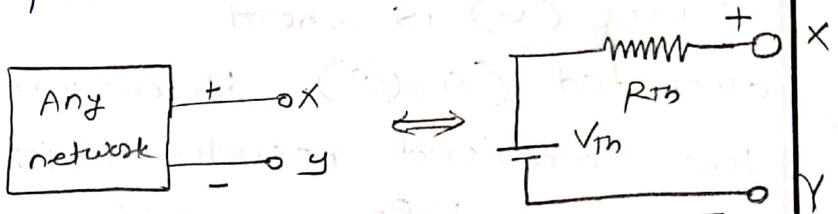
* Thevenin's Theorem:-

Thevenin theorem states that the entire network connected to two terminals can be replaced by a single voltage source V_{TH} in series with single resistance R_{Th} connected ~~two~~ same the two terminals.

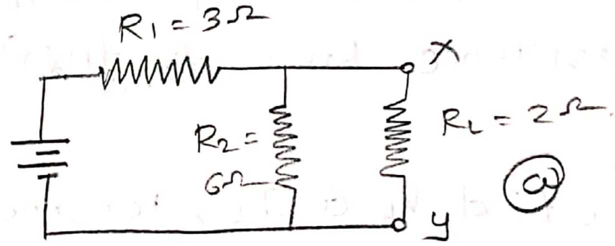
V_{Th} is open circuit voltage across terminals x & y. R_{Th} is open circuit resistance across x & y.



Any network converted to the Thevenin equivalent circuit.

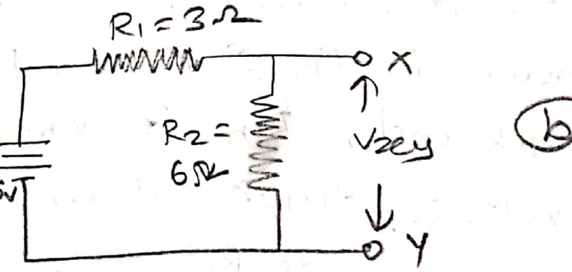
Consider an example. (fig ⓐ). Let us find the voltage V_L & current I_L through load resistance R_L of 2Ω.

Step ① ⓐ original circuit with load resistance R_L across x & y



Step ② To apply Thevenin theorem, disconnected R_L in fig ⓑ

As a result, $R_1 = 3\Omega$ & $R_2 = 6\Omega$ form a series voltage divider. Now,



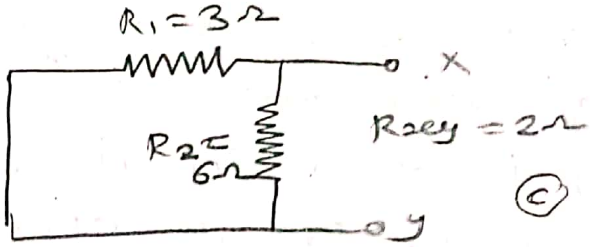
voltage across R_2 is same as open circuit voltage V_{xy}. Using voltage divider formula,

$$V_{R_2} = \frac{R_2}{R_1 + R_2} \times V = \frac{6}{3+6} \times 36 = \frac{6}{9} \times 36$$

$\therefore V_{R_2} = 24V = V_{xy}$.

This is V_{Th}. It is positive at terminal x.

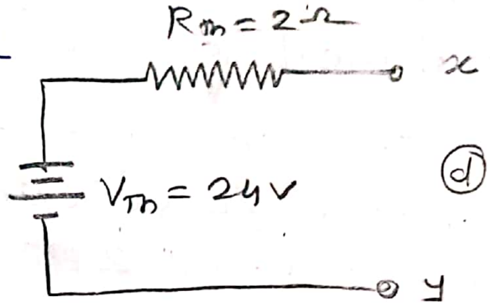
Step ③:- To find R_{th}, load resistance R_L is still disconnected. Now, source (V) is short circuited (fig ⓒ). R_1 becomes parallel to R_2. the combined resistance is,



$$R_{Th} = \frac{R_1 R_2}{R_1 + R_2} = \frac{3 \times 6}{3+6} = \frac{18}{9} = 2\Omega.$$

