SOLVING CIRCUITS.

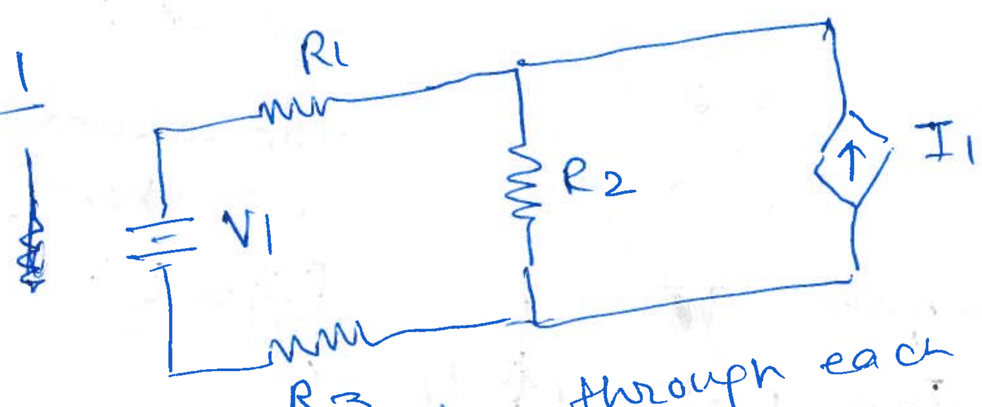
1) principle of superposition - the ~~total~~ principle states that the total effect of multiple contributing sources on a linear circuit is equal to the sum of the individual effects of the sources, taken one at a time.

Step-1 - turn off all but one source, and compute any circuit parameter. Repeat for all sources.

Turn off voltage source by short-circuit
" " current " " open " .

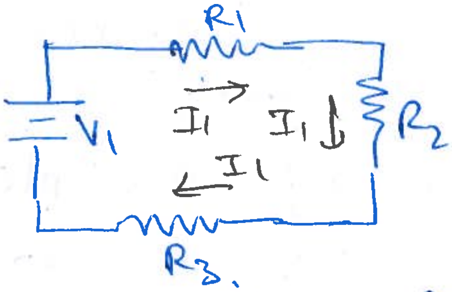
Step-2 To get the total resultant parameter, add the parameter obtained from each source.

Examp-1

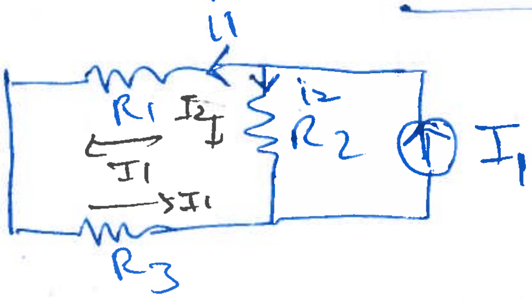


find current flowing through each circuit element.

Solution. principle of superposition.



$$i_1 = i_2 = i_3 = \frac{V_1}{R_1+R_2+R_3}$$



$$i_2 = \frac{(R_1+R_2)\,I_1}{R_1+R_2+R_3}$$

$$i_1 = i_3 = \frac{R_2 I_1}{R_1+R_2+R_3}$$

So, using superposition

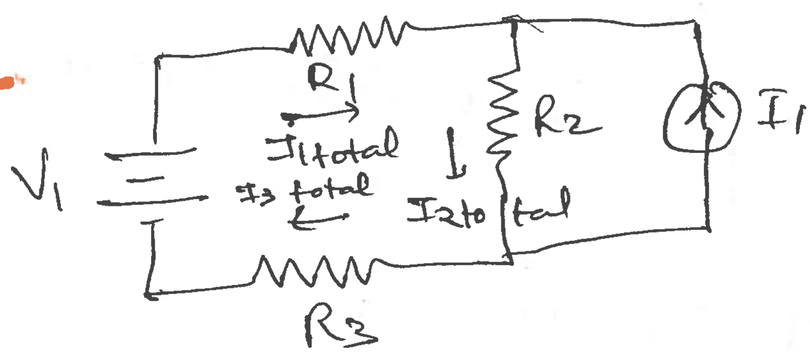
$$i_{1total} = \frac{V_1}{R_1+R_2+R_3} - \frac{I_1R_2}{R_1+R_2+R_3}$$

Note, direction matters.
Be careful.

