Circuit Theory & Analysis

Thevenin's Theorem

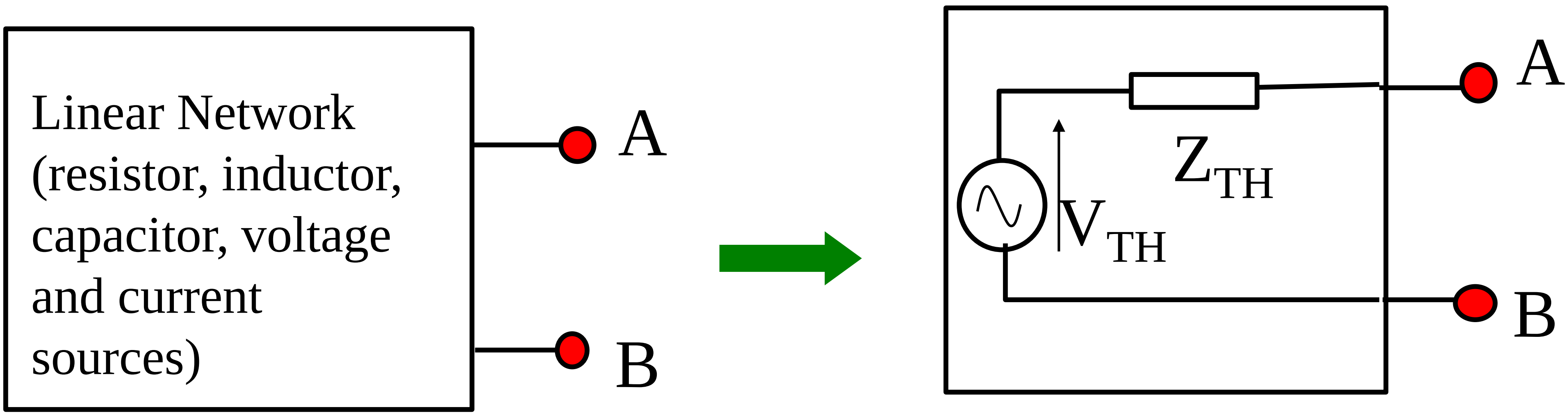
Objectives

- Understand the principles of Thevenin's and Norton's theorems.
- Apply Thevenin's and Norton's theorems to solve any given DC and AC circuits by finding their respective equivalent circuits.

Thevenin's Theorem

It states that any linear circuit between two points A and B can be replaced by an equivalent circuit consisting of a voltage source ***in series*** with a single impedance.

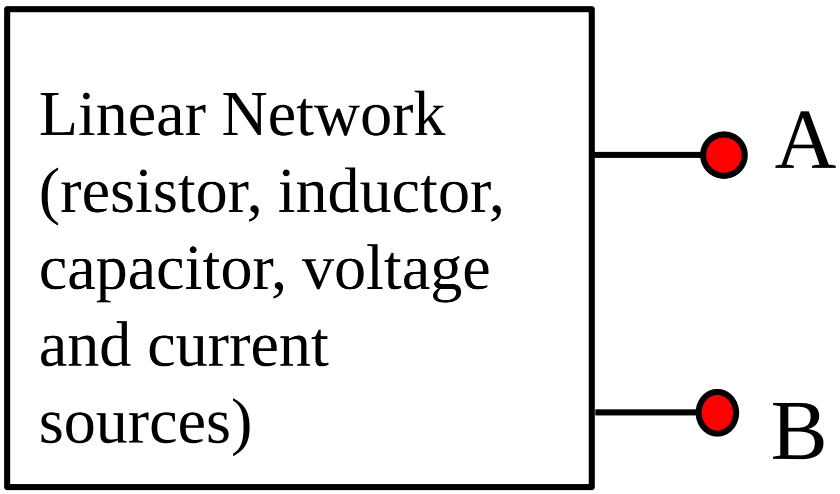
Thevenin's Theorem

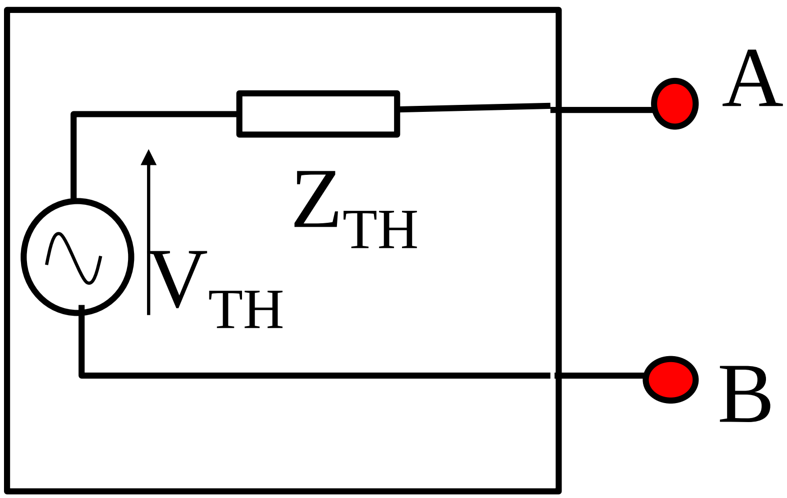


Thevenin's Equivalent Circuit

V_{TH} - Thevenin's voltage, equals to the open-circuit voltage across terminals A & B in the original linear network.

Thevenin's Theorem

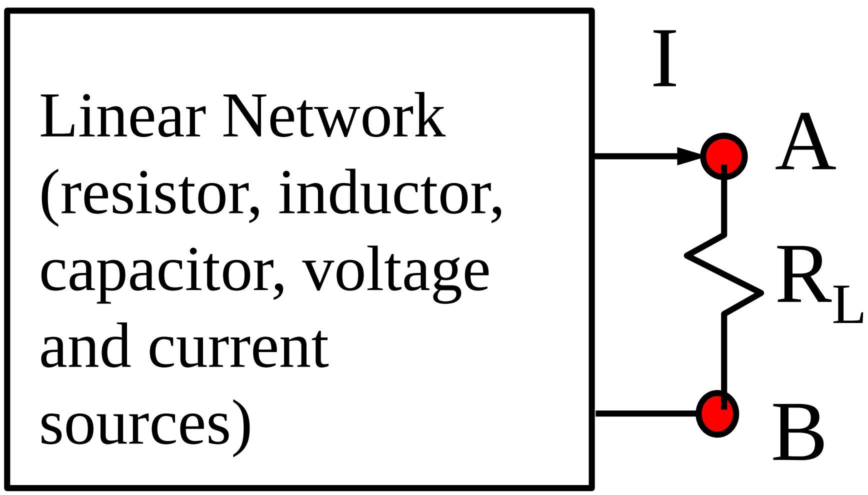




Thevenin's Equivalent Circuit

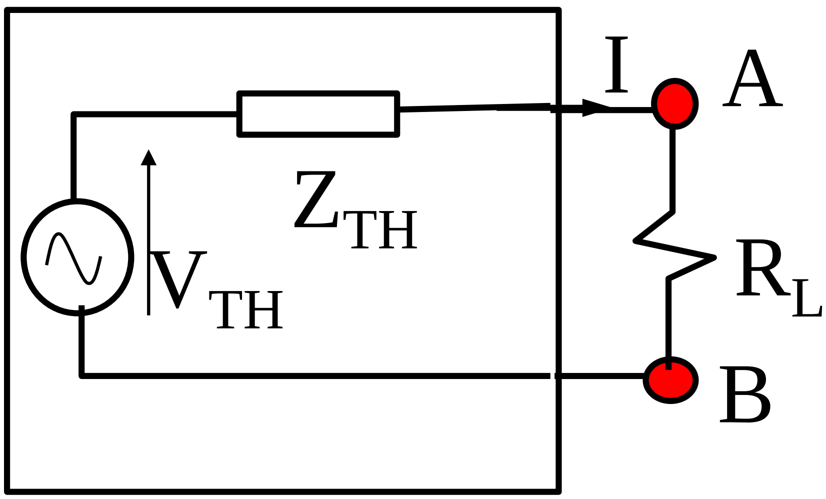
Z_{TH} - Thevenin's impedance, equals to the impedance across terminals A & B in the original linear network, with all the voltage and current sources reduced to zero.

Thevenin's Theorem



Let's put a load resistor R_L across AB in the original linear network. The current I flowing in R_L is found to be, say, 5 A.