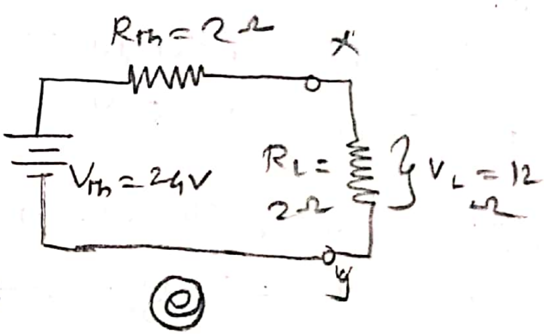
Step ④:-

Hence thevenin equivalent circuit consists of equivalent voltage $V_{Th} = 24V$ in series with equivalent resistance $R_{Th} = 2\Omega$ (fig ⓓ).



Step ⑤:-

To find V_L & I_L, reconnect R_L to terminals x & y of Thevenin equivalent circuit. as shown in fig ⓔ. Then R_L is in series with R_{Th} & V_{Th}.



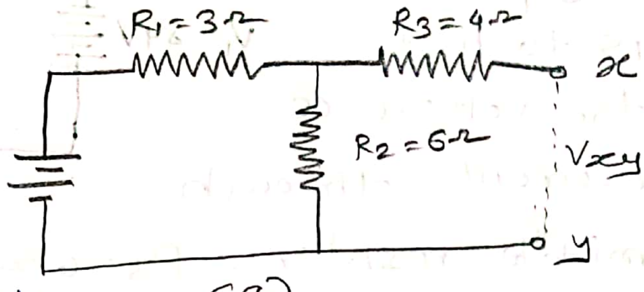
Using voltage divider formula for $R_{Th} = 2\Omega$ & $R_L = 2\Omega$

$$V_L = \frac{R_L}{R_{Th} + R_L} \times V_{Th} = \frac{2}{4} \times 24 = 12V$$

& $I_L = \frac{V_L}{R_L} = \frac{12V}{2\Omega} = 6$ Ampere

I_L is also flows through R_{th}.

Consider a fig -:-

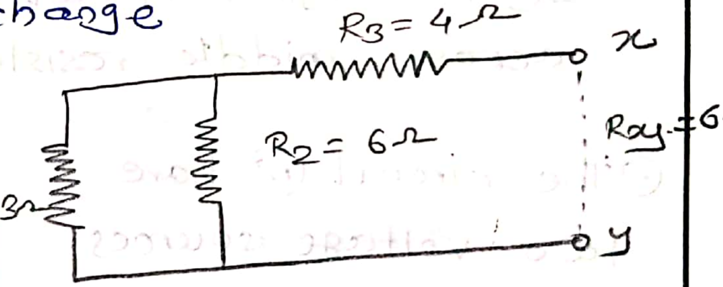


(a)

Circuit (a) is to be thevinized.

Here circuit with $R_3 = 4\Omega$ in series with terminal x. (a) Voltage V_{xy} is still 24V.

(b) But here R_3 does not change value of V_{xy}.



(b)

~~Resistance of R_{xy} is~~

$$\cancel{R_{3y} = \frac{R_1R_2}{R_1+R_2} = \frac{3\times6}{3+6}}$$

$$\cancel{R_{3y} = 6\Omega}$$

$$\& \cancel{R_{Th} = R_{xy} + R_3 = 6}$$

Here R_1 & R_2 are in parallel combination so they give combined resistence,

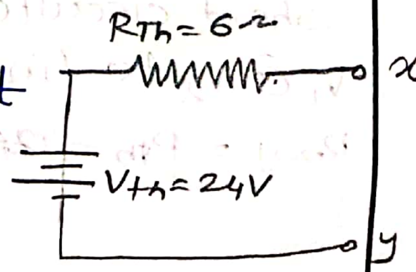
$$= \frac{R_1R_2}{R_1+R_2} = \frac{18}{9} = 2\Omega$$

