

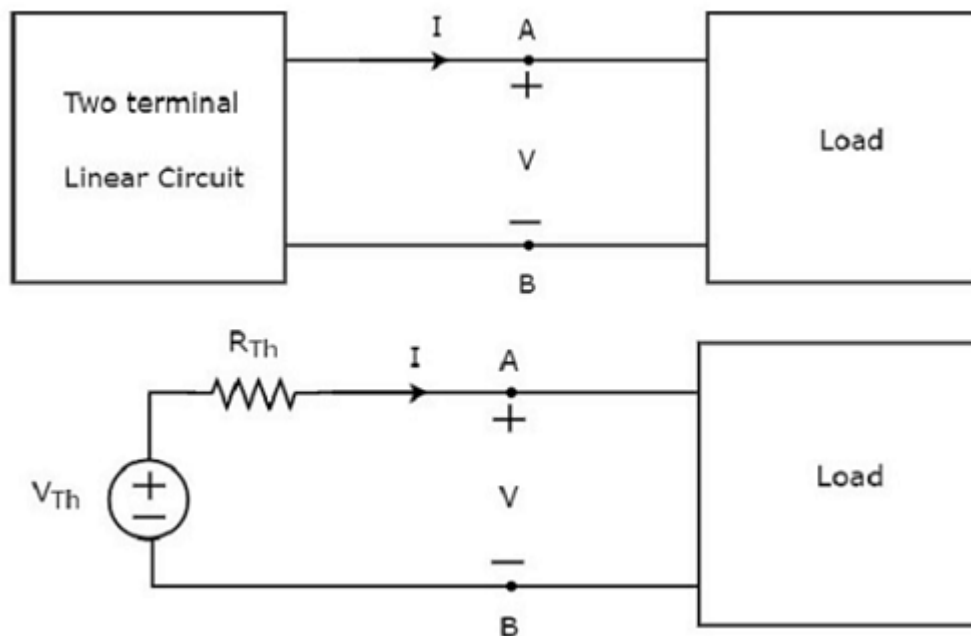
Network Theory - Thevenin's Theorem

Thevenin's theorem states that any two terminal linear network or circuit can be represented with an equivalent network or circuit, which consists of a voltage source in series with a resistor. It is known as Thevenin's equivalent circuit. A linear circuit may contain independent sources, dependent sources, and resistors.

If the circuit contains multiple independent sources, dependent sources, and resistors, then the response in an element can be easily found by replacing the entire network to the left of that element with a **Thevenin's equivalent circuit**.

The **response in an element** can be the voltage across that element, current flowing through that element, or power dissipated across that element.

This concept is illustrated in following figures.



Thevenin's equivalent circuit resembles a practical voltage source. Hence, it has a voltage source in series with a resistor.

- The voltage source present in the Thevenin's equivalent circuit is called as Thevenin's equivalent voltage or simply **Thevenin's voltage, V_{Th}** .
- The resistor present in the Thevenin's equivalent circuit is called as Thevenin's equivalent resistor or simply **Thevenin's resistor, R_{Th}** .

Methods of Finding Thevenin's Equivalent Circuit

There are three methods for finding a Thevenin's equivalent circuit. Based on the **type of sources** that are present in the network, we can choose one of these three methods. Now, let us discuss two methods one by one. We will discuss the third method in the next chapter.

Method 1

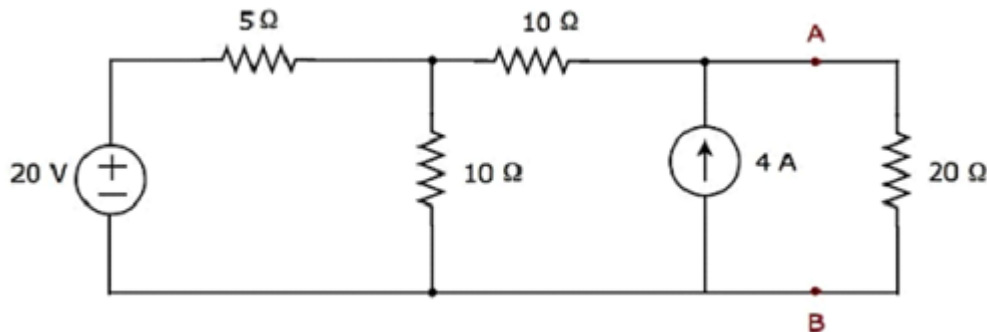
Follow these steps in order to find the Thevenin's equivalent circuit, when only the **sources of independent type** are present.