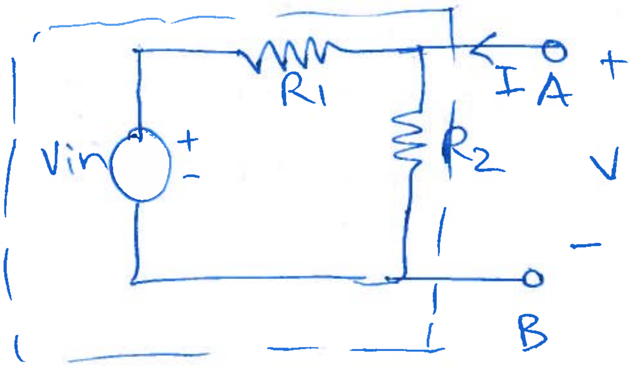
$$i_{2total} = \frac{V_1 + (R_1+R_2)\,I_1}{R_1+R_2+R_3}$$

$$i_{3total} = \frac{V_1 - I_1R_2}{R_1+R_2+R_3}$$

the assumed directio are shown in figure)



Thevenin Equivalent Circuit

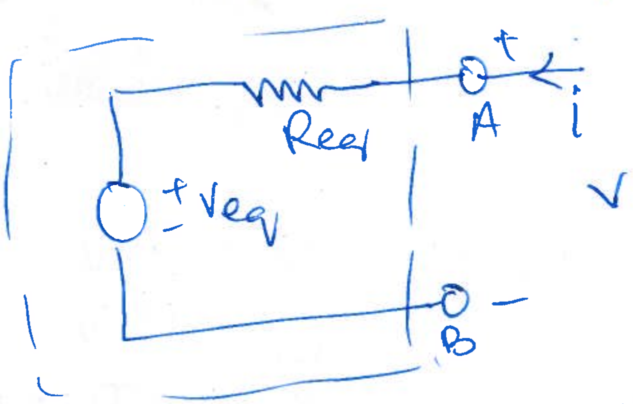


To establish a V-I relationship ~~between~~ for the boxed circuit element, we can use principle of superposition.

'Voltage across R2' = $V_{\text{when } Vin=0}$ (short circuit the voltage source) + $V_{i=0}$ (keep the output terminal open).

$$v = \cancel{Vin}\; i\,[R_1 \| R_2] + \frac{Vin\, R_2}{R_1 + R_2}$$

$$v = R_{eq}\, i + V_{eq}$$

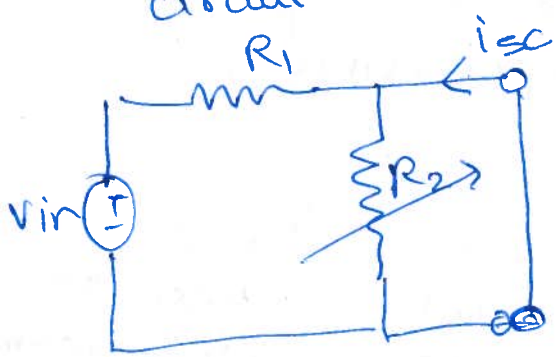


Steps 1: 'V_{eq}' or output voltage is computed by assuming an 'open circuit';

Step 2 - 'R_{eq}' is calculated by setting each independent voltage source to short circuit and each independent current source as open circuit, and then calculate resistance looking inward from the terminal

Step-2 can also be replaced with a more practical (experiment) step.