& this resistance in series with $R_3 = 4\Omega$

$\therefore R_{Th} = 2+4 = 6\Omega$

(b) Resistance R_{xy} is 6Ω

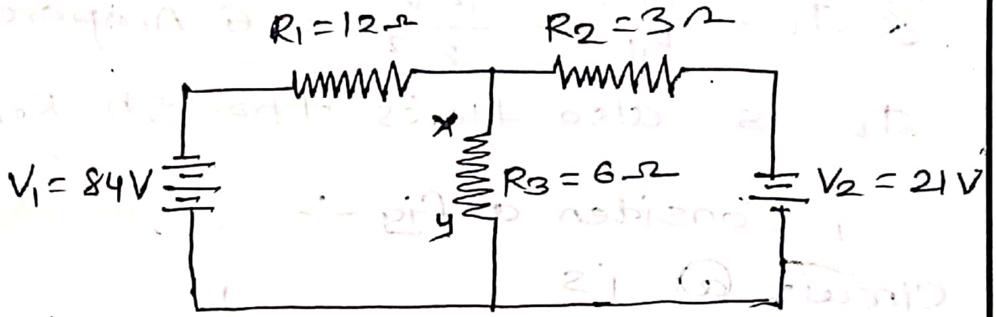
(c) Thus, thevenin equivalent circuit consists of $V_{Th} = 24V$ & $R_{Th} = 6\Omega$.



(c)

Example II:-

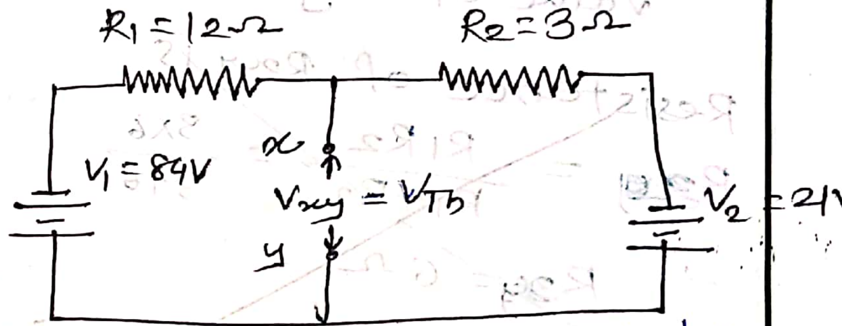
The problem is to find the voltage & current through middle resistance $R_3 = 6\Omega$.



(a)

① Make the terminals x & y across R_3 (fig ⓐ)
fig ⓐ is original circuit with terminals x & y across middle resistance R_3.

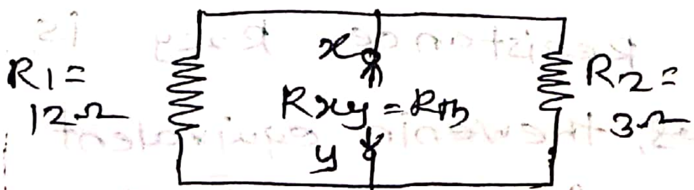
② The circuit ⓑ have two voltage sources terminals x & y can be thevenized using formulae for V_{Th} & R_{Th}. Here dissconnected R_3 to find V_{xy}.



