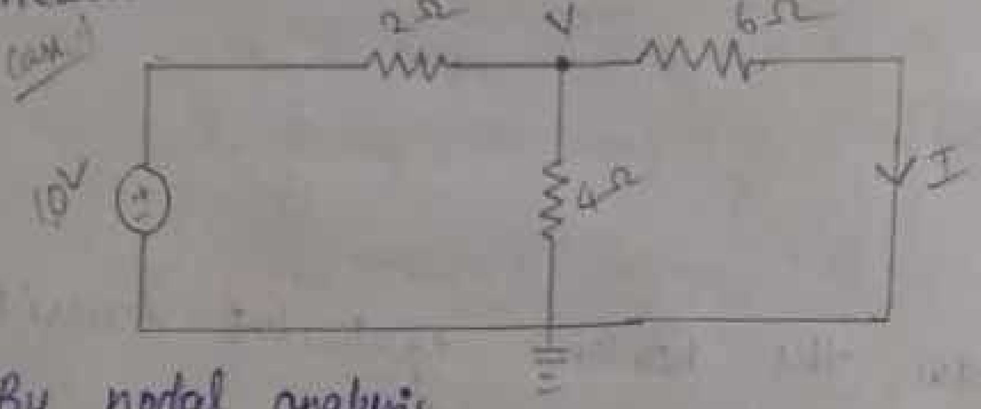
* Verify reciprocity theorem for the following network.




Sol: By nodal analysis

$$\frac{V-10}{2} + \frac{V}{4} + \frac{V}{6} = 0$$

$$\frac{6V - 60 + 3V + 2V}{12} = 0$$

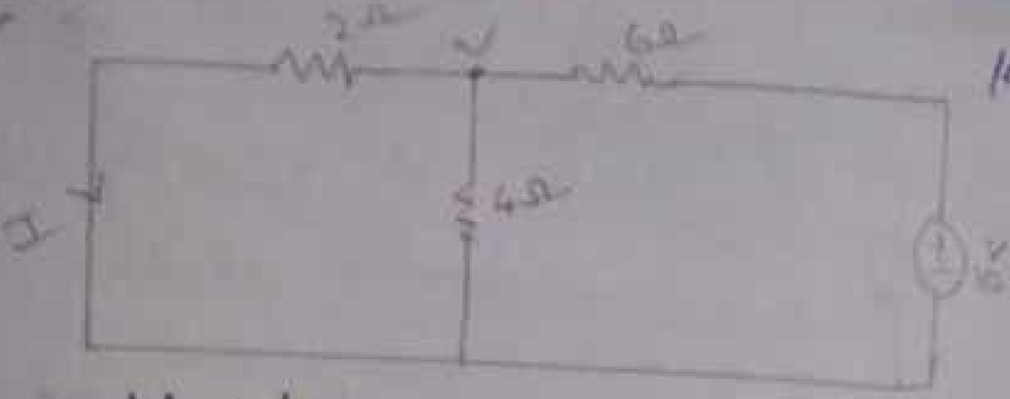
$$6V - 60 + 5V = 0$$

$$11V = 60$$

$$V = \frac{60}{11}$$

$$\boxed{V = 5.45V}$$

$$V = IR \Rightarrow I = \frac{V}{R} = \frac{5.45}{6} = 0.908A$$




By nodal analysis,

(12)

$$\frac{V}{2}+\frac{V}{4}+\frac{V-10}{6}=0$$

$$\frac{6V+3V+2V-20}{12}=0$$

$$11V=20 \Rightarrow V=\frac{20}{11}=1.81V$$

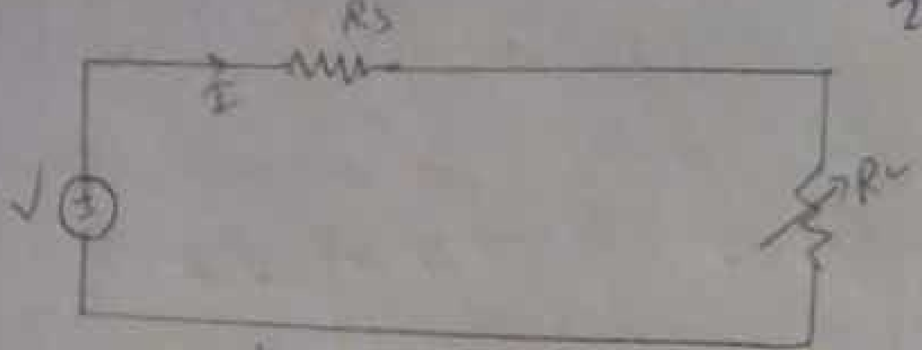
$$I=\frac{V}{R}=\frac{1.81}{2}=0.9A$$

Here the current flows in case (i), case (ii) are equal. So it satisfies the reciprocity theorem.