Step-2 (alternate). Short circuit the output terminal and and measure the current going in the circuit



$$i_{sc} = \frac{-V_{in}}{R_1}$$

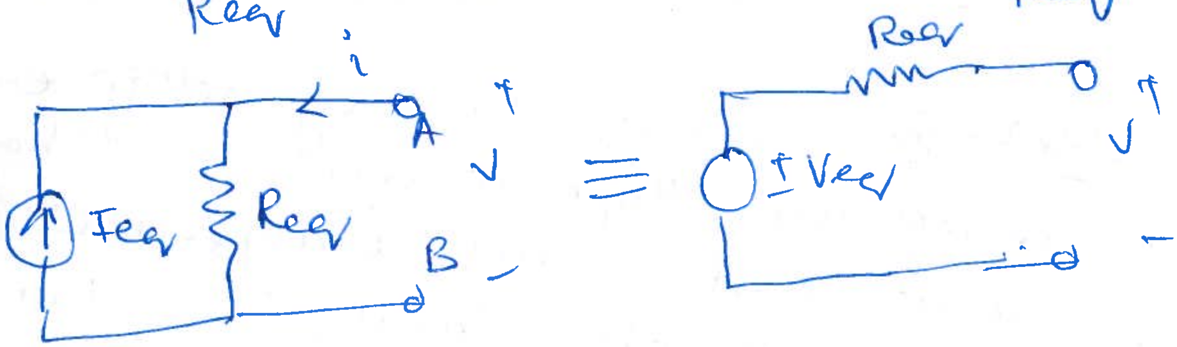
then, $$R_{eq} = -\frac{V_{eq} \text{ (or } V_{oc})}{i_{sc}}$$

$$= \frac{\cancel{V_{in}} R_2 R_1}{(R_1+R_2)\cancel{V_{in}}} = \frac{R_1 R_2}{R_1+R_2} = R_1 \| R_2$$

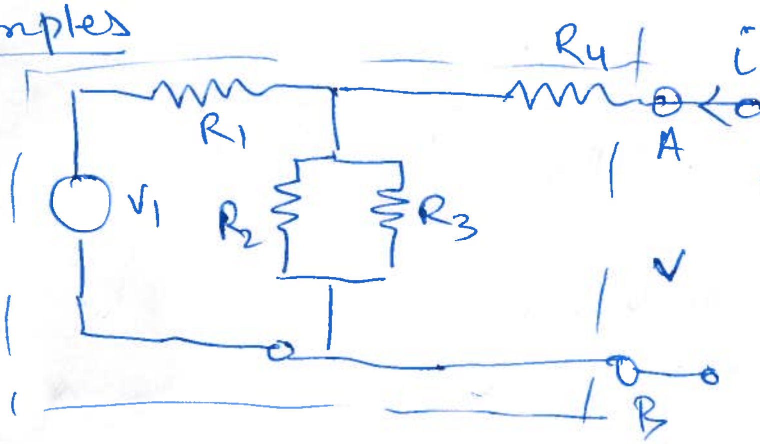
Mayer-Norton Equivalent

$$V = R_{eq}\, i + V_{eq}$$

$$i = \frac{V}{R_{eq}} - i_{eq} \; ; \text{ where } i_{eq} = \frac{V_{eq}}{R_{eq}}$$

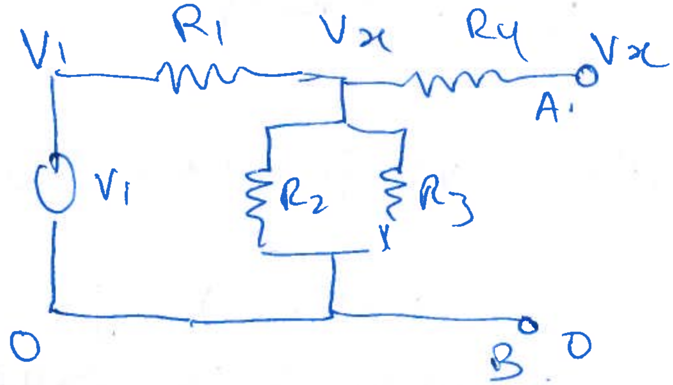


Examples



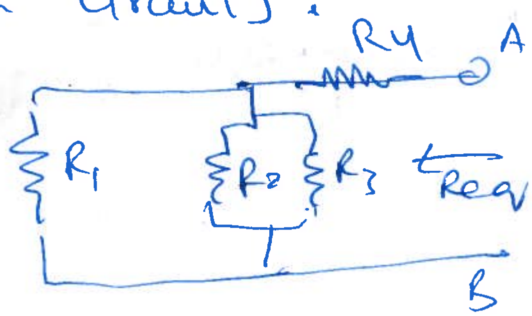
find, V_{eq}, R_{eq} and i_{eq} thus, ~~draw~~ find the thevenin and norton equivalent.