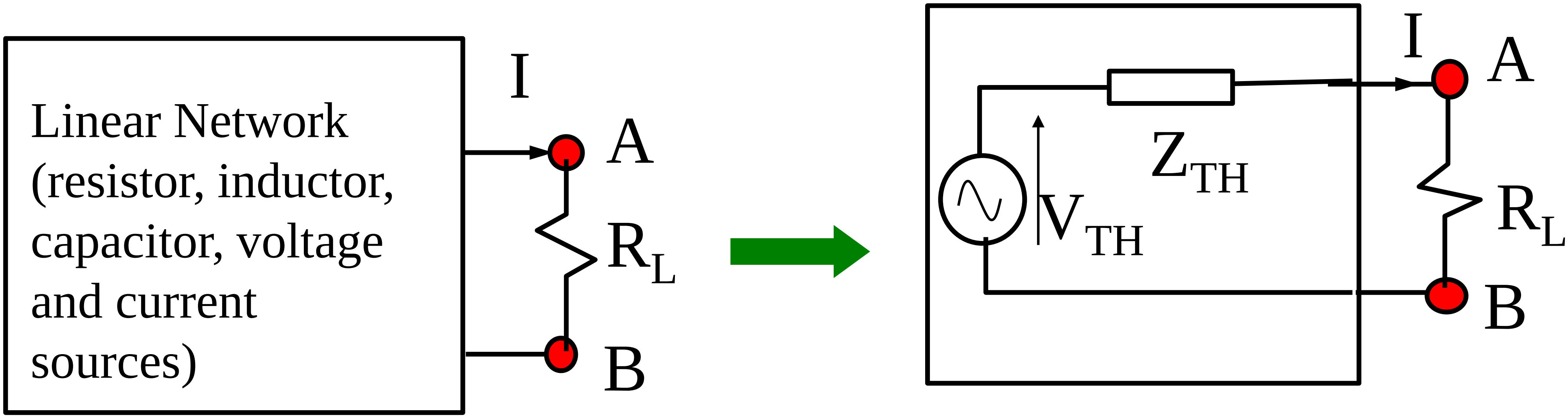
Thevenin's Theorem



Thevenin's Equivalent Circuit

After finding V_{TH}, Z_{TH} and obtained the Thevenin's circuit, the same resistor R_L is put across terminals A & B of the equivalent circuit. Same current I of 5 A will flow through R_L.

Thevenin's Theorem



Thevenin's Equivalent Circuit

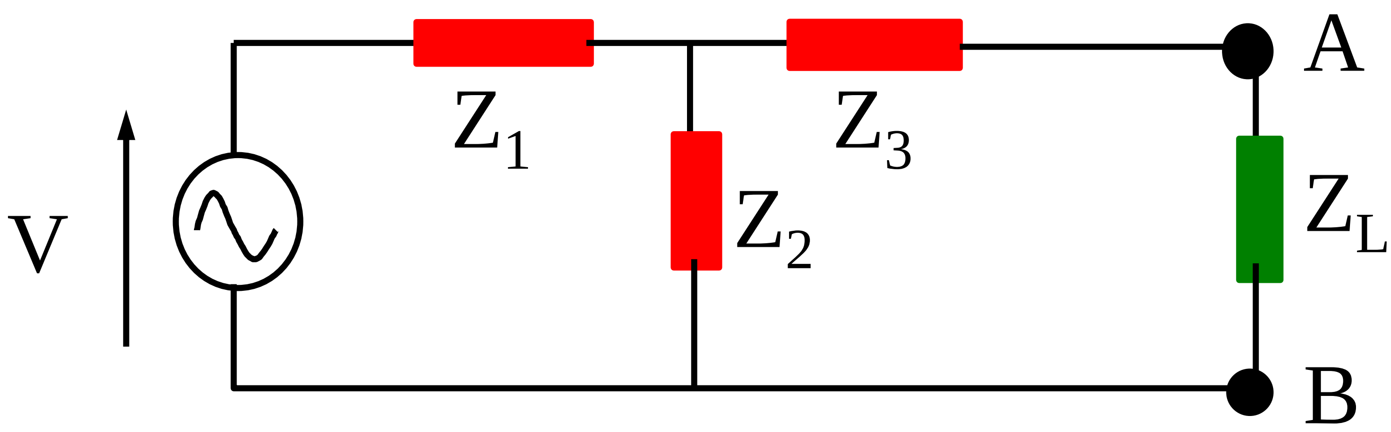
As far as the load R_L is concerned, the two circuits are equivalent.

Thevenin's Theorem

- ***Usage of the Theorem***
  - ☞ It is used for solving complicated circuit by replacing it with a simpler equivalent circuit.
  - ☞ It can be applied to both **DC** and **AC** circuits.
- ***Advantage:***

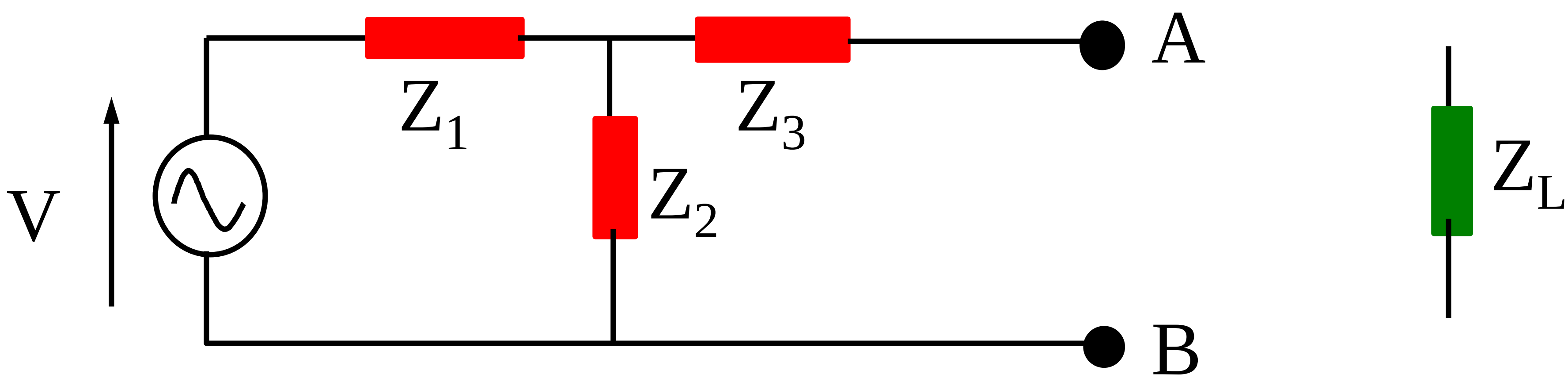
☞ The advantage of thevenin's method is that once the equivalent circuit is formed, it can be re-used for different load conditions, connected to the two terminals.

Thevenin's Theorem



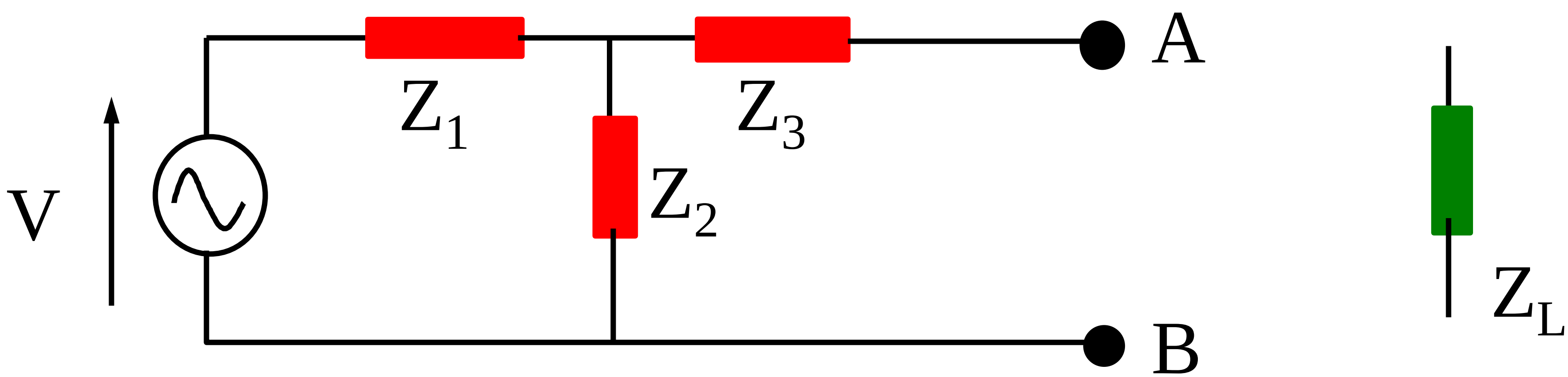
Given this original circuit, find the Thevenin's equivalent circuit across terminals A & B.

Procedure in applying Thevenin's Theorem



Step 1 - Disconnect the load Z_L from the circuit such that terminals A & B are now open-circuit.