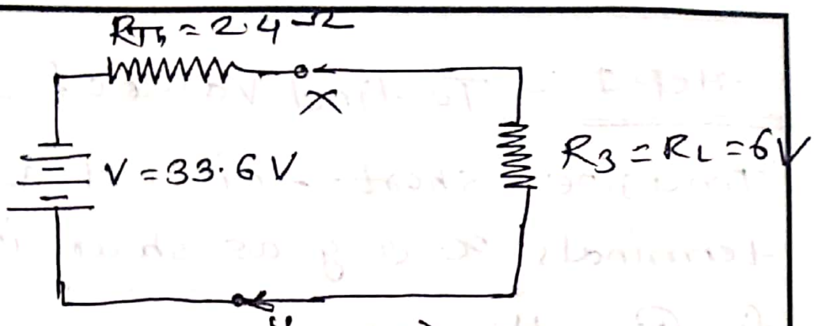
$$V_{Th} = V_{xy} = \frac{V_1R_2 + V_2R_1}{R_1+R_2} = \frac{(-84)3 + (-21)(12)}{12+3} = \frac{-504}{12}$$
$$= -33.6V$$

$$\& \ R_{Th} = R_{xy} = \frac{R_1R_2}{R_1+R_2} = \frac{36}{15} = 2.4\Omega$$

③ circuit ⓒ is short circuited V_1 & V_2 to find $R_{xy} = R_{Th} = 2.4\Omega$



(4) fig. (d) is thevenin equivalent with $R_3 (= R_L)$ reconnected to terminals x & y.



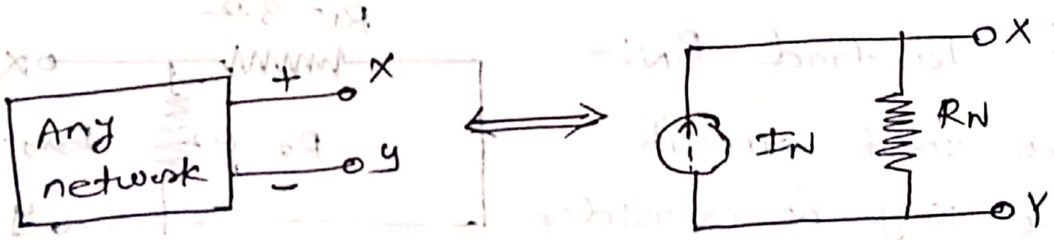
(d)

$$I_L = \frac{V_{Th}}{R_{Th}+R_L} = \frac{33.6}{2.4+6} = \frac{33.6}{8.4} = \underline{4 \text{ Ampere}}$$

& $V_L = 6 \times 4 = \cancel{R_L \times R_L} = R_L \times I_L = \underline{24V}$

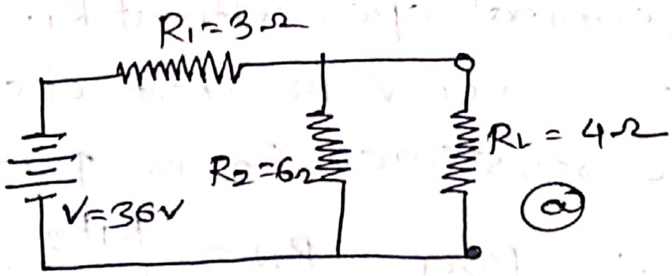
* Norton's Theorem:-

Norton theorem is useful to simplify a network in terms of current instead of voltages. It states that "the entire network connected to any two terminals x & y can be replaced by a single current source I_N in parallel with single resistance R_N.



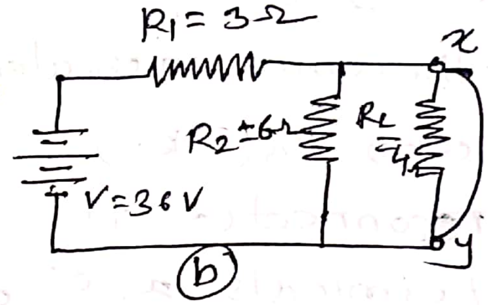
Example I:-

(a) is original circuit. Let us calculate current I_L through load resistance $R_L = 4\Omega$ as shown in fig (a)

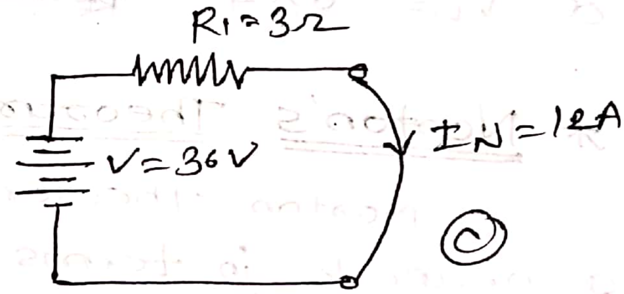


(a)

Step I :- To find value of I_N.