- **Step 1** – Consider the circuit diagram by opening the terminals with respect to which the Thevenin's equivalent circuit is to be found.
- **Step 2** – Find Thevenin's voltage V_{Th} across the open terminals of the above circuit.
- **Step 3** – Find Thevenin's resistance R_{Th} across the open terminals of the above circuit by eliminating the independent sources present in it.
- **Step 4** – Draw the **Thevenin's equivalent circuit** by connecting a Thevenin's voltage V_{Th} in series with a Thevenin's resistance R_{Th} .

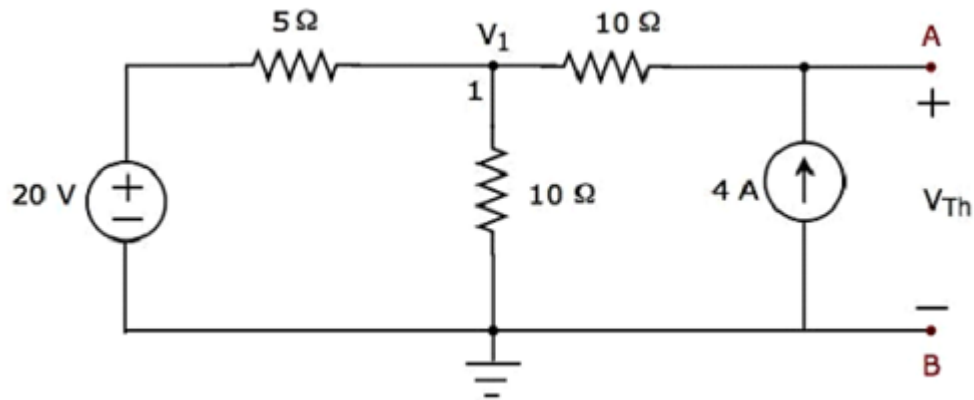
Now, we can find the response in an element that lies to the right side of Thevenin's equivalent circuit.

Example

Find the current flowing through $20\ \Omega$ resistor by first finding a **Thevenin's equivalent circuit** to the left of terminals A and B.



Step 1 – In order to find the Thevenin's equivalent circuit to the left side of terminals A & B, we should remove the $20\ \Omega$ resistor from the network by **opening the terminals A & B**. The modified circuit diagram is shown in the following figure.



Step 2 – Calculation of Thevenin's voltage V_{Th} .

There is only one principal node except Ground in the above circuit. So, we can use **nodal analysis** method. The node voltage V_1 and Thevenin's voltage V_{Th} are labelled in the above figure. Here, V_1 is the voltage from node 1 with respect to Ground and V_{Th} is the voltage across 4 A current source.

- The **nodal equation** at node 1 is

$$\frac{V_1 - 20}{5} + \frac{V_1}{10} - 4 = 0$$

$$\Rightarrow \frac{2V_1 - 40 + V_1 - 40}{10} = 0$$

$$\Rightarrow 3V_1 - 80 = 0$$

$$\Rightarrow V_1 = \frac{80}{3} V$$

- The voltage across series branch 10 Ω resistor is

$$V_{10\Omega} = (-4)(10) = -40V$$

- There are two meshes in the above circuit. The **KVL equation** around second mesh is

$$V_1 - V_{10\Omega} - V_{Th} = 0$$

- Substitute the values of V_1 and $V_{10\Omega}$ in the above equation.