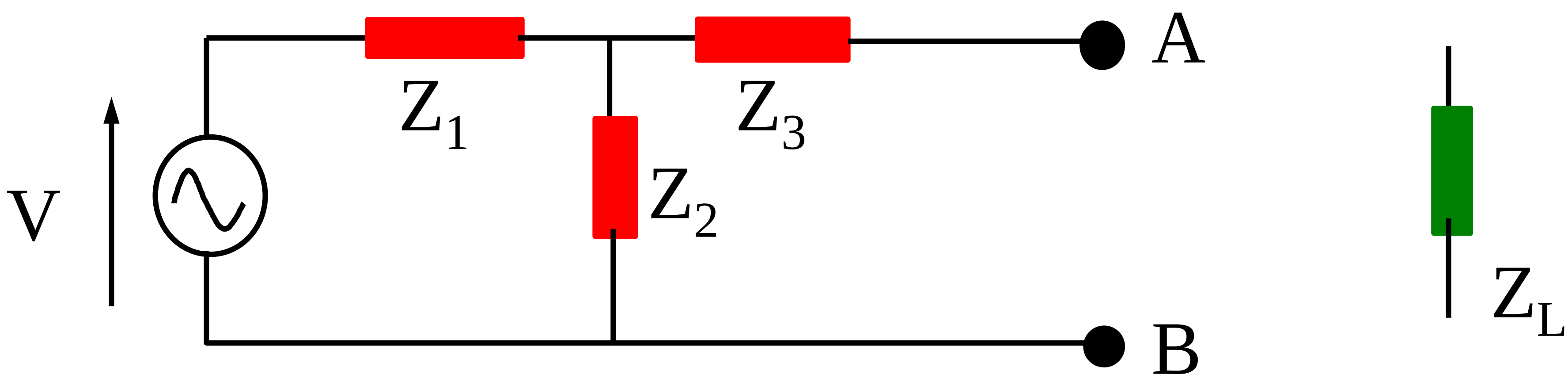
Procedure in applying Thevenin's Theorem



Step 2 - calculate (or measure, if you are doing an experiment) the open-circuit voltage across AB. This is then the V_{TH}.

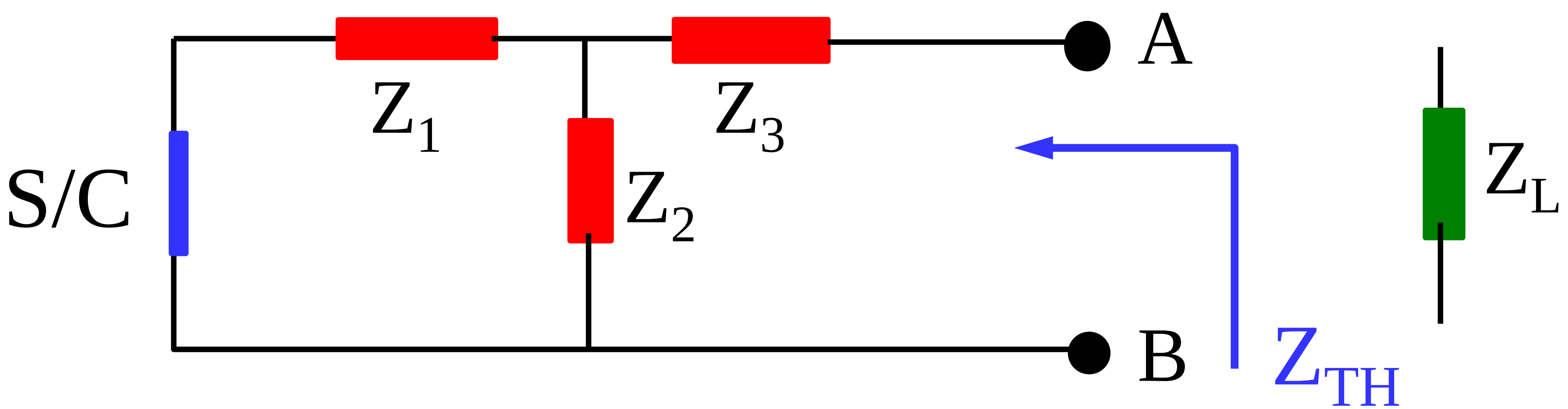
For computing you can only use either the application of Ohm’s Law or Mesh/Loop Analysis method.

Procedure in applying Thevenin's Theorem



In this example, $V_{TH} = V \times Z_2 / (Z_1 + Z_2)$

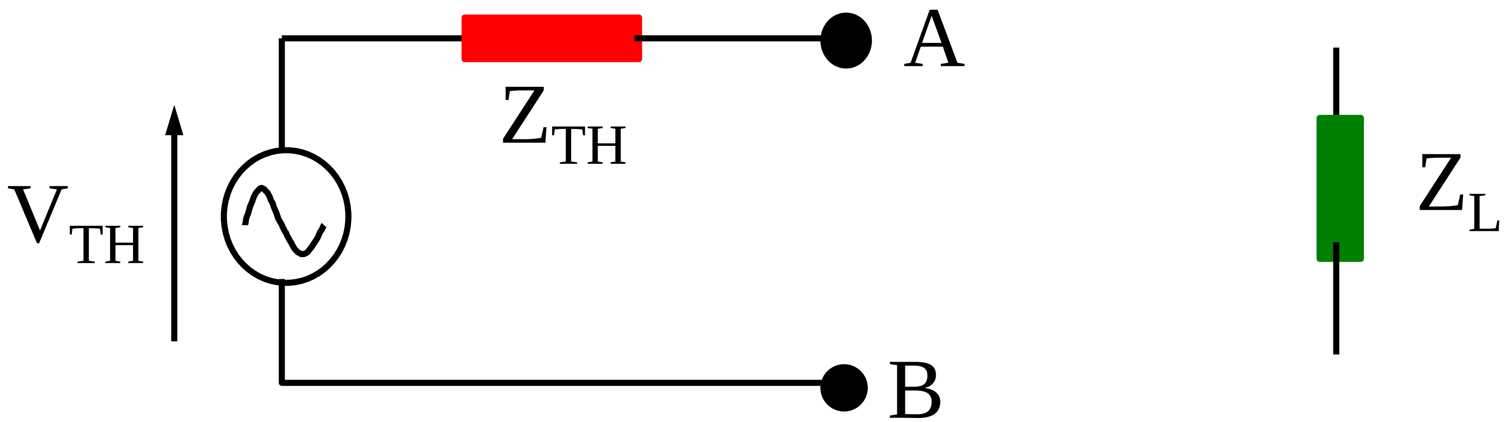
Procedure in applying Thevenin's Theorem



Step 3 - Replace the voltage source by a short circuit (current source by open circuit) and calculate the impedance across A & B by looking into the source free circuit. **This is the Z_{TH}.**

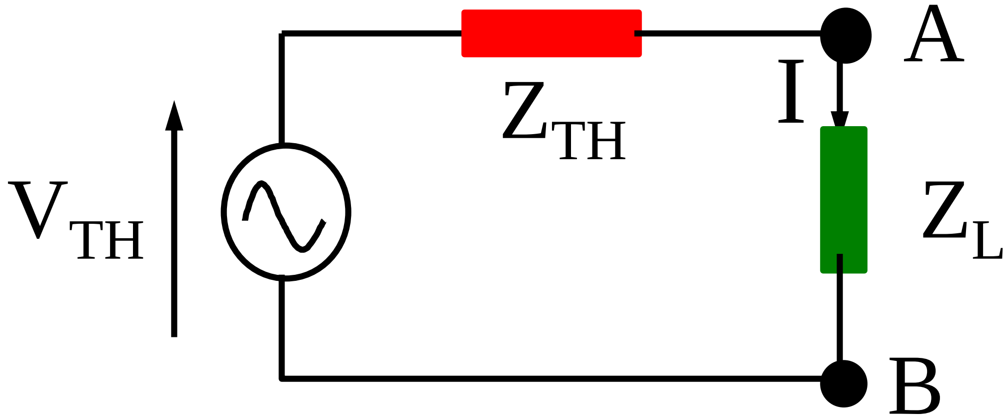
For this example, $Z_{TH} = (Z_1 // Z_2) + Z_3$

Procedure in applying Thevenin's Theorem



Step 4 - Knowing V_{TH} and Z_{TH}, the Thevenin's equivalent circuit can now be formed.

Procedure in applying Thevenin's Theorem



$I = V_{TH} / (Z_{TH} + Z_L)$

This value of I will have the same value when Z_L is connected in the original circuit.

If it is the current through Z_L you want to find, then Z_L should be reconnected across A & B.

Procedure in applying Thevenin's Theorem

NOTE:

Source Conversion is not allowed.

Example 1.9

Consider the network as shown below, find the Thevenin's equivalent circuit across terminals AB.