Imagine short-circuit across terminals x & y as shown in fig (b). Here short circuit R_L & also R_2 due to R_2 & R_L are parallel. Then only resistence in circuit is $R_1 = 3\Omega$ in series with $V = 36V$ as shown in fig (c).

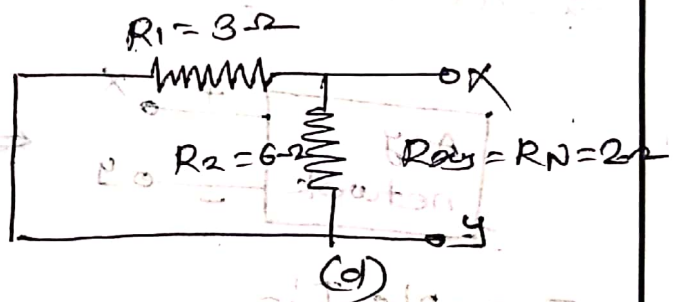


The short circuit current is $I_N = \frac{V}{R_1} = \frac{36}{3}$

$\therefore$ $I_N = 12A$

This $I_N = 12A$ is total current available from current source in Norton equivalent circuit shown in fig (c).

Step II :- To find R_N:-



Remove short circuit across x & y & consider terminal open without R_L.

Now source V is short circuited shown in fig (d).

so resistence R_2 is parallel to R_1

$$\therefore R_{eq} = R_N = \frac{R_1 R_2}{R_1 + R_2} = \frac{6 \times 3}{6+3} = 2\Omega$$

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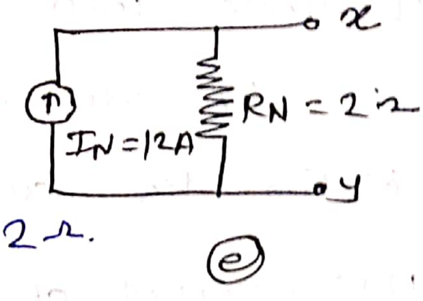
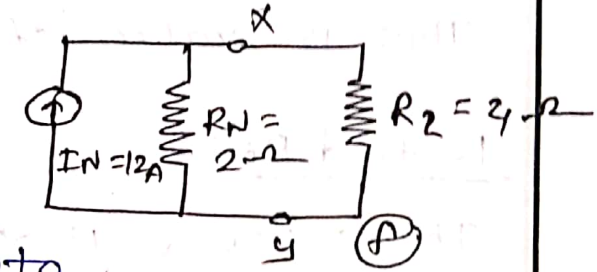
Step III :- Draw a Norton equivalent circuit as shown in fig (e). It consists of current source $I_N = 12A$ & $R_N = 2\Omega$.

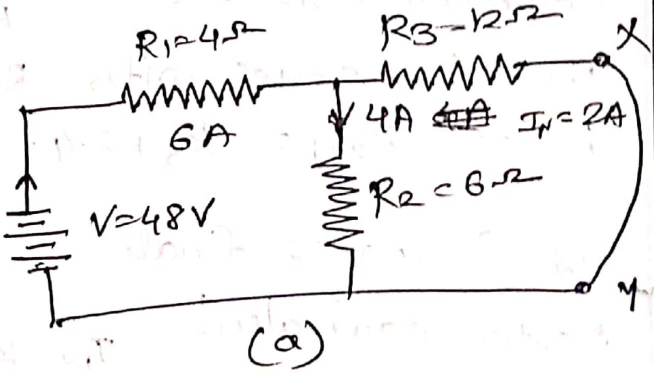


Step IV :- To calculate I_L:-
Reconnect $R_L = 4\Omega$ between x & y as shown in fig (f). Current source still delivers 12 A; but current divides into two branches of $R_N = 2\Omega$ & $R_L = 4\Omega$. Current through load resistence R_L is equal to



$$I_L = I_N \times \frac{R_N}{R_N + R_L} = 12 \times \frac{2}{2+4} = \underline{4A}$$

Example II :-



In fig (a), $I_N = 2A$ is a branch current. I_N is through short-circuited terminals x, y & R_3.

