Unit-1

Kirchhoff's law

Kirchhoff's current law (1st law)

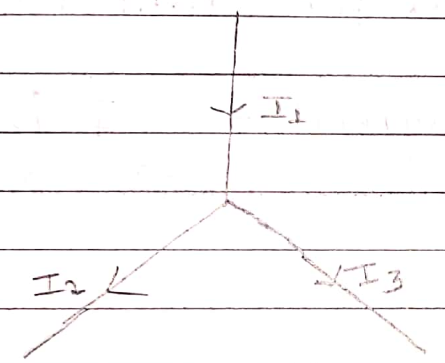
It states that in any network of conductors, the algebric sum of currents meeting at a point (or Junction) is zero.

i.e $\Sigma I = 0$

$I_1 - I_2 - I_3 = 0$

$I_1 = I_2 + I_3$

Incoming current = Outgoing current.



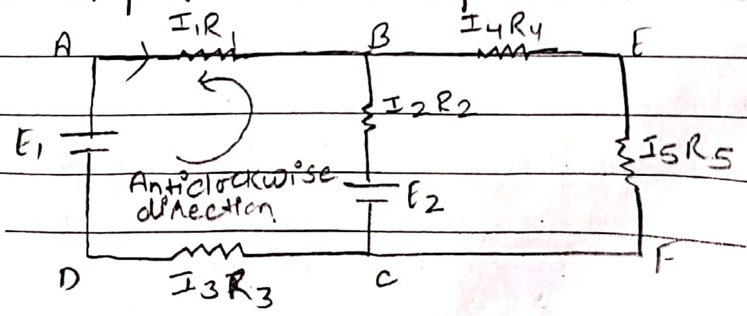
Kirchhoff's voltage law (2nd law)

It states that the algebraic sum of all IR drops and EMFs in any closed loop (or mesh) of a network is zero.

i.e $\Sigma E = \Sigma IR$

This law is in accordance with conversation of energy.

Explanation of Second law



In loop ABCD

$$\Sigma E = \Sigma IR$$

Sign convention for EMF (E)

In going from $-$ve to $+$ve, take emf (E) as ($+$ve)

In going from $+$ve to $-$ve, take emf (E) as $-$ve

Sign convention for current (I)

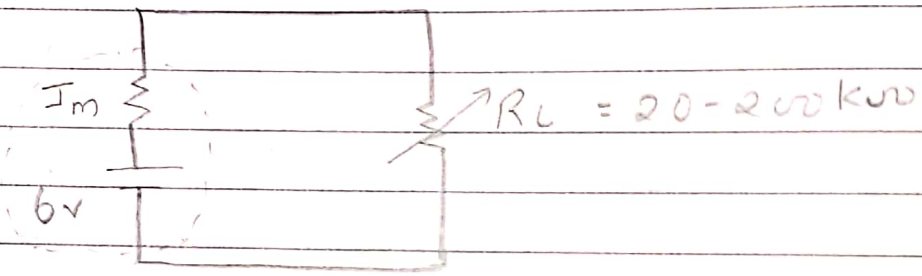
Anticlockwise current $\longrightarrow$ I is $+$ve

Clockwise " $\longrightarrow$ I is $-$ve

Network Theorems

Ideal constant current Source

It is that voltage source whose internal resistance is infinite and offers constant current. But in practice a current source must have a very high resistance as compared to that of load resistance.



For $R_L = 20k\Omega$

$= 20\times10^3\Omega$

$= 2\times10^4\Omega$

$r = 10^6$

$= 100\times10^4\Omega$

$$I = \frac{V}{R}$$

$$= \frac{6}{(2\times10^4 + 100\times10^4)}$$

$$= \frac{6}{10^4\times120}$$

$I = 0.05\times10^{-4}$ A

Ideal Constant-Voltage Source

It is that voltage source or generator whose output voltage remains absolutely constant whatever the change

$\S$ If current is divided then it is parallel combination.
If current is not divided then it is series combination

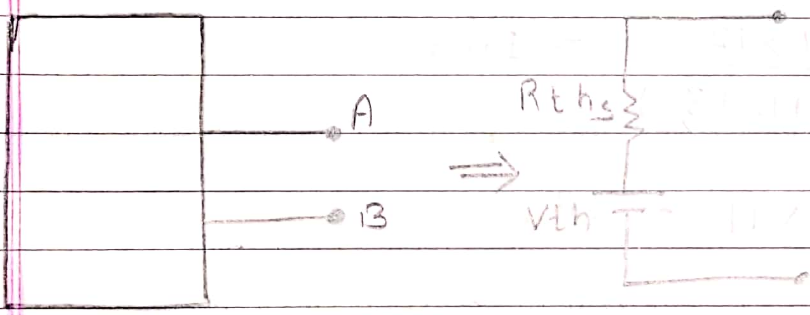
in load current.

Thevenn's Theorem

This theorem is very useful to know the amount of power current or voltage drop in a particular component of given circuit.

With the help of these theorem a complex circuit can be simplified to a series circuit consisting of:

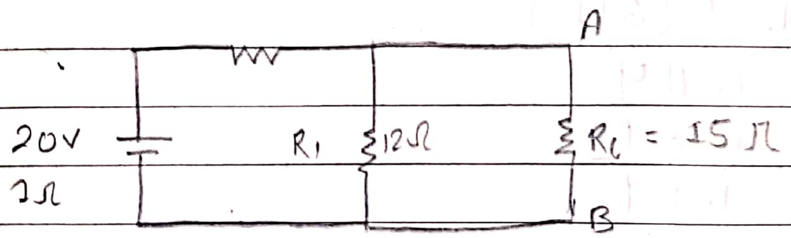
i) An ideal voltage source
ii) A resistance connected in series with it.



The above figure indicates that a whole network is converted to a single voltage source (Vth) and a series resistance (rth).

Steps to thevenize a circuit.

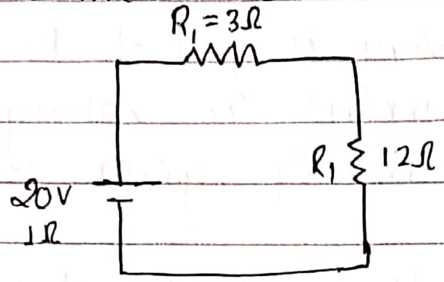
let us ~~consider~~ take an example:



let us try to find current through load

resistance ($R_L = 15\Omega$)

Step1: Disconnet the load resistance (R_L)



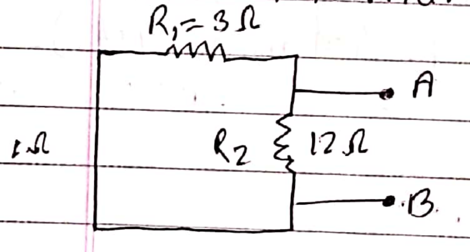
Step2: With the load terminals A and B open Calculate open circuit voltage (V_{OC})

$$V_{AB} = V_{CD} = V_{BC}$$

$$\frac{24 \times 12}{(1+12+3)} \quad \cancel{= 18V}$$

$$V_{th} = 18V$$

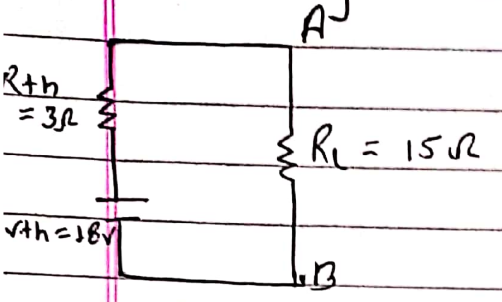
Step3: Remove the voltage source living behind their internal resistance.



$$R_{th} = 12 \parallel (3+1)$$
$$= 12 \parallel 4$$
$$= \frac{12 \times 4}{12+4}$$
$$= \frac{48}{16}$$
$$= 3\Omega$$

Voltage source → short circuit
Current source → open circuit.

Step 4: Finally insert the load resistance



Current through R_L is:-

$$I = \left(\frac{V_{th}}{R_{th} + R_L}\right)$$

$$= \frac{18}{3+15}$$

$$= 18/18$$

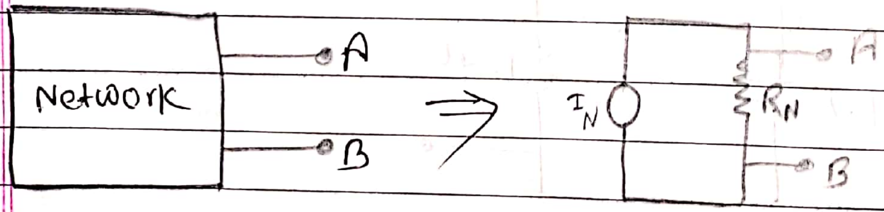
$$= 1 \Omega$$

Norton's theorem

This theorem is used where it is easier to simplify a network in terms of current insted of voltage. This theorem reduces a complicated network to a simple parallel circuit consisting of:

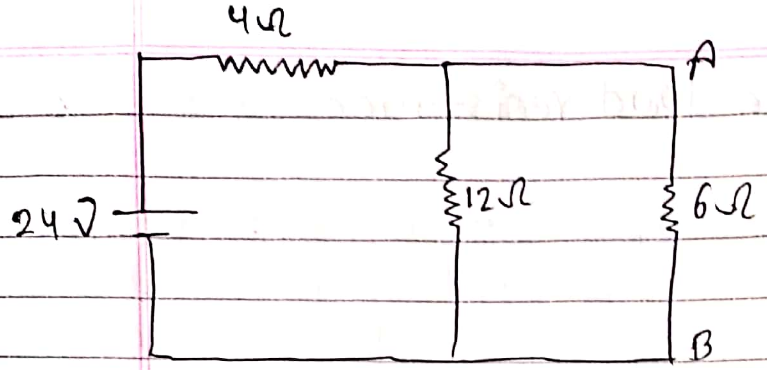
a) An ideal current source (I_N) of infinite resistance.

b) A resistance (R_N) in parallel with it.

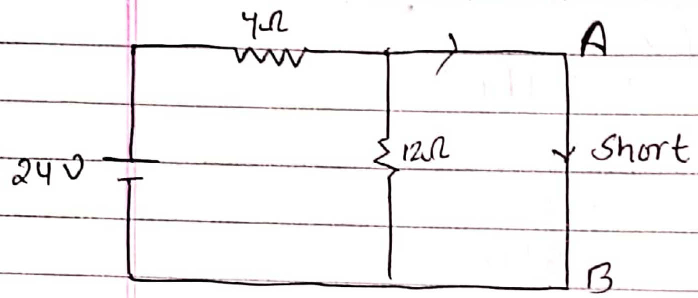


Step to Nortonise a given electrical circuit.

let us take an example.



Step1: Remove a load resistance and put a short across terminals A and B.



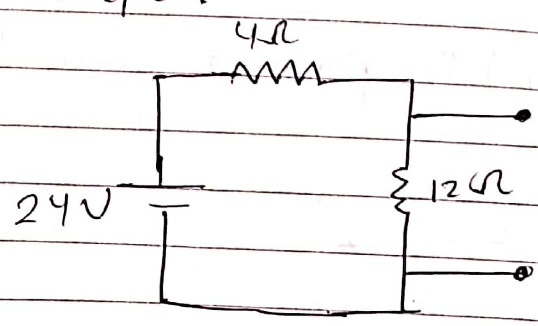
Now,

Short circuit current $(I_{sc}) = \dfrac{V}{R}$

$= \dfrac{24}{4}$

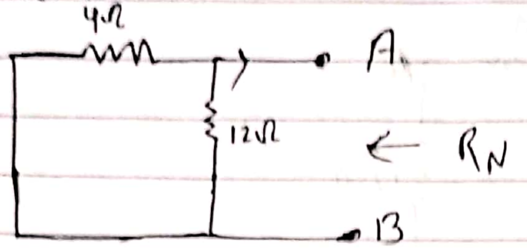
I_{sc} or $I_N = 6\,A$

Step2: Remove the short from terminals A and B & left them open.



Step3: Remove the battery and Replace it by it's internal resistance. The resistance (R_N) of the

circuit will be found by vewing back from terminals A and B.



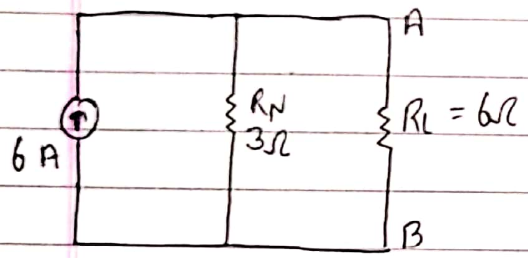
$$R_N = 4 \parallel 12$$

$$= \frac{4 \times 12}{4+12}$$

$$= \frac{48}{16}$$

$$= 3\Omega$$

Step4: The Nortor's equivalent circuit

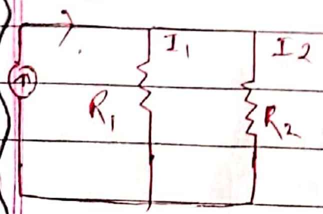


Current through R_L is $I_L = \left(\frac{3}{3+6}\right) \times 6$

$$= \frac{18}{9}$$

$$= 2A$$

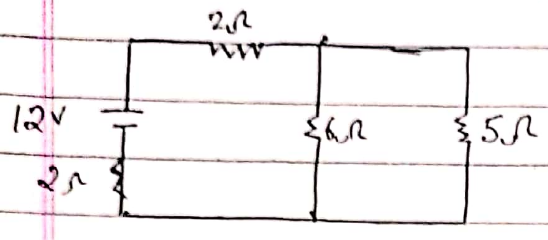
Formula



$$I_1 = \left(\frac{R_2}{R_1+R_2}\right) I$$

$$I_2 = \left(\frac{R_1}{R_1+R_2}\right) I$$

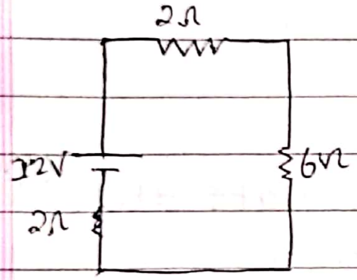
Q) Use Thevenin's theorem to find current across 5Ω.



Soln:

Here,

Disconnet the load resistance (R_L)



calculate open circuit voltage (V_{oc})

$$I = \frac{V}{R}$$

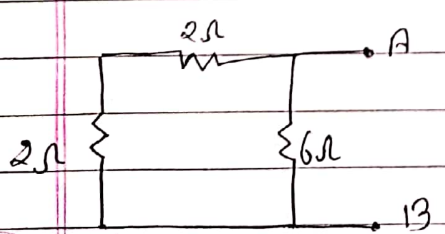
$$= \frac{2}{2+6+2} = 1.2A$$

$$V_{OC} = V_{AB} = V_{CD} = I.R$$

$$= 1.2 \times 6$$

$$V_{th} = 7.2\ V$$

Remove the voltage source living behind their internal resistance.

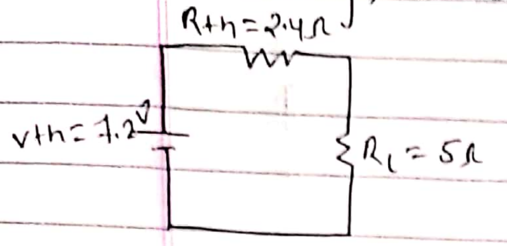


$$R_{th} = (2+2) \| 6$$

$$= 4 \| 6$$

$$= \frac{4 \times 6}{4+6} = 2.4\Omega$$

Finally, insert the load resistance.



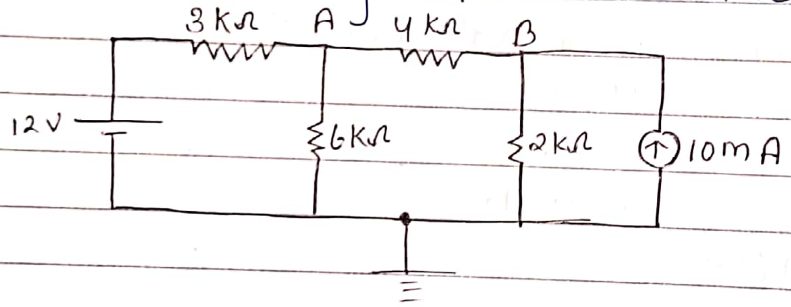
$$I = \frac{V}{R}$$

$$= \frac{7.2}{(2.4+5)}$$

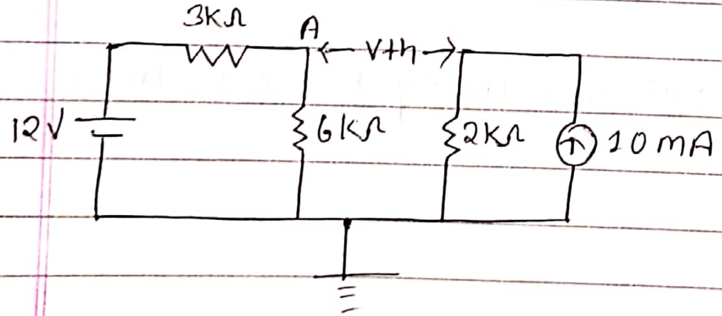
$$= \frac{7.2}{7.4}$$

$$= 0.97\,A$$

Q) Using thevenin's theorem calculate the current through 4kΩ resistance. [IMP]



Let, us remove load resistance and left terminals A and B open.



$V_{OC} = V_{AB} = V_{th} = ?$

$V_B = I \cdot R$

$= 10mA \times 2k\Omega$

$= 10\times10^{-3} \times 2\times10^{3}$

$= 20V$

Now,

Current through $6k\Omega = \frac{12}{(3+6)\times10^{-3}}$

$= \frac{12\times10^{-3}}{9}$

$= 1.33\times10^{-3}A$

$V_{AQ} = V_A = I \cdot R$

$= 1.33\times10^{-3}\times6\times10^{3}$

$= 7.98V$

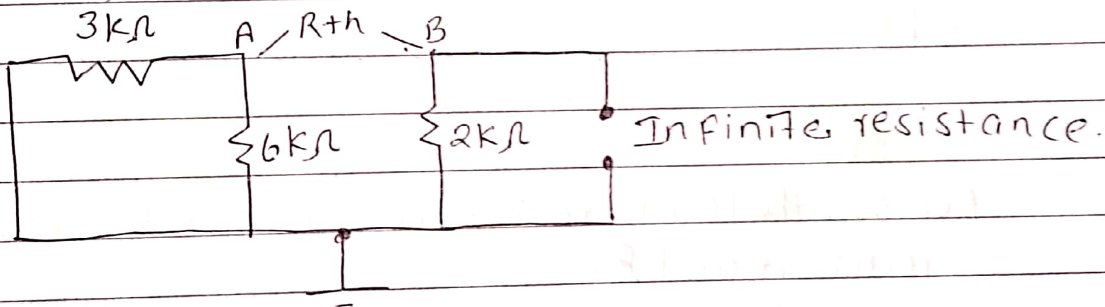
Now,

$V_{th} = V_{AB} = V_B - V_A$

$= 20 - 7.98$

$= 12.08V$

Remove the voltage source living behind their internal resistance.



$= 6 \| 3$

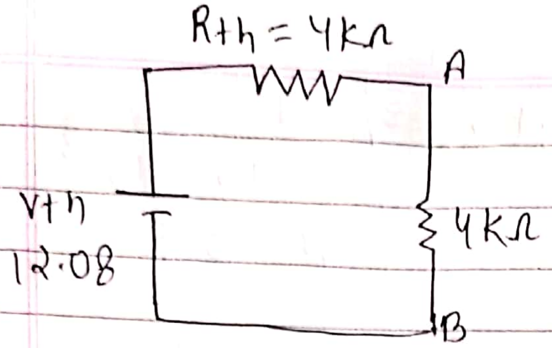
$= \frac{6\times3}{6+3}$

$= 2k\Omega$

$R_{th} = 2+2$

$= 4k\Omega$

finally, insert the load resistance.

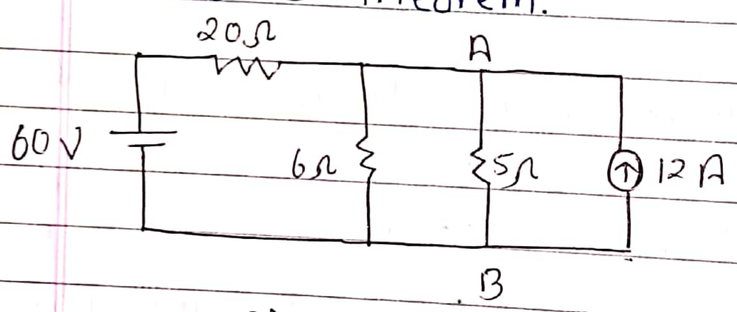


$$I = \frac{V_{th}}{R_{th} + R_L}$$

$$= \frac{12.08}{4+4}$$

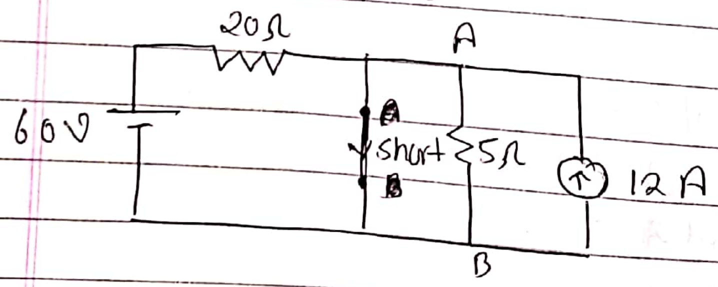
$$= 3.02\,A$$

Q) Find current through 6Ω resistance using Norton's theorem.



Soln:

Remove ~~the~~ load resistance & short circuit term A and B.



$$R_N = 20 \parallel 5$$

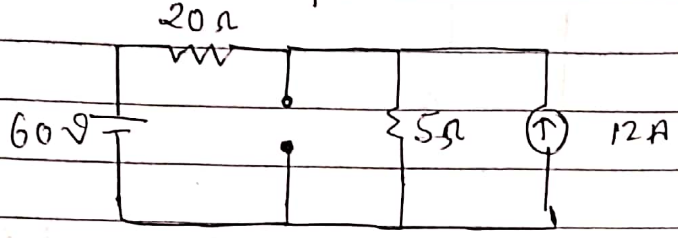
$$= \frac{20 \times 5}{20+5}$$

$$= 4\Omega$$

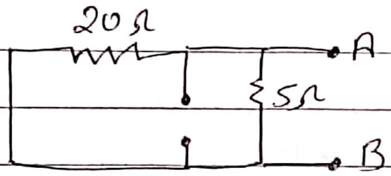
$$I_{SC} = \frac{60}{20} + 12$$

$$= 15$$

Remove the short from terminals A & B & left them open.



And, Remove the battery and replace it by internal resistance.

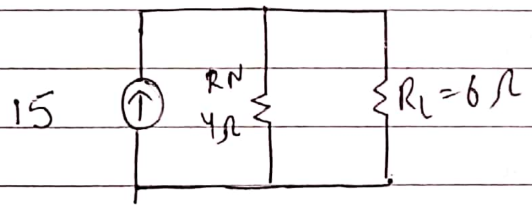


$$R_N = 20 \| 5$$

$$= \frac{20 \times 5}{20+5}$$

$$= 4\Omega$$

Finally, Norton's equivalent circuit is:

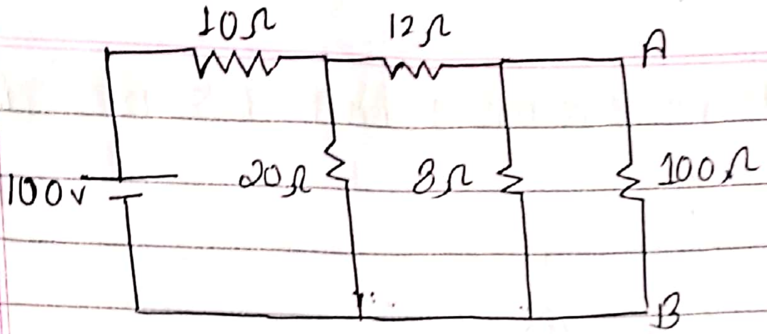


$$I = \frac{I_N \times R_N}{R_N + R_L}$$

$$= 15 \times \frac{4}{4+6}$$

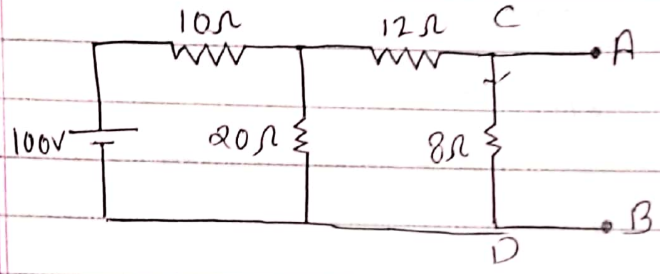
$$= 6A$$

Q) Using Thevenin's theorem find current through 100 Ω.



Soln:

Remove the load resistance (R_L) & left terminals A and B open.



At first, 12Ω and 8Ω are in series

$12+8$

$= 20\Omega$

Again, 20Ω & 20Ω are parallel

So, $20 \| 20$

$= \frac{20\times20}{20+20}$

$= 10\Omega$

Finally, 10Ω & 10Ω are in series

$R_{eq} = 10+10$

$= 20\Omega$

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

$= \frac{100}{20}$

$= 5A$

$\therefore I_{CD} = \frac{5}{2}$

$= 2.5\,A$

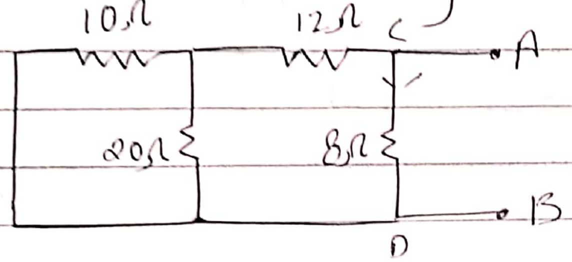
$V_{CD} = I_{CD} \times R$

$= 2.5 \times 8$

$= 20\,V$

$\therefore V_{th} = 20\,V$

Remove the ~~battery~~ voltage sources.



Here, 10 Ω & 20 Ω are in parallel.

$= 10 \parallel 20$

$= \frac{10 \times 20}{10 + 20}$

$= 6.6\,\Omega$

Again,

12Ω & 6.6 are in series.

$= 12 + 6.6$

$= 18.64$

And, 18.6 Ω & 8 Ω are in parallel

$18.6 \parallel 8$

$= \frac{18.6 \times 8}{18.6 + 8}$

$R_{th} = 5.59\,\Omega$

Finally, insert load resistance.