SUBJECT: BASIC ELECTRONICS

Superposition Theorem

Elementrix Classes

Superposition Theorem

According to the **Superposition Theorem**, the response **(voltage or current)** at any point in a **linear electrical network** with multiple **independent sources** can be calculated by calculating the individual contributions of each source while assuming the other sources are **"turned off"** or replaced by their **internal resistances**.

Steps of Superposition Theorem

1. **Turn Off All but One Source:** Consider only one independent source (voltage or current source) active, while all other independent sources are turned off (replaced by their internal resistances, which are typically zero for ideal voltage sources and infinite for ideal current sources).

2. Analysis of the Circuit: With only one source active, analyze the circuit using circuit analysis techniques such as Ohm’s law, Kirchhoff’s law, and other relevant methods.

3. Calculation of the Response: Determine the voltage, current, or any other required parameters in the circuit due to the single active source.

4. Repeat for Each Source: Repeat steps 1 to 3 for each independent source in the circuit.

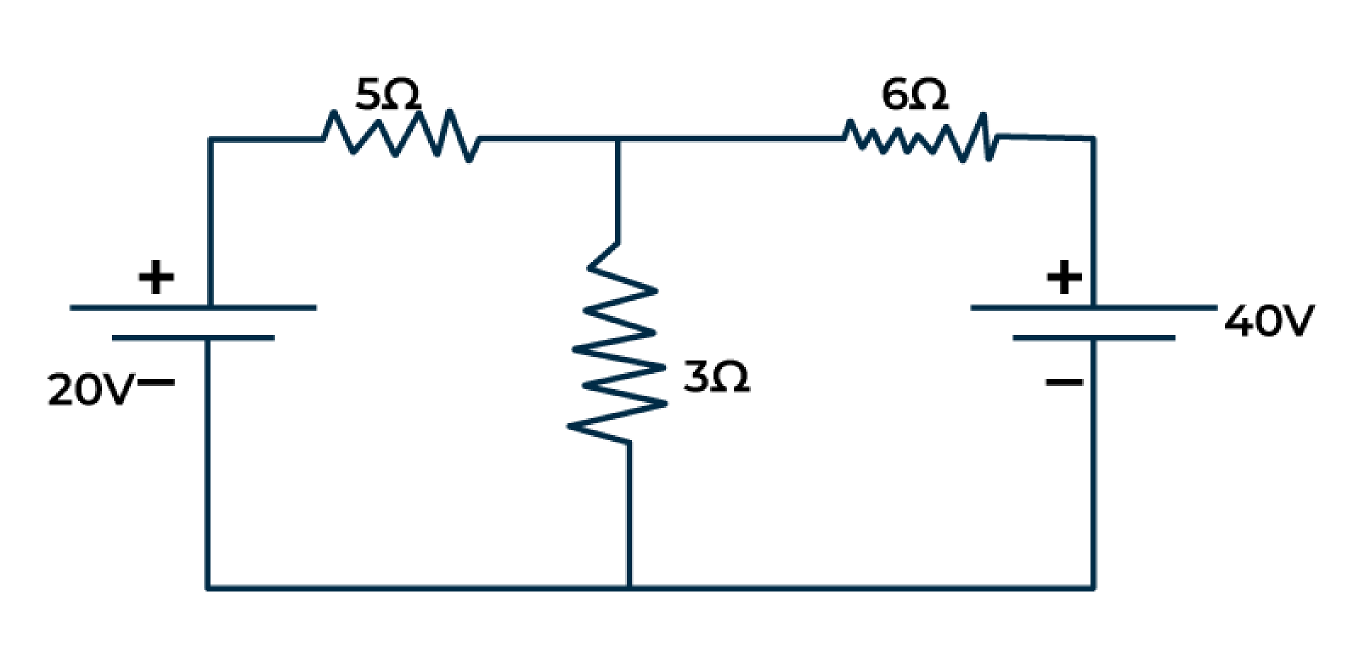
5. Combine Responses: After calculating the response for each individual source, you may determine the total response at the required by adding or superimposing the individual response from each source.

The **Superposition Theorem** only applies to **linear circuits** in which the relationship between voltage and current is constant and does not include nonlinear components such as diodes or transistors.

The Superposition Theorem can significantly simplify the analysis of complex circuits, especially when there are many independent sources. However, this theorem can be time-consuming for circuits with a large number of sources, as you need to perform separate calculations for each source. In such cases, other circuit analysis techniques like nodal analysis or mesh analysis might be more efficient.