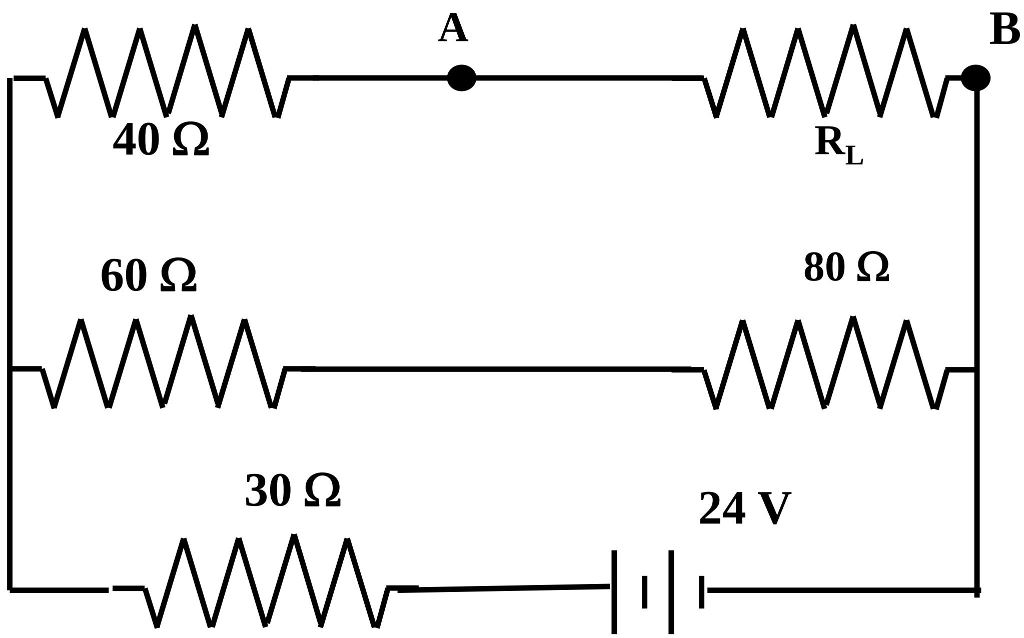
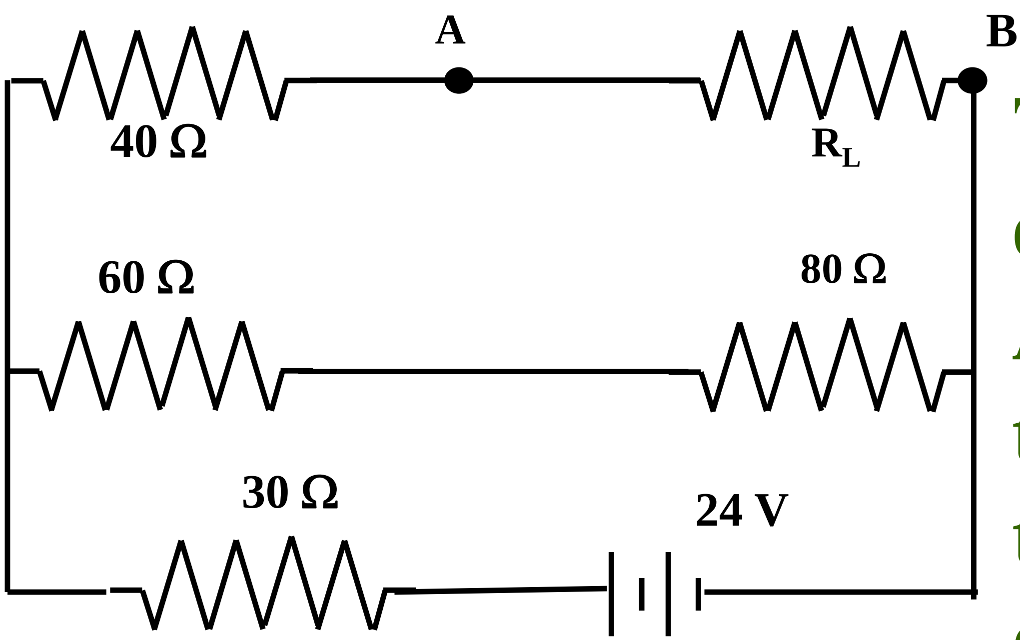


Figure 1.31

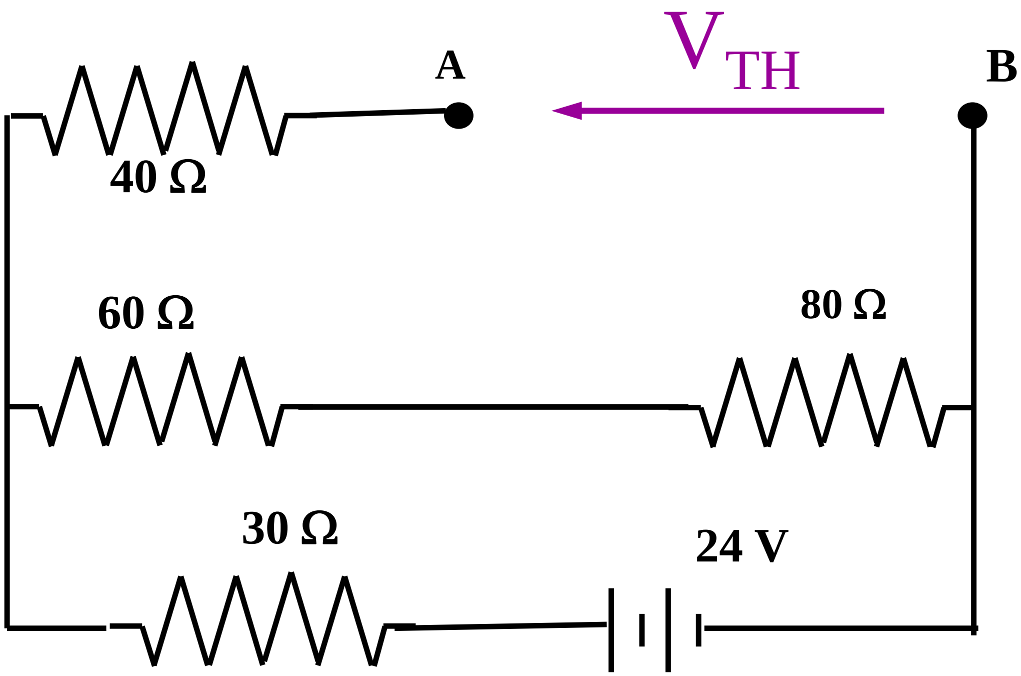
Example 1.9



To find the Thevenin's equivalent circuit across AB, the first thing to do is to remove R_L such that terminals A & B are now open-circuit.

