# Basic Electrical Engineering
# KEE101

## Department of Engineering
## Uttar Pradesh Textile Technology Institute
## Session 2019-20
## Semester-II

# BASIC CIRCUIT ELEMENT

Two Basic quantities are to be addressed

**Voltage (V)** and **Current (I)**

**Current**: Actual flow of charge

**Voltage**: Potential difference which cause flow of current

# Network

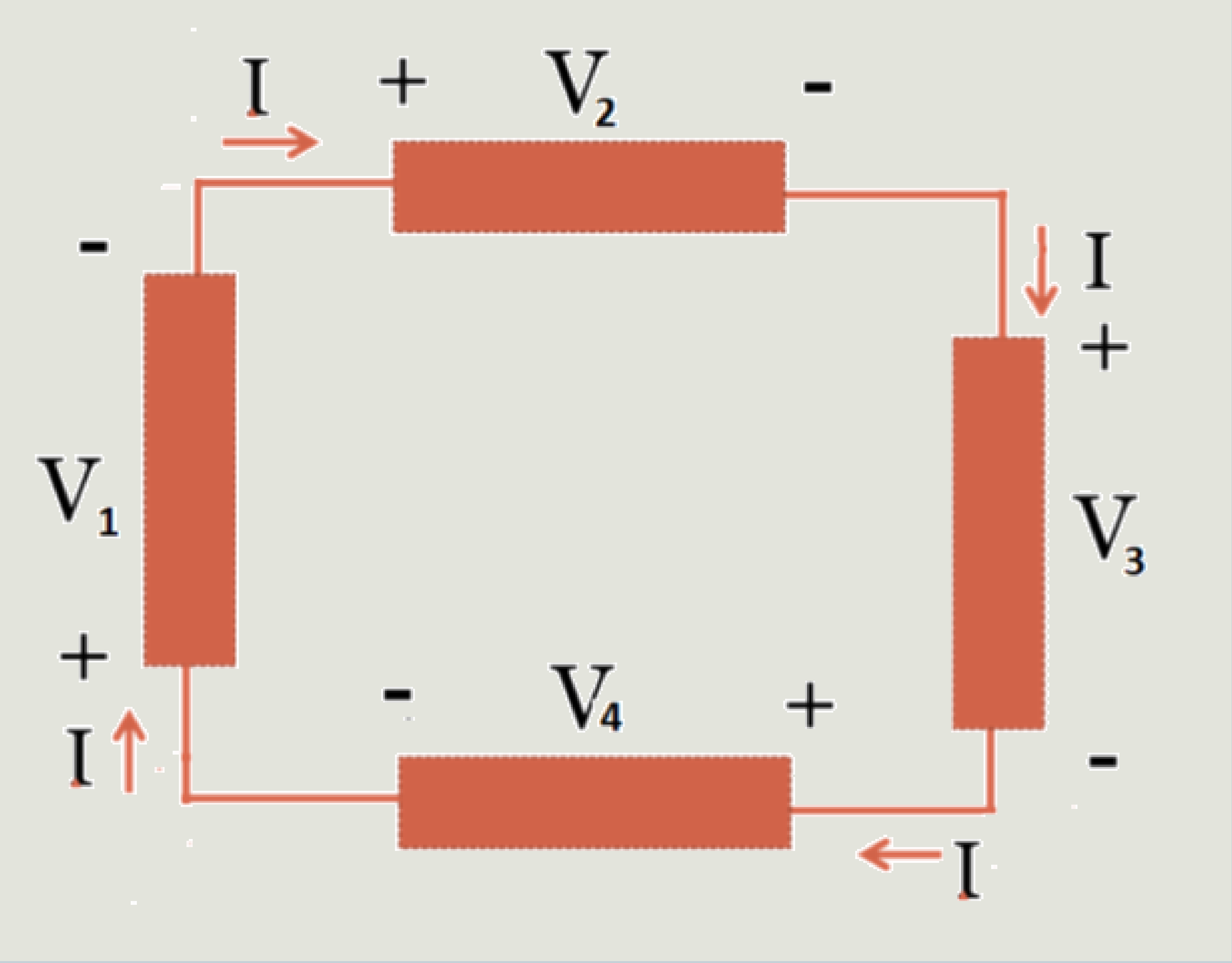

Branch:
The Element with its terminals is termed as a branch.