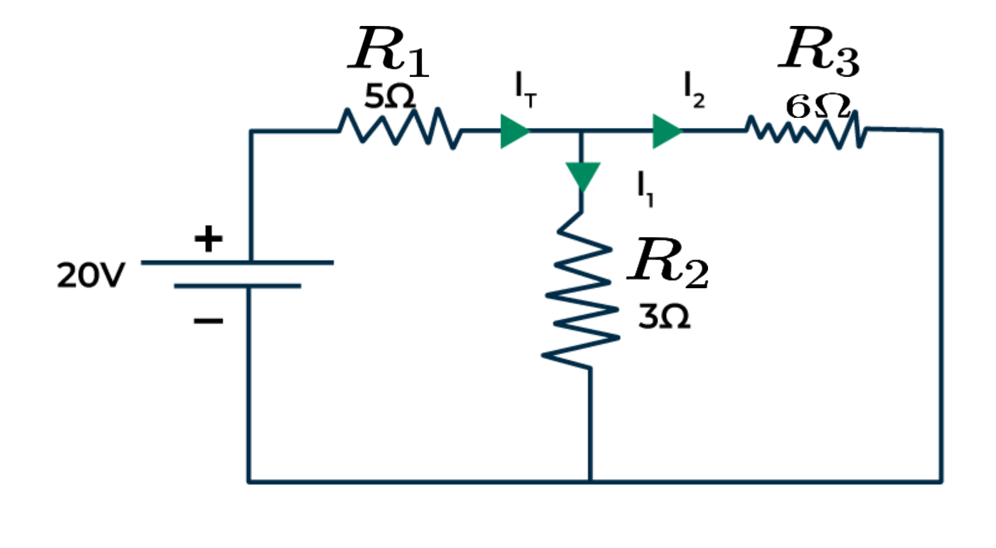
Example

Find the current through 3 Ω resistor using superposition theorem.



Answer: (i) To find I_1

Consider the 20 V voltage source alone. Short circuit the other voltage source.



To find the current through 3 Ω resistor, it is necessary to determine the total current supplied by the source (I_T).

If we observe the circuit, 3 Ω and 6 Ω resistors are in parallel with each other. This parallel combination is connected in series with a 5 Ω resistor. The equivalent or total resistance is obtained as below,

$$R_T = 5 + \frac{3 \times 6}{3 + 6} = 7\Omega \qquad \left(R_T = R_1 + \frac{R_2 . R_3}{R_2 + R_3} \right)$$

By applying Ohm's law,

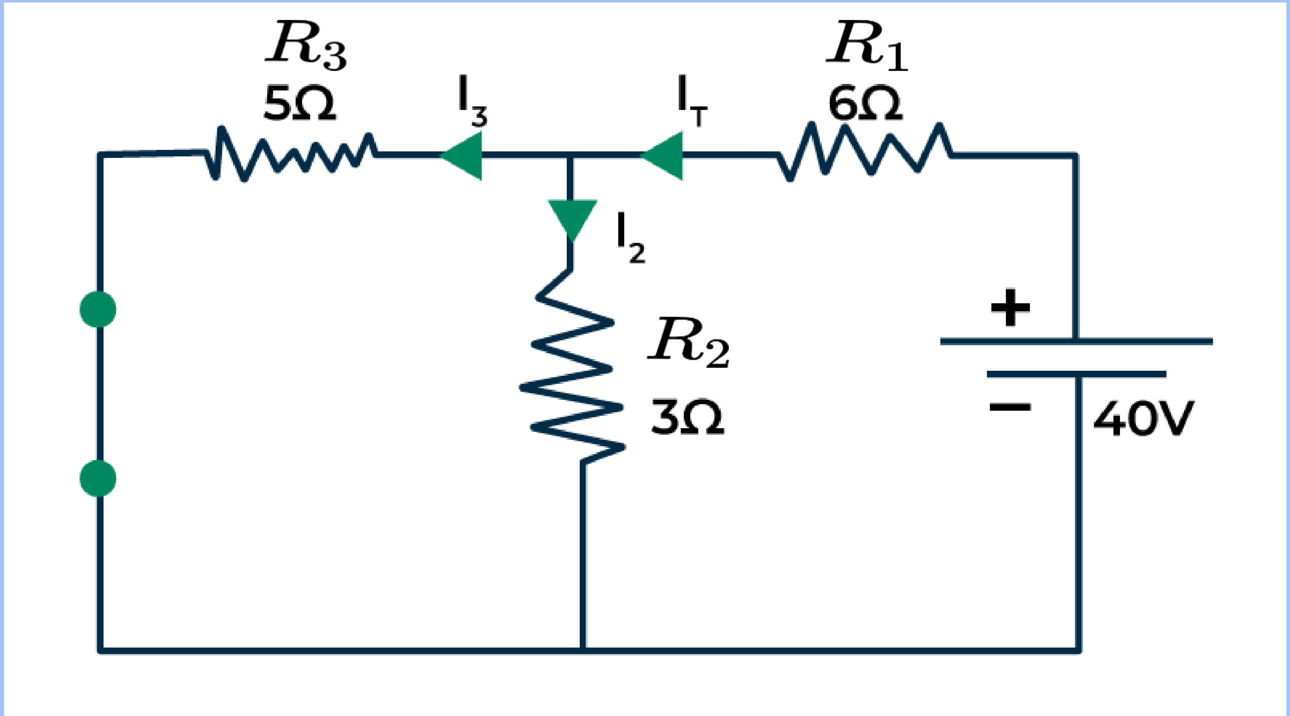
$$I_T = \frac{V}{R_T} = \frac{20}{7} = 2.857A$$