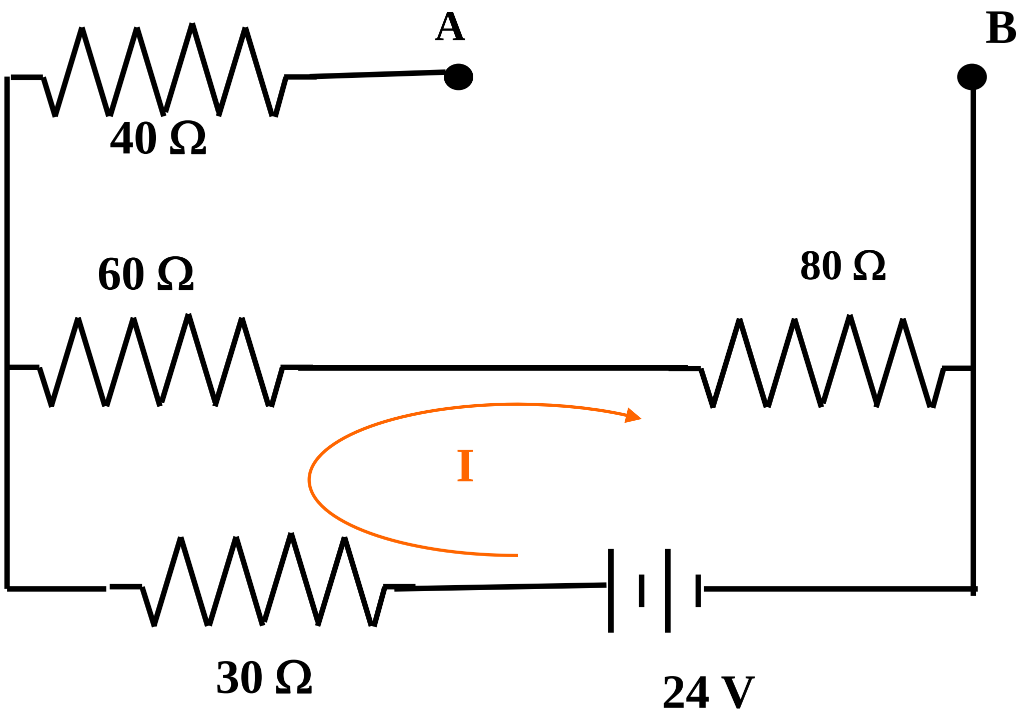
Example 1.9

The resultant circuit therefore becomes



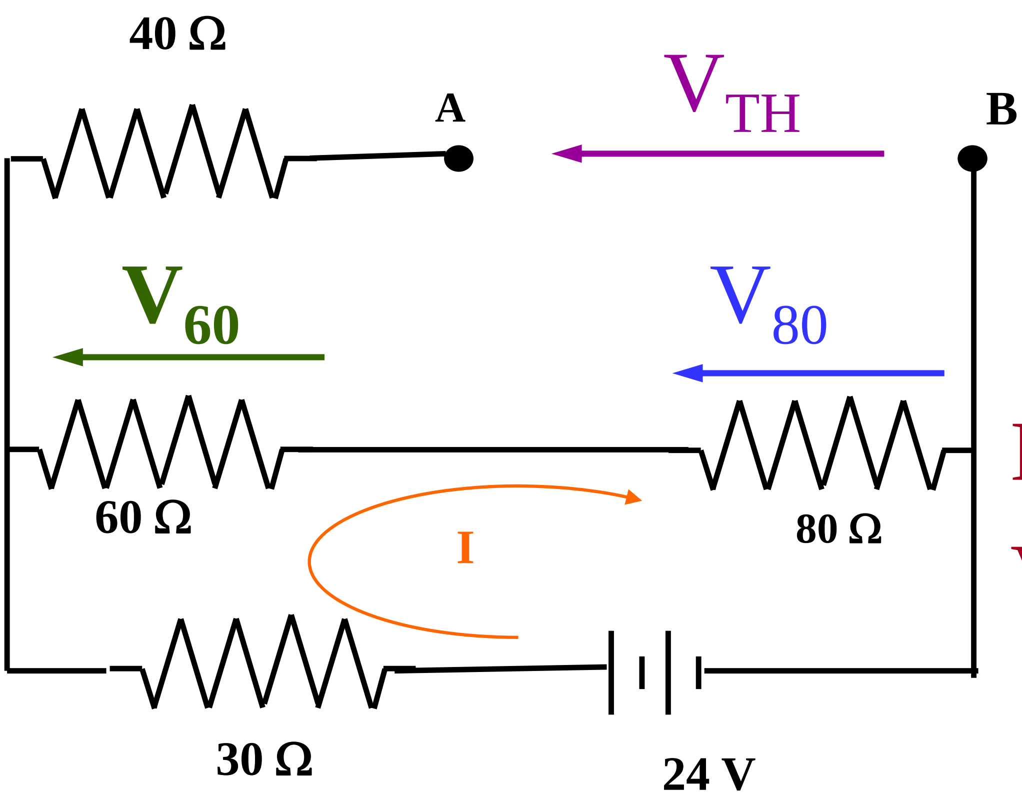
Next is to find the open-circuited voltage across terminals A & B (V_{AB}), and that is the V_{TH}.

Example 1.9



$$I = \frac{24}{30 + 60 + 80} = 0.141\,\text{A}$$

Example 1.9



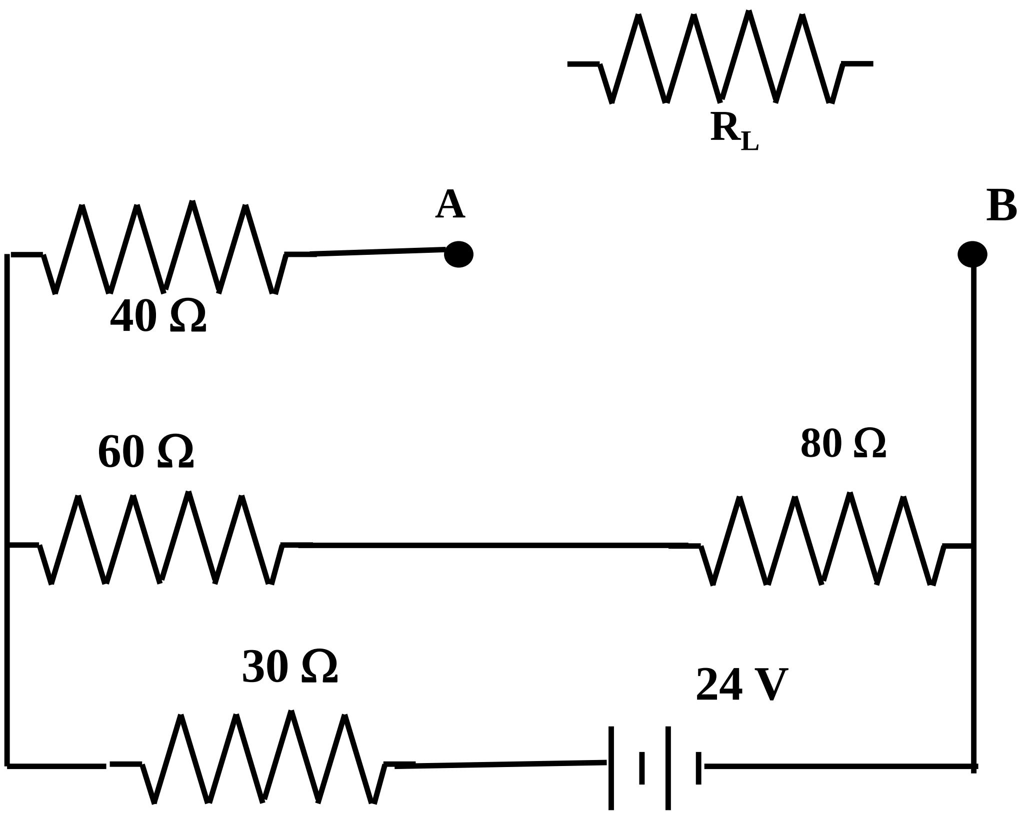
$$V_{60\Omega} = (0.141)\,60 = 8.47\text{ V}$$

$$V_{80\Omega} = (0.141)\,80 = 11.29\text{ V}$$

By KVL, $V_{AB} - V_{60} - V_{80} = 0$

$$V_{AB} = V_{60} + V_{80}$$
$$= 8.47 + 11.29$$
$$= 19.76\text{ V} = V_{TH}$$

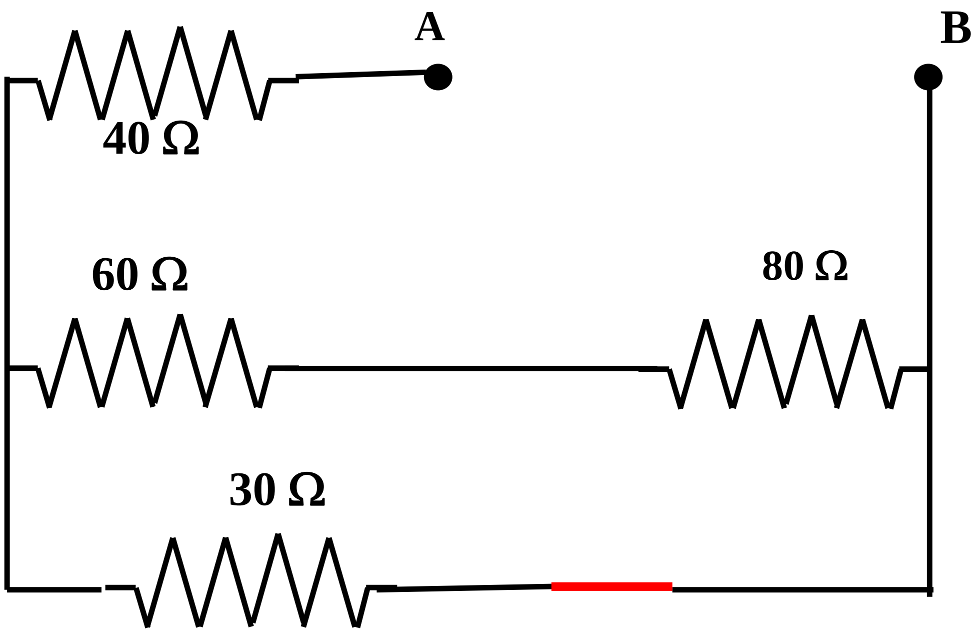
Example 1.9



To find the Thevenin's resistance across AB, first remove R_L such that terminals A & B are now open-circuit.