Network:
Network is interconnection of such branches connected together by wires.

# Basic Circuit Element

- Any closed path through two or more elements of the network in the network is a loop.
- Any non-trivial network will have at least one such loop.

# Understanding Loop

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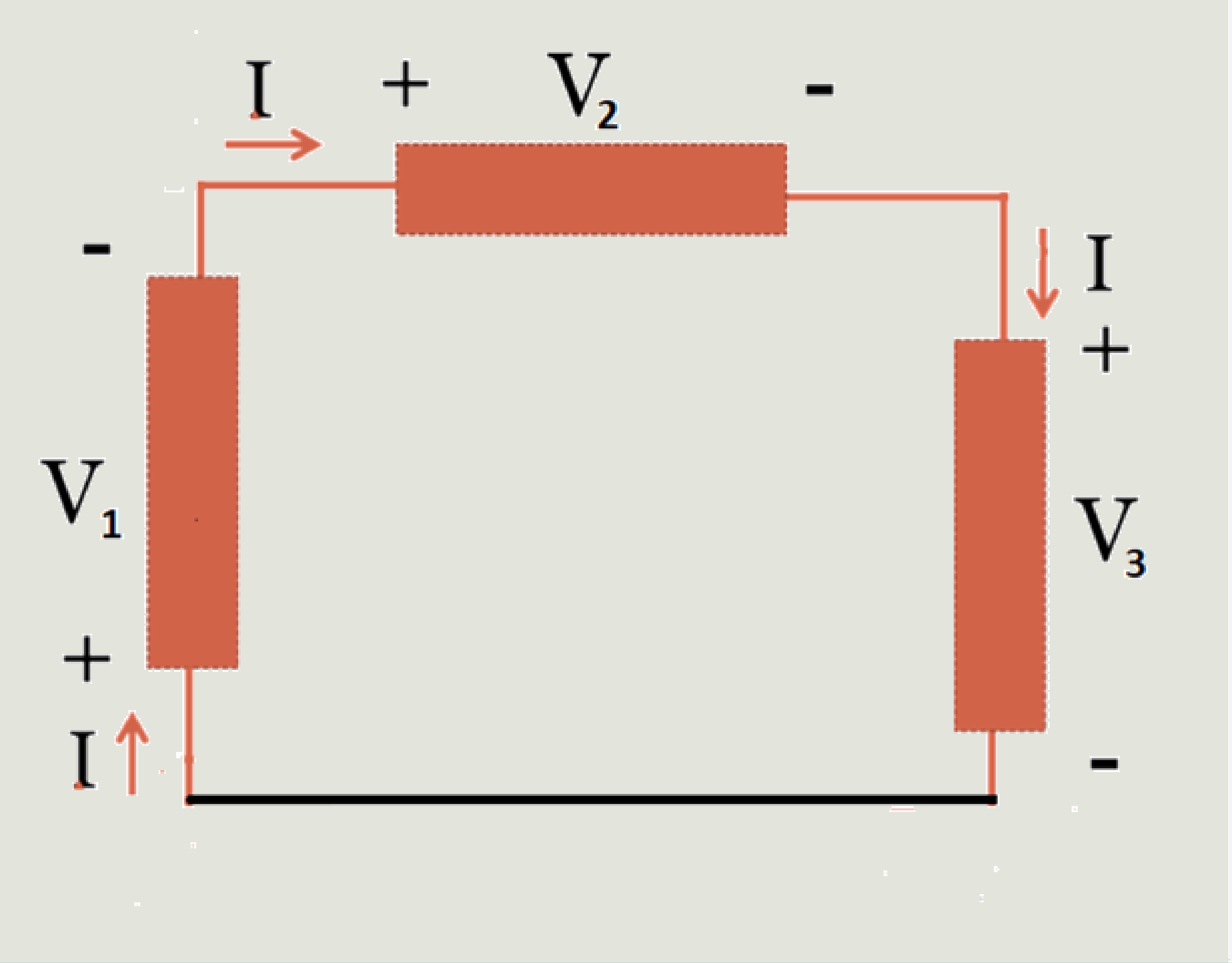
# Understanding Loop

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