Step-1 . Open circuit $(i=0)$



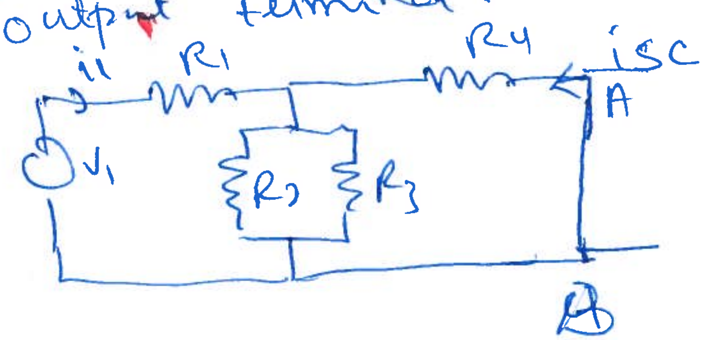
$$V_x = \frac{(R_2 \| R_3) V_1}{R_1 + R_2 \| R_3}$$

Step 2 . Compute R_{eq} by setting all independent voltage source to short circuit (and current source to open circuit).



$$R_{eq} = R_1 \| R_2 \| R_3 + R_4$$

Step 2 (alternative) / practical - short circuit the output terminal.



$$i_1 = \frac{V_1}{R_1 + R_2 \| R_3 \| R_4}$$

$$i_{sc} = \frac{-i_1 (R_2 \| R_3)}{R_4 + R_2 \| R_3}$$

thus, $i_{sc} = -\frac{V_1 \, (R_2 || R_3)}{(R_1 + R_2 || R_3 || R_4)(R_4 + R_2 || R_3)}$

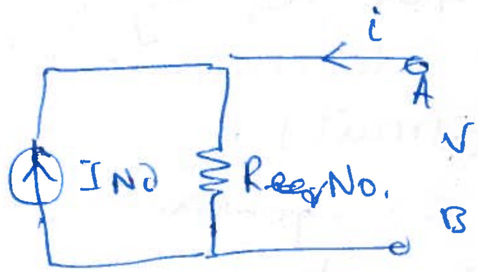
$$R_{eq} = \frac{V_{eq}\ (\text{or } V_{oc})}{-I_{sc}}$$

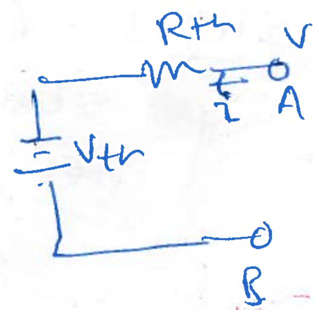
$$= \frac{\cancel{V_1 (R_2 || R_3)}}{\cancel{R_1 + R_2 || R_3}} \left[\frac{(R_1 + R_2 || R_3 || R_4)(R_4 + \cancel{R_2 || R_3})}{\cancel{V_1}\ \cancel{(R_2 || R_3)}} \right]$$

$= R_1 + R_2 || R_3 || R_4$ (verified as well)

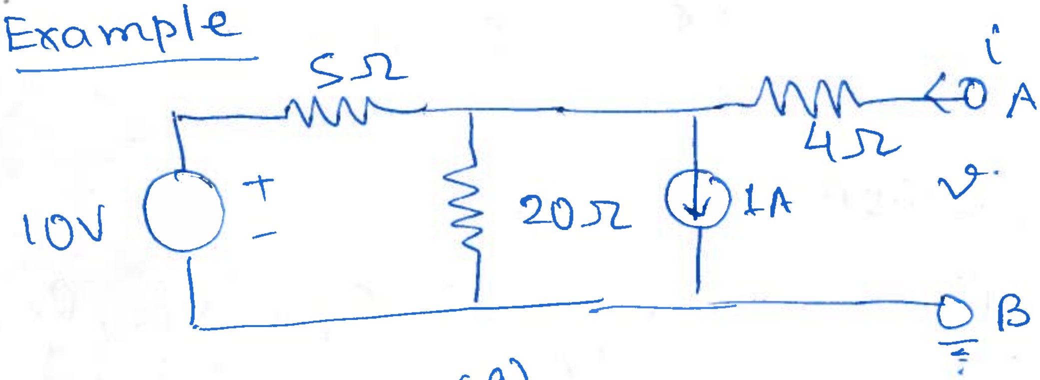
(3) $I_{eq} = -i_{sc} = \frac{V_1 \, (R_2 || R_3)}{(R_1 + R_2 || R_3 || R_4)(R_4 + R_2 || R_3)}$