**Maximum power transfer theorem:-**

Maximum power transfer theorem states that Maximum power transmitted from a source to load when ~~load~~ source resistance is equal to the load resistance.

"Prove that source resistance is equal to the load resistance"




From the above circuit current $I = \frac{V}{R_S + R_L}$

Power delivered to the load $P = I^2 R_L$

$$P = \frac{V^2}{(R_S+R_L)^2} \cdot R_L$$

To get the maximum power for finding the value of $R_L$, Differentiate P with respective $R_L$ on both sides and equating with to zero.

$$P = \frac{V^2 R_L}{(R_S + R_L)^2}$$

$$\frac{dP}{dR_L} = \frac{d}{dR_L}\left(\frac{V^2 R_L}{(R_S+R_L)^2}\right) = 0$$

$$\Rightarrow \frac{(R_S+R_L)^2 \cdot V^2 - V^2 R_L (2(R_S+R_L))}{(R_S+R_L)^4} = 0$$

$$\Rightarrow (R_S+R_L)^2 \cdot V^2 - V^2 R_L (2(R_S+R_L)) = 0$$

$$\Rightarrow V^2 (R_S+R_L) \left\{(R_S+R_L) - 2R_L\right] = 0$$

$$\Rightarrow R_S + R_L - 2R_L = 0$$

$$\Rightarrow R_S - R_L = 0 \Rightarrow \boxed{R_S = R_L}$$

* Determine the load resistance to recieve maximum power from source and also find the maximum power delivered to the load.

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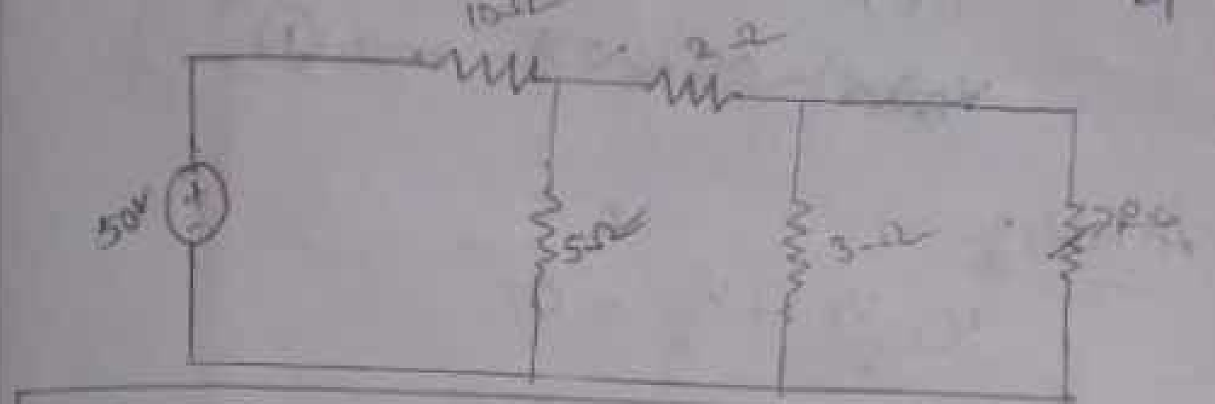
(14)



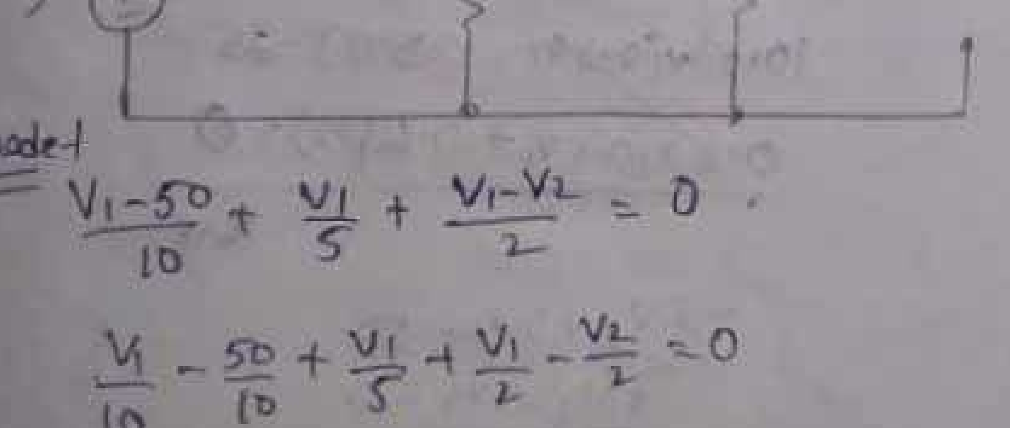

Procedure :-

→ Open circuit $R_L$

→ find out the thevinin's voltage at the open terminals.