Example 1.9

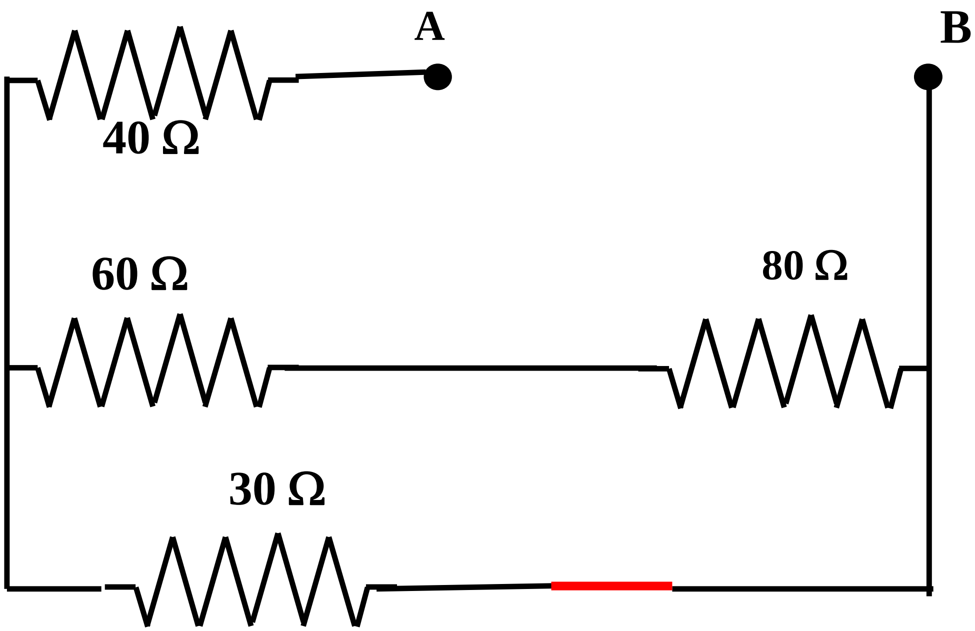
The resultant circuit therefore becomes



Next, replace the 24 V voltage source by a short circuit.

Then find the resistance across terminals A & B. That is the R_{TH}.

Example 1.9



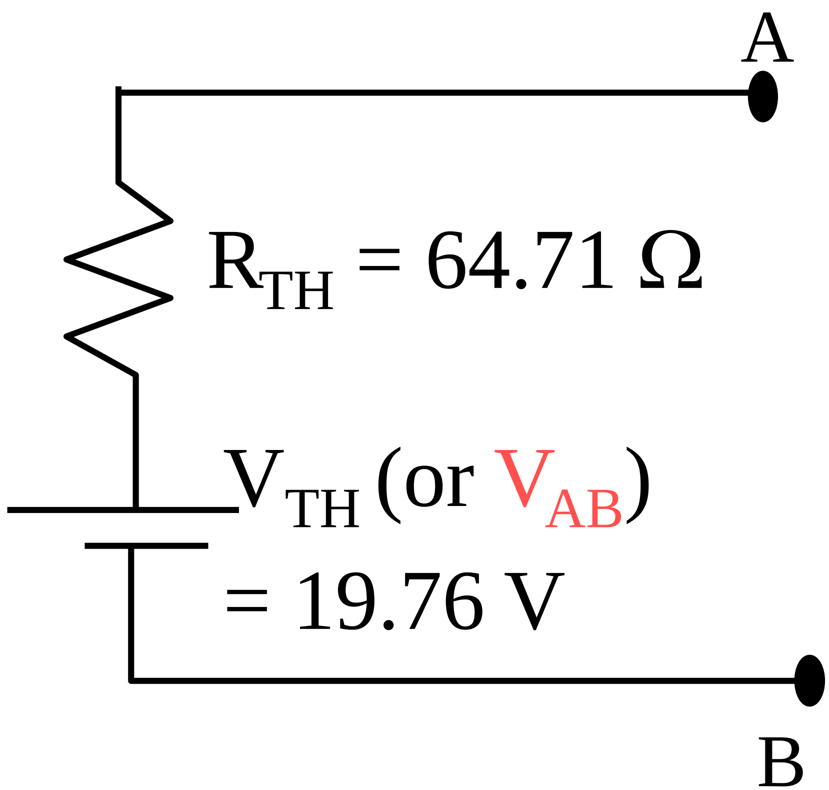
$$R_1 = 60 + 80 = 140\Omega$$

$$R_{//} = \frac{140 \times 30}{140 + 30} = 24.71\Omega$$

$$R_{AB} = 24.71 + 40 = 64.71\Omega = R_{TH}$$

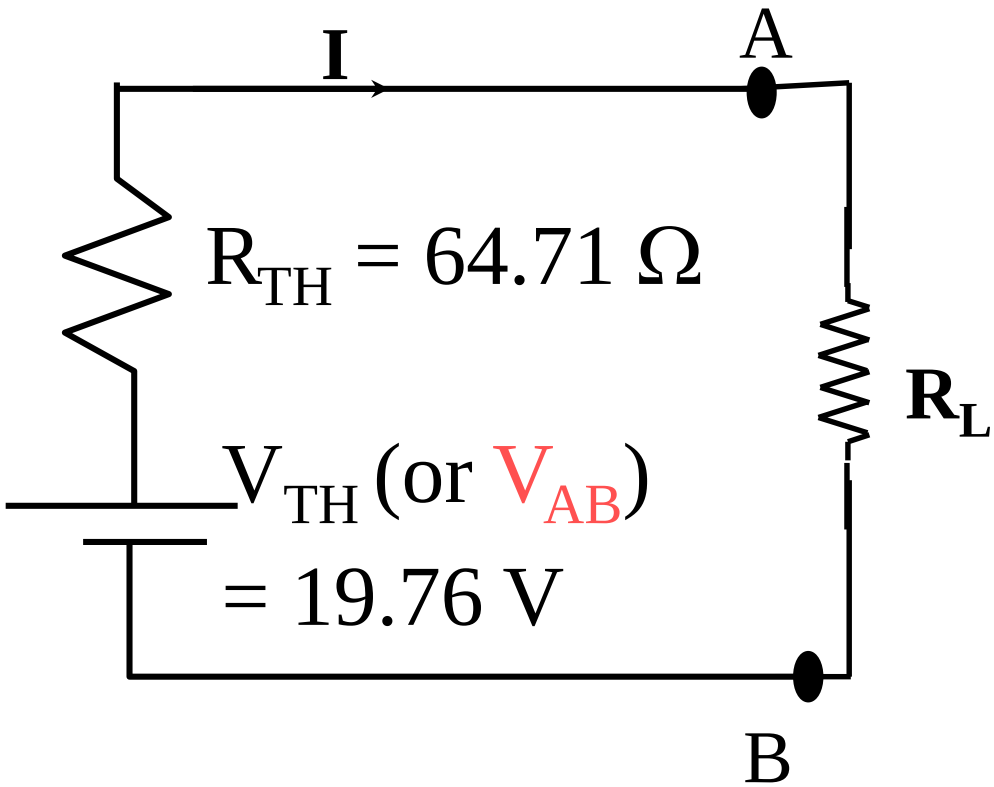
So V_{TH} (or V_{AB}) = 19.76 V and R_{TH} = 64.71 Ω, the Thevenin's equivalent circuit can now be drawn.

Example 1.9



Thevenin's equivalent circuit

Example 1.9

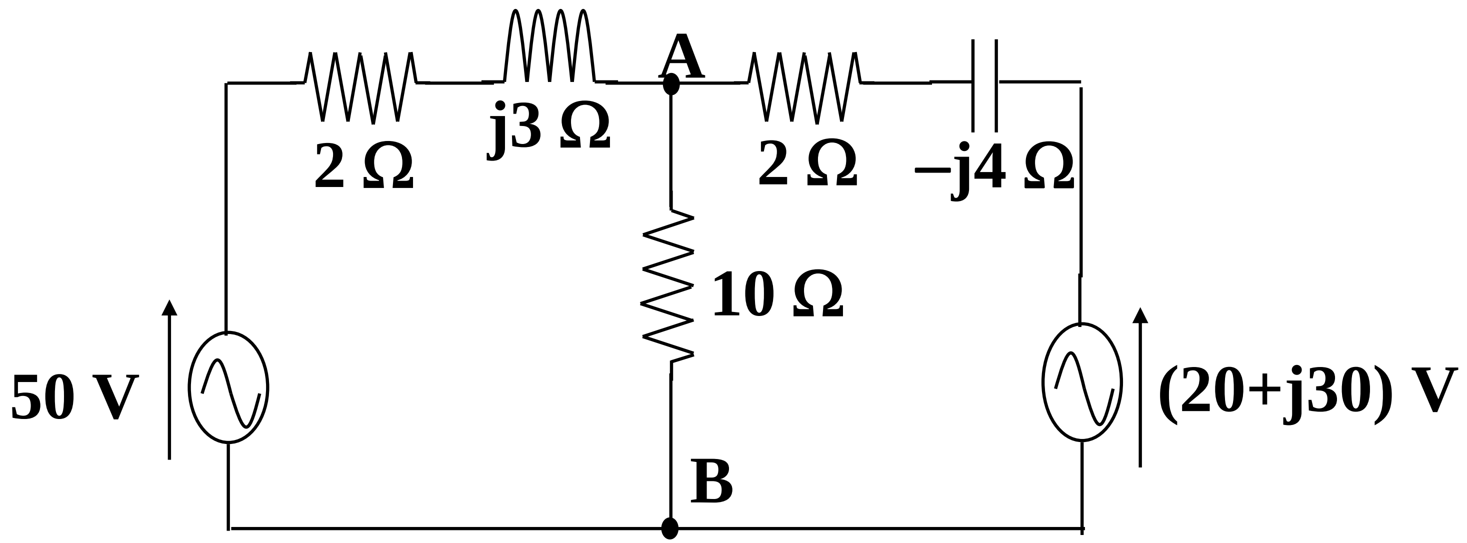


If it is necessary to find the current through the load resistor R_L in the original circuit, you can find the same current by connecting R_L across terminals A & B in this Thevenin's circuit.