$$\left. \begin{aligned} R_{th} &= R_{No} = R_{eq} \\ V_{th} &= V_{eq} = V_{oc} \\ i_{No} &= i_{eq} = -I_{sc} \end{aligned} \right\}$$





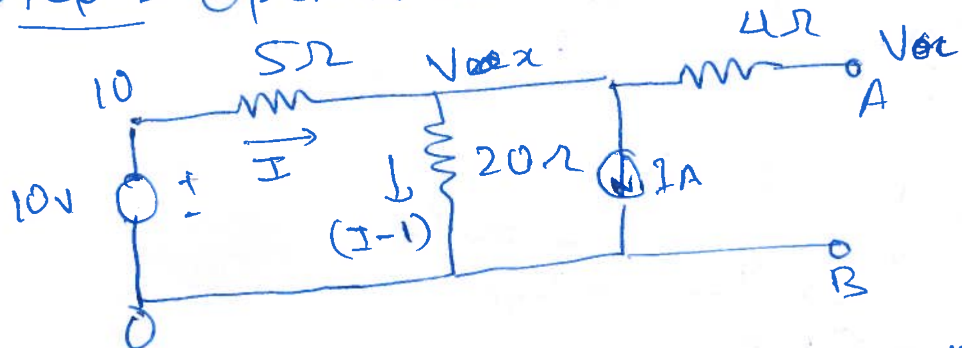
Example



(a)

find, V_{eq} (V_{oc}), R_{eq} and $I_{eq} = (-I_{sc})$

Step-1 Open circuit ($i = 0$)



V_{oc} ($i=0$)

$V_{oc} = V_x$

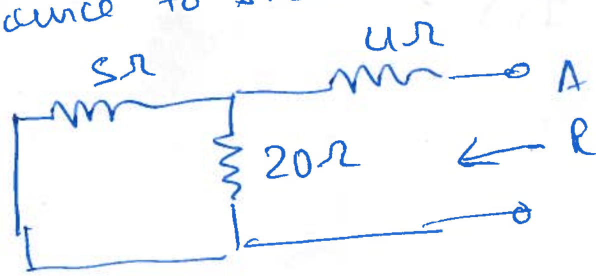
$$10 - 5I - (I-1)\times 20 = 0$$

$$10 - 25I + 20 = 0$$

$$I = \frac{30}{25} = \frac{6}{5} = 1.2\ \text{A}$$

$$V_x = 10 - 5\times 1.2 = 4\,\text{V} = V_{oc} = V_{eq}$$

Step-2 Compute R_{eq} by setting independent voltage source to short circuit, current source to open circuit.



$$\leftarrow R_{eq} = 4 + 5 \| 20$$

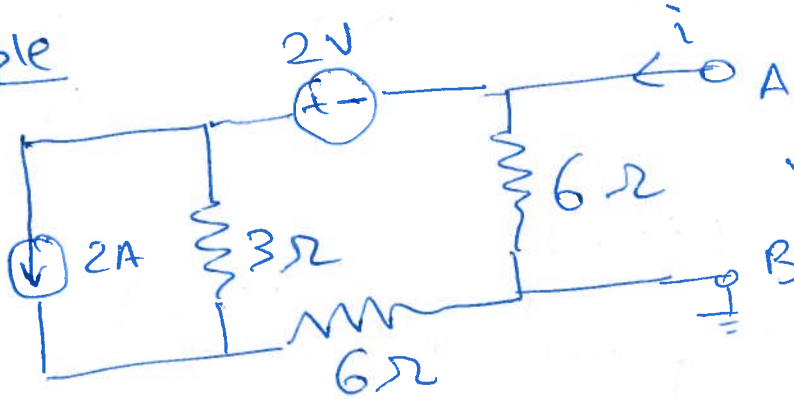
$$= 4 + \frac{\cancel{5}\times\cancel{20}\,4}{\cancel{25}\,\cancel{5}} = 8\,\Omega$$