→ find out the $R_{th}$

→ Draw the thevinin's equivalent circuit




At node 1

$$\frac{V_1-50}{10} + \frac{V_1}{5} + \frac{V_1-V_2}{2} = 0$$

$$\frac{V_1}{10} - \frac{50}{10} + \frac{V_1}{5} + \frac{V_1}{2} - \frac{V_2}{2} = 0$$

$$V_1\left(\frac{1}{10}+\frac{1}{5}+\frac{1}{2}\right) - \frac{V_2}{2} = 5$$

$$V_1\left(\frac{2+4+10}{20}\right) - \frac{V_2}{2} = 5$$

$$\left(\frac{V_1+2V_1+5V_1}{10}\right)-\frac{V_2}{2}=5$$ 22

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$$\frac{8V_1}{10}-\frac{V_2}{2}=5$$

$$\frac{8V_1-5V_2}{10}=5$$

$$8V_1-5V_2=50 \rightarrow (1)$$

$$\frac{V_2-V_1}{2}+\frac{V_2}{3}=0$$

$$\frac{V_2}{2}-\frac{V_1}{2}+\frac{V_2}{3}=0$$

$$\frac{V_2}{2}+\frac{V_2}{3}-\frac{V_1}{2}=0$$

$$\frac{3V_2+2V_2-3V_1}{6}=0$$

$$5V_2-3V_1=0$$

$$-3V_1+5V_2=0 \rightarrow (2)$$

Solve (1) & (2), (1).

$$-3V_1+\cancel{5V_2}=50$$

$$8V_1-\cancel{5V_2}=0$$

$$5V_1=50$$

$$\boxed{V_1=10}$$

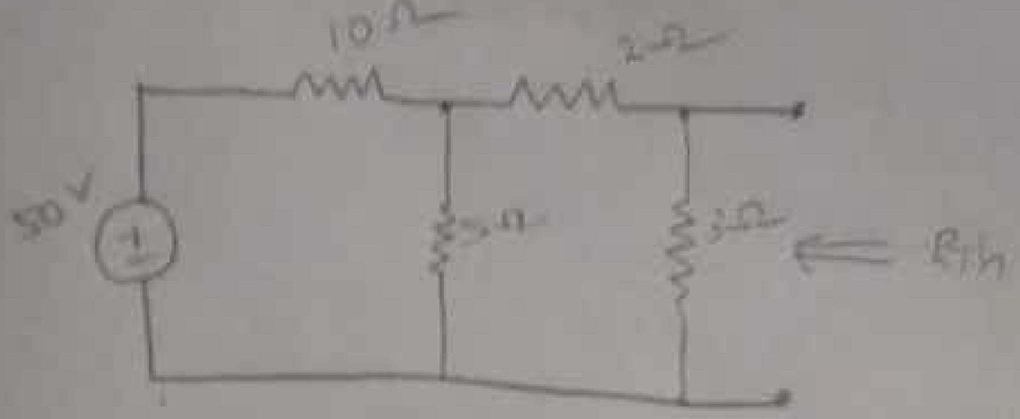
put $V_1=10$ in eq (2)

$$-3(10)+5V_2=0$$

$$\Rightarrow 30=5V_2$$

$$\boxed{V_2=6}$$

$\therefore V_1=10, \quad V_2=6$

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$$R_{eq} = \frac{50}{15} = 3.33$$

$$R_{eq} = 3.33 + 2 = 5.33$$

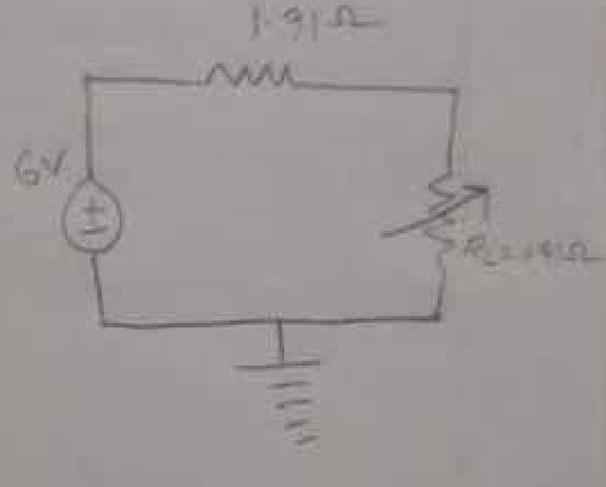
$$R_{eq} = \frac{5.33(3)}{3+5.33} = 1.91\Omega$$

$$\boxed{R_{th} = 1.91\Omega}$$

From maximum power transfer theorem

$$R_{th} = R_S = R_L = 1.91\Omega$$

Now




$$P = I^2 R_L$$

$$I = \frac{V}{R_S + R_L}$$

$$= \frac{6}{1.91 + 1.91}$$

$$= \frac{6}{3.82}$$

$$= 1.57\Omega$$

$$P = (1.57)^2 (1.9)$$

$$\boxed{P = 4.68 \text{ watts}}$$

Power delivered to the load = 4.68W