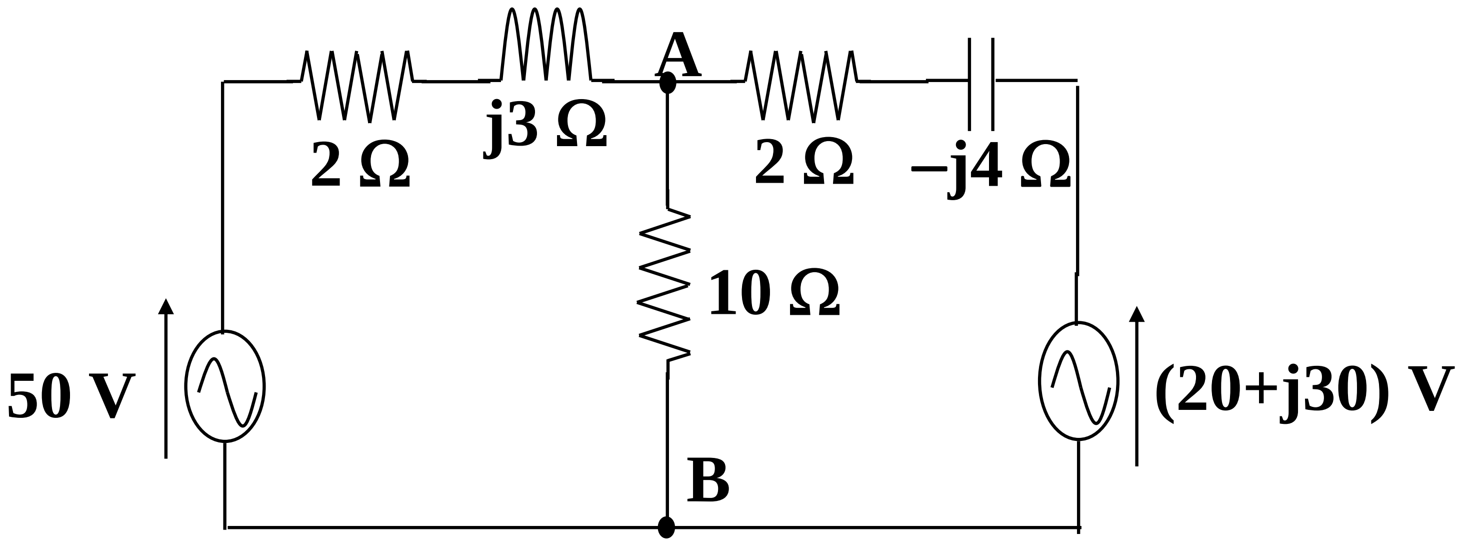
$$I = 19.76 / (64.71 + R_L) \quad A$$

Example 1.10

Apply Thevenin's theorem and calculate the current and the power dissipated in the 10 ohm resistor.

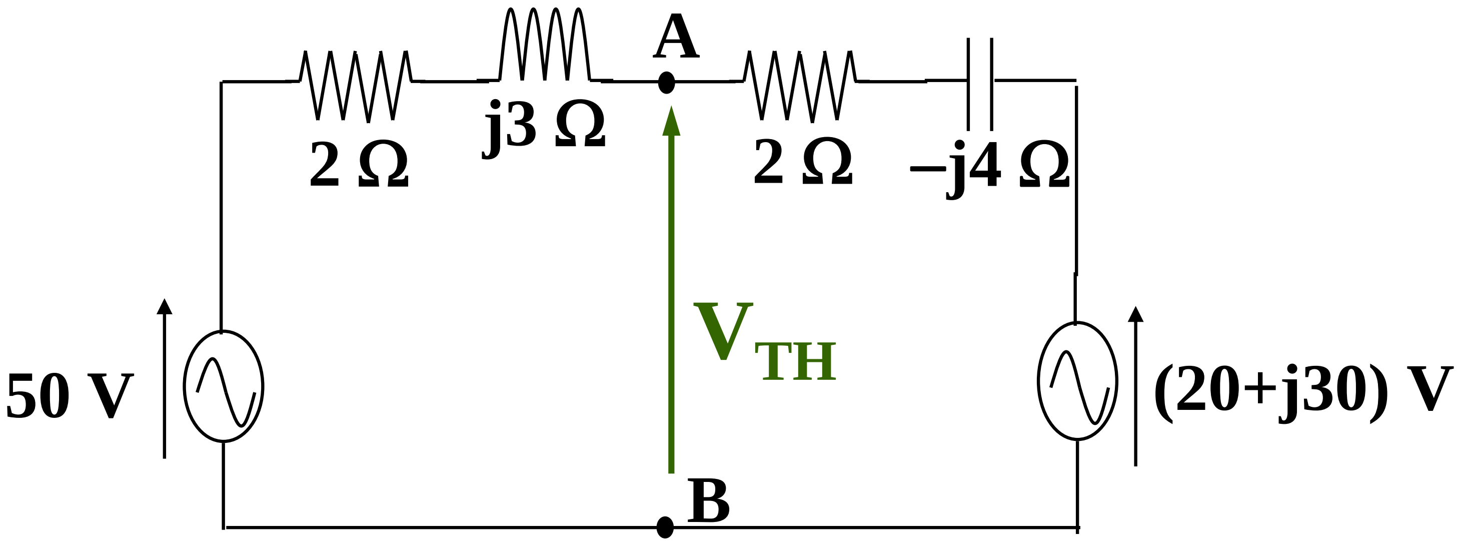


Example 1.10



To find the Thevenin's equivalent circuit across AB, remove R_L such that terminals A & B are now open-circuit.

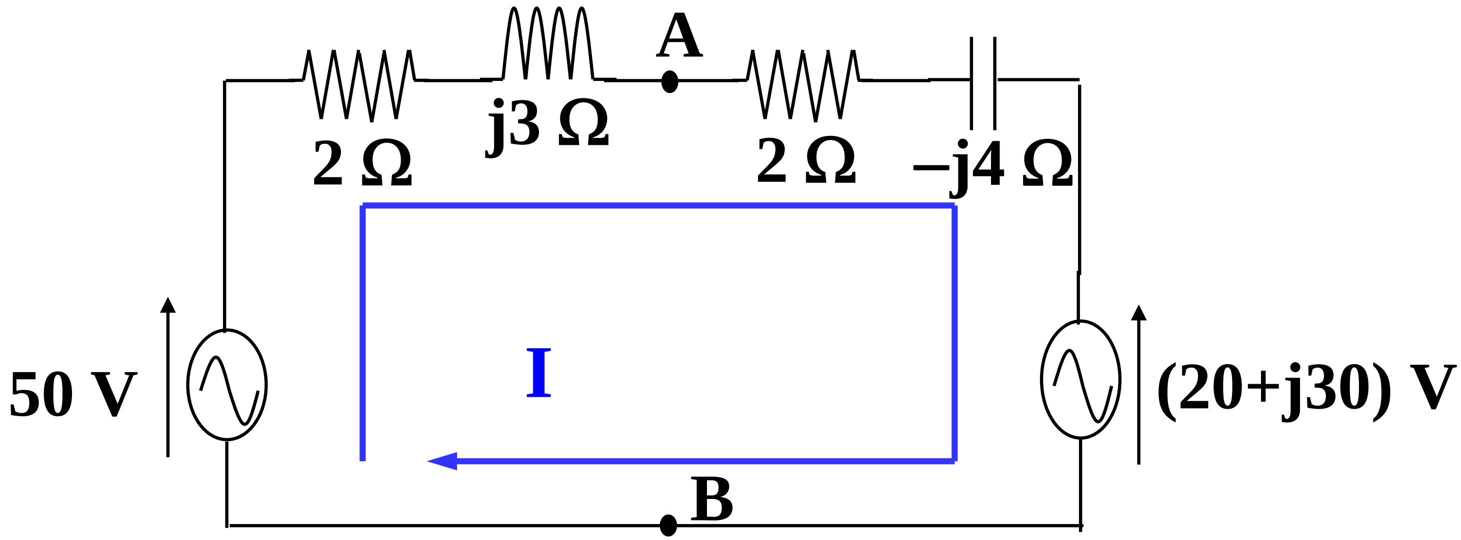
Example 1.10



The open circuit voltage across AB is the V_{TH}.

Example 1.10

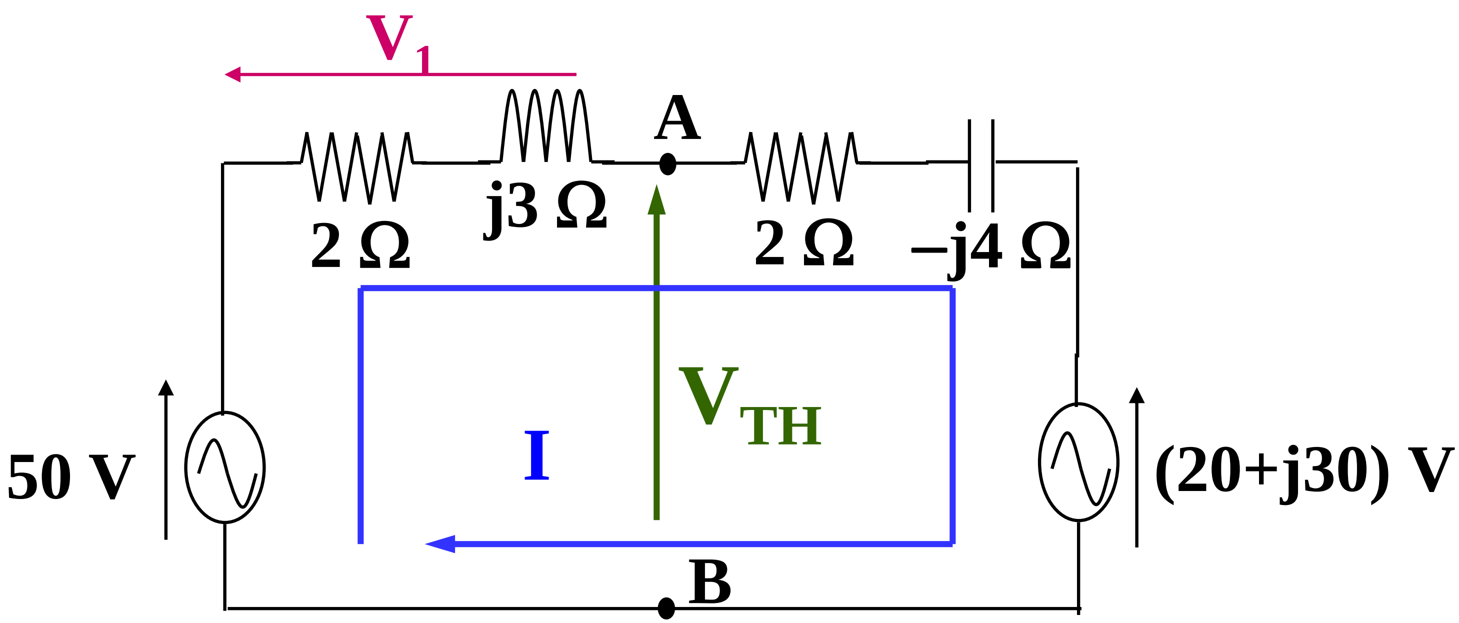
The open circuit voltage across AB = V_{TH}.



$$I = \frac{50-(20+j30)}{(2+j3)+(2-j4)} = 10.29\angle -30.96^\circ \text{ A}$$

Example 1.10

The open circuit voltage across AB = V_{TH}.

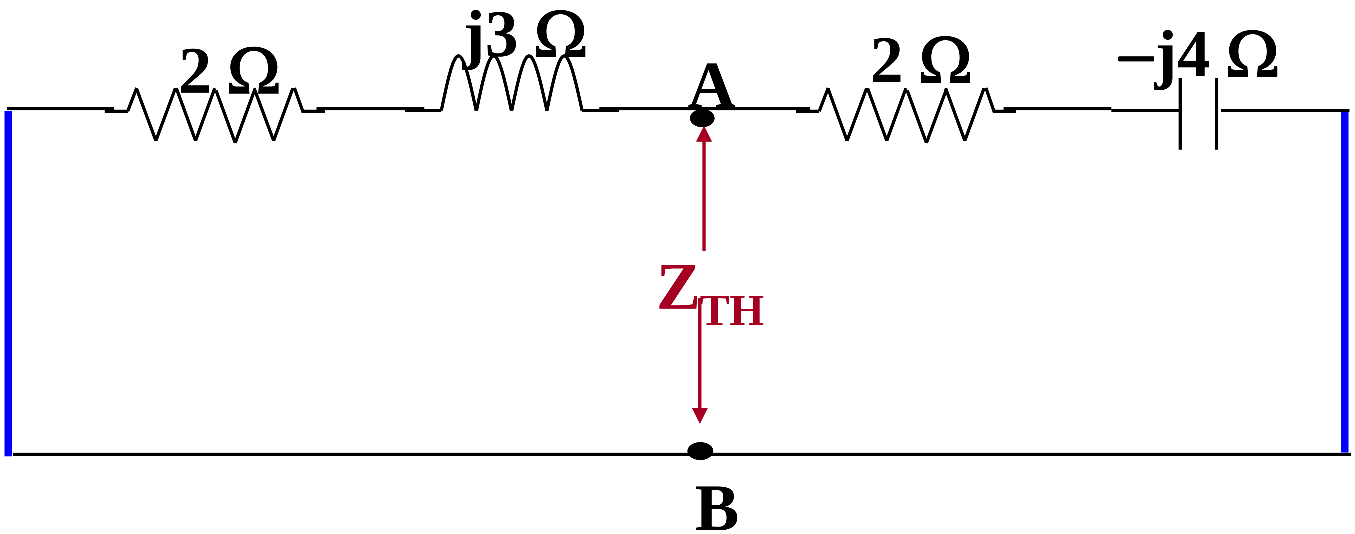


$$\therefore \quad V_{TH} + V_1 = 50$$

$$V_{TH} = 50 - (10.29\angle -30.96^\circ)(2 + j3)$$

$$= 22.88\angle -43.96^\circ \text{ V}$$

Example 1.10



Thevenin's equivalent impedance Z_{TH} is the impedance measured between A & B with all voltage sources replaced by short circuits and current sources by open circuits.

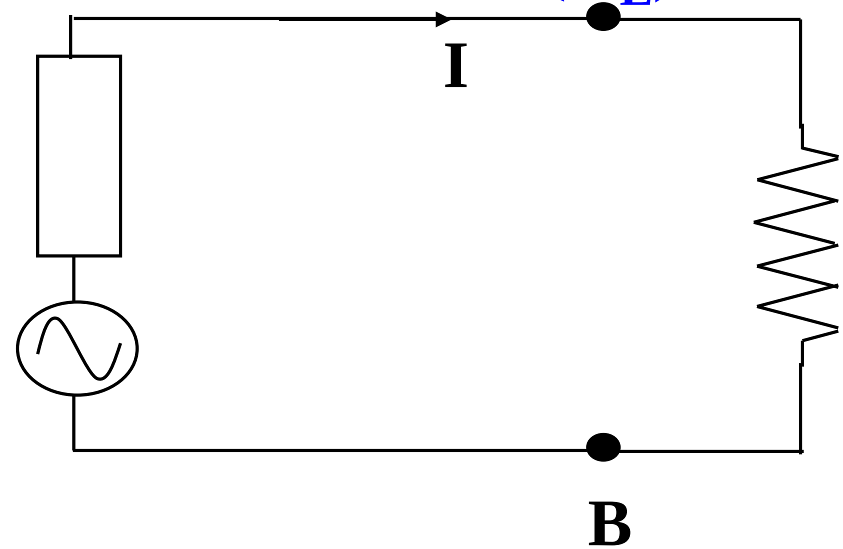
$$Z_{AB} = Z_{TH} = \frac{(2 + j3)(2 - j4)}{(2 + j3) + (2 - j4)} = (3.88 + j0.47)\,\Omega$$

Example 1.10

Thevenin's equivalent circuit with load (R_L)

Z_{TH} = 3.88+j 0.47 Ω

V_{TH} = 22.88∠–43.96° V



R_L = 10 Ω

$$\therefore\ I = \frac{V_{TH}}{Z_{TH} + R_L} = \frac{22.88\angle -43.96^\circ}{13.88 + j0.47} = 1.65\angle -46^\circ\ A$$

Power dissipated in the 10-ohm resistor: $P_{10\Omega} = I^2R_L$

$= 1.65^2 x10 = 27.23$ W

…next topic

Norton's Theorem

Nurturing Curious Minds, Producing Passionate Engineers

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