Step-3 $i_{eq} = \frac{V_{eq}}{R_{eq}} = \frac{4V}{8\Omega} = 0.5A$

$i_{sc} = -I_{eq} = -0.5A$

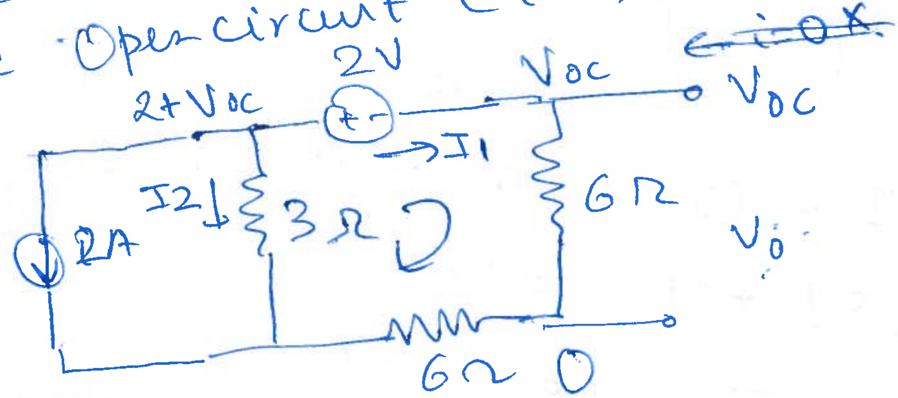
Example

find voc, Req and isc.



Solution

Step-1 Open circuit ($i=0$)



$I_1 + I_2 = -2$ (KCL)

$-2 - I_1 6 - I_1 6 + 3 I_2 = 0$

$12 I_1 - 3 I_2 = -2$

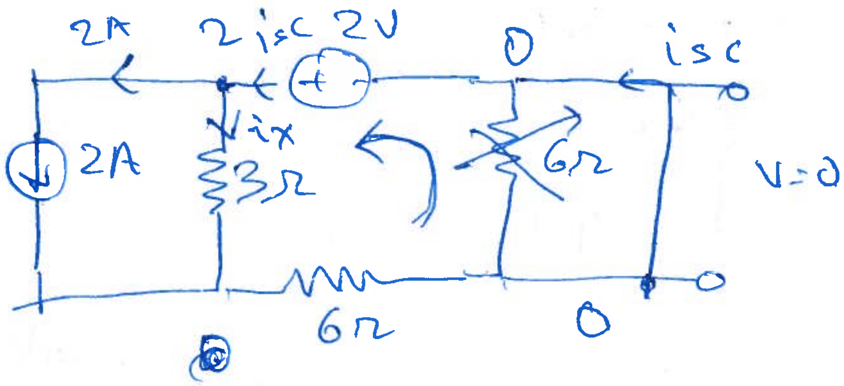
$12 I_1 - 3(-2 - I_1) = -2$

$15 I_1 = -8$

$I_1 = \frac{-8}{15}$

$V_{oc} = \cancel{6}\,2 \times \left(\frac{-8}{\cancel{15}\,5}\right) = -3.2V$

Step 2 (alternative) Short Circuit (V=0).