Now, the current through 3 Ω resistor is determined by using current divider rule. It is given by,

$$I_1 = 2.857A \times \left(\frac{6}{6 + 3} \right) = 1.904A \qquad \left[I_1 = I_T \left(\frac{R_3}{R_3 + R_2} \right) \right]$$

(ii) To find I_2.

Consider the 40 V voltage source alone. Short circuit the other voltage source.



Now, to find the current through 3 Ω resistor, it is necessary to determine the total current supplied by the source (I_T).

If we observe the circuit, 3 Ω and 5 Ω resistors are in parallel with each other. This parallel combination is connected in series with a 6 Ω resistor. Hence the equivalent or total resistance is obtained as below

$$R_T = 6 + \left(\frac{3 \times 5}{3 + 5}\right) = 7.875\Omega \qquad \left(R_T = R_1 + \frac{R_2 \times R_3}{R_2 + R_3}\right)$$

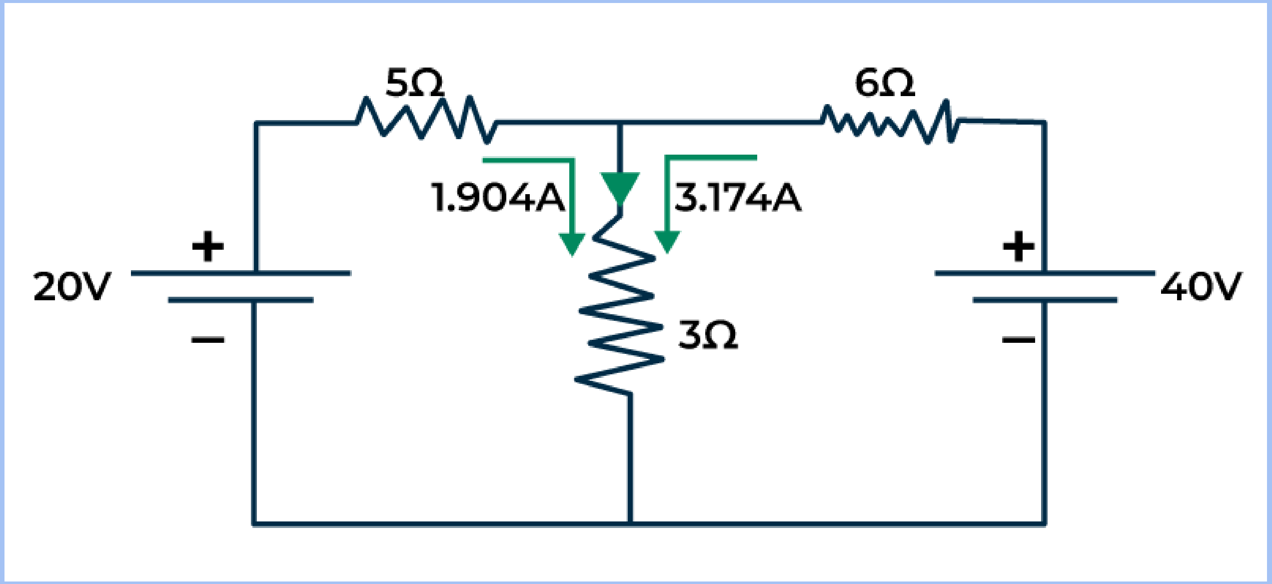
By applying Ohm's law,

$$I_T = \frac{V}{R_T} = \frac{40}{7.875} = 5.079A$$

Now, the current through 3 Ω resistor is determined by using current divider rule. It is given by,

$$I_2 = 5.079A \times \left(\frac{5}{5+3}\right) = 3.174A \qquad \left[I_2 = I_T\left(\frac{R_3}{R_3+R_2}\right)\right]$$

The below figure shows the resultant circuit, which depicts the currents produced because of two voltage sources 20 V and 40 V acting individually.



By superposition theorem, the total current is determined by adding the individual currents produced by 20 V and 40 V.

Therefore, the current through 3 Ω resistor is = $\mathbf{I_1 + I_2 = 1.904 + 3.174 = 5.078\ A}$

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