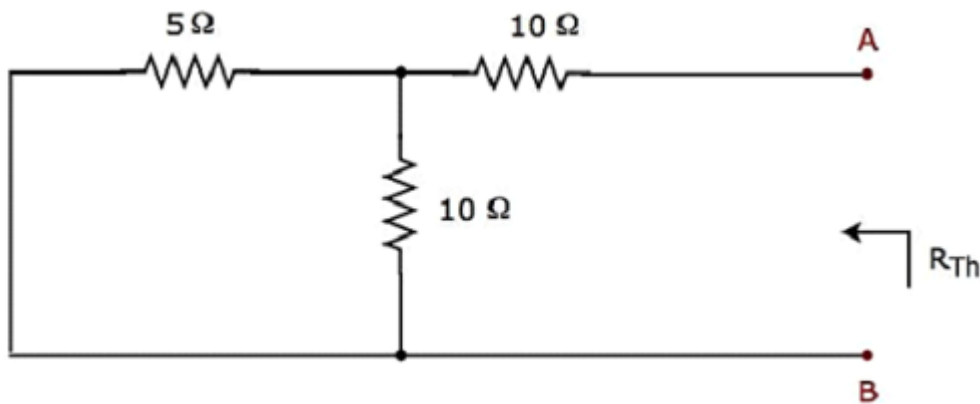
$$\frac{80}{3} - (-40) - V_{Th} = 0$$

$$V_{Th} = \frac{80 + 120}{3} = \frac{200}{3} V$$

- Therefore, the Thevenin's voltage is $V_{Th} = \frac{200}{3} V$

Step 3 – Calculation of Thevenin's resistance R_{Th} .

Short circuit the voltage source and open circuit the current source of the above circuit in order to calculate the Thevenin's resistance R_{Th} across the terminals A & B. The **modified circuit diagram** is shown in the following figure.

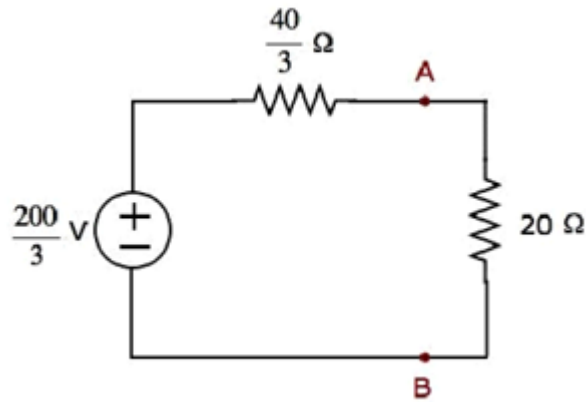


The Thevenin's resistance across terminals A & B will be

$$R_{Th} = \left(\frac{5 \times 10}{5 + 10} \right) + 10 = \frac{10}{3} + 10 = \frac{40}{3} \Omega$$

Therefore, the Thevenin's resistance is $R_{Th} = \frac{40}{3} \Omega$.

Step 4 – The Thevenin's equivalent circuit is placed to the left of terminals A & B in the given circuit. This circuit diagram is shown in the following figure.



The current flowing through the 20Ω resistor can be found by substituting the values of V_{Th} , R_{Th} and R in the following equation.

$$I = \frac{V_{Th}}{R_{Th} + R}$$

$$I = \frac{\frac{200}{3}}{\frac{40}{3} + 20} = \frac{200}{100} = 2 \text{ A}$$

Therefore, the current flowing through the 20Ω resistor is **2 A**.

Method 2

Follow these steps in order to find the Thevenin's equivalent circuit, when the **sources of both independent type and dependent type** are present.

- **Step 1** – Consider the circuit diagram by opening the terminals with respect to which, the Thevenin's equivalent circuit is to be found.
- **Step 2** – Find Thevenin's voltage V_{Th} across the open terminals of the above circuit.
- **Step 3** – Find the short circuit current I_{SC} by shorting the two opened terminals of the above circuit.
- **Step 4** – Find Thevenin's resistance R_{Th} by using the following formula.

$$R_{Th} = \frac{V_{Th}}{I_{SC}}$$

Step 5 – Draw the **Thevenin's equivalent circuit** by connecting a Thevenin's voltage V_{Th} in series with a Thevenin's resistance R_{Th} .

Now, we can find the response in an element that lies to the right side of the Thevenin's equivalent circuit.