$$i_{sc} = 2 + i_x \quad (KCL)$$

$$i_x = (i_{sc} - 2)$$

$$(KVL) - \quad +2 - 3(i_{sc} - 2) - i_{sc}(6) = 0$$

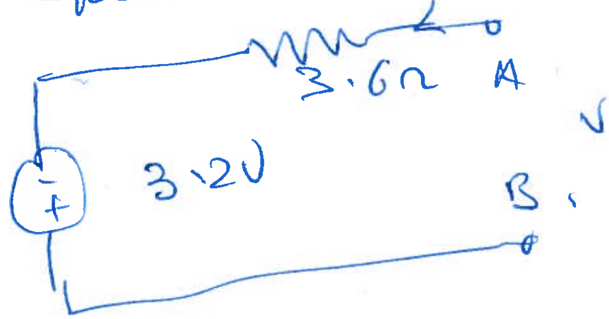
$$8 - 9I_{sc} = 0$$

$$I_{sc} = 8/9 \text{ A.}$$

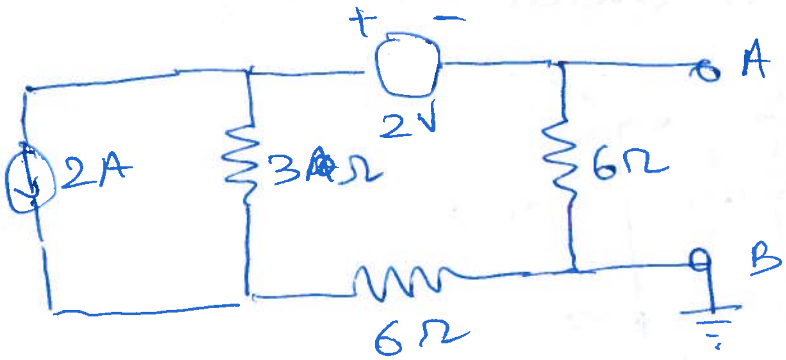
$$R_{eq} = -\frac{V_{oc}}{I_{sc}} = \frac{\cancel{8} \times 9^{3}}{\cancel{15} \times \cancel{8}_{5}}$$

$$= \frac{-1(+3\cdot2)V}{8} \times 9 = 3.6\,\Omega = R_{eq}$$

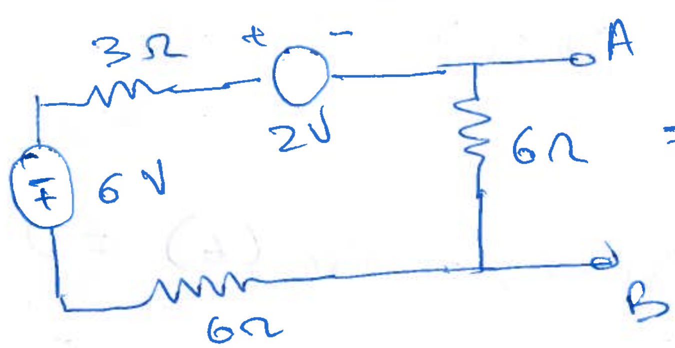
thevenin equivalent



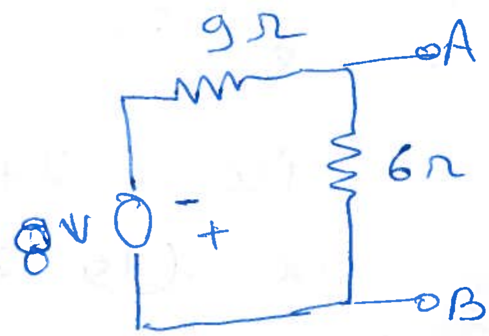
Alternative method (Rethink!)



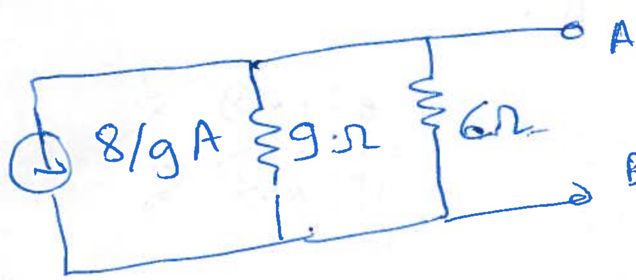
≡



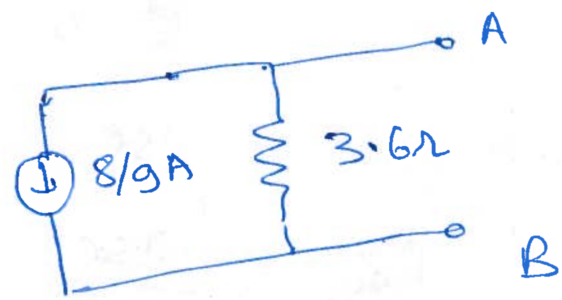
≡



≡



≡



≡