To calculate I_N :- The parallel combination of R_3 & R_2 is equal to $\frac{R_2 R_3}{R_2 + R_3} = \frac{6 \times 12}{6 + 12} = \frac{72}{18} = 4\Omega$

Hence total resistence is $R_1 + \frac{R_2 R_3}{R_2 + R_3} = 4 + 4 = 8\Omega$

Hence total current from the source is $\frac{V}{R} = \frac{48}{8}$
$= \underline{6A}$

It divides into $I \times \frac{R_3}{R_2+R_3} = 6 \times \frac{12}{6+12} = \underline{\underline{4A}}$

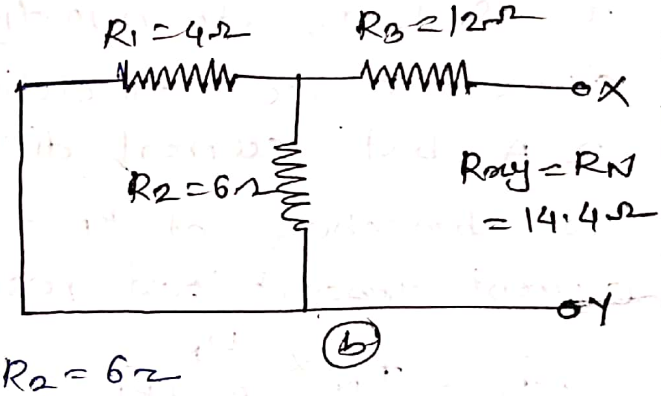
$\therefore$ 4A current flows through R_2.

& for R_3, current is $I \times \frac{R_2}{R_3+R_2} = 6 \times \frac{6}{6+12} = \underline{\underline{2A}}$

This current of 2A flowing through R_3 flows through short circuited terminals x & y.

This is value of $I_N = 2A$.

To find R_N:–



The source V is short circuited in fig (b). Also short circuit removed from x & y. Here,

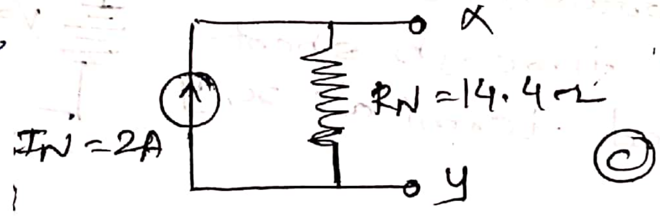
$R_1 = 4\Omega$ is parallel with $R_2 = 6\Omega$

Combined resistance is $\frac{R_1 R_2}{R_1+R_2} = \frac{4 \times 6}{4+6} = \underline{2.4\Omega}$

This is series with $R_3 = 12\Omega$.

Hence $R_{eq} = R_3 + 2.4 = 12 + 2.4 = \underline{\underline{14.4\Omega}} = \underline{\underline{R_N}}$

Fig (c) shows final Norton equivalent circuit.



* **Equivalence between Thevenin Theorem & Norton theorem:–**

Thevenin theorem says that any network can be replaced by voltage source & a series resistance, while Norton's theorem states that the same network can

be replaced by current source & shunt resistance.
It is possible to convert a Thevenin form to a Norton theorem & vice-versa.

The conversion formulae are:-

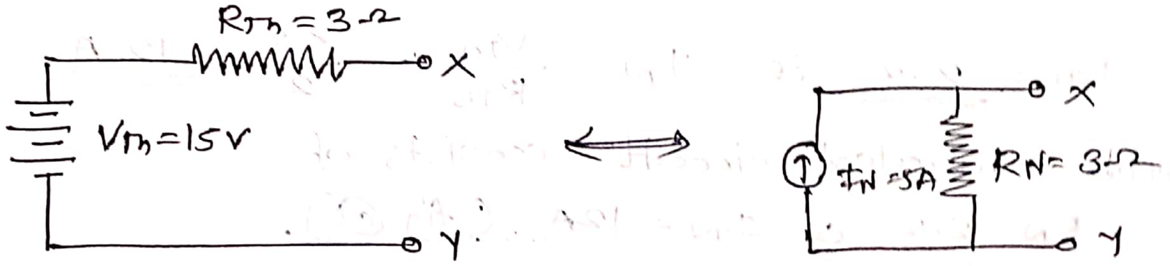
① Thevenin from Norton :-

$R_{Th} = R_N$ & $V_{Th} = I_N \times R_N$

② Norton from Thevenin :-

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

Example:- I

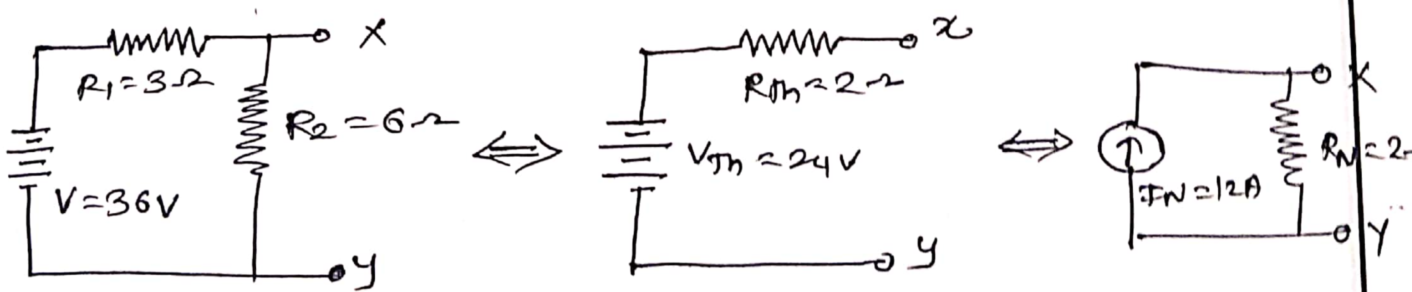


ⓐ Thevenin equivalent circuit ⓑ corresponding Norton equivalent circuit

$R_{Th} = R_N = \underline{3\,\Omega}$

$V_{Th} = 15\,V \Rightarrow I_N = \frac{V_{Th}}{R_{Th}} = \frac{15}{3} = \underline{5A}$

Example of Thevenin - Norton Conversion:-



ⓐ original circuit ⓑ Thevenin equivalent ⓒ Norton equivalent

Here in fig ⓐ, voltage across R_2 is same as open voltage across terminals x & y.

Using voltage divider formula,

$$V_{xy} = V_{Th} = \frac{R_2}{R_1 + R_2} \times V = \frac{6}{3+6} \times 36$$

$$\therefore \underline{\underline{V_{Th} = 24V}}$$

$$\& \quad R_{Th} = \frac{R_1 R_2}{R_1 + R_2} = \frac{3 \times 6}{3+6} = \frac{18}{9} = \underline{\underline{2\Omega}}$$

Thevenin equivalent circuit consists of

$V_{Th} = 24V$ & $R_{Th} = 2\Omega$ (fig ⓑ).

$$R_N = R_{Th} = \underline{\underline{2\Omega}} \quad \& \quad I_N = \frac{V_{Th}}{R_{Th}} = \frac{24}{2} = \underline{\underline{12\,A}}$$

Norton equivalent circuit consists of

$R_N = 2\Omega$ & $I_N = 12A$ (fig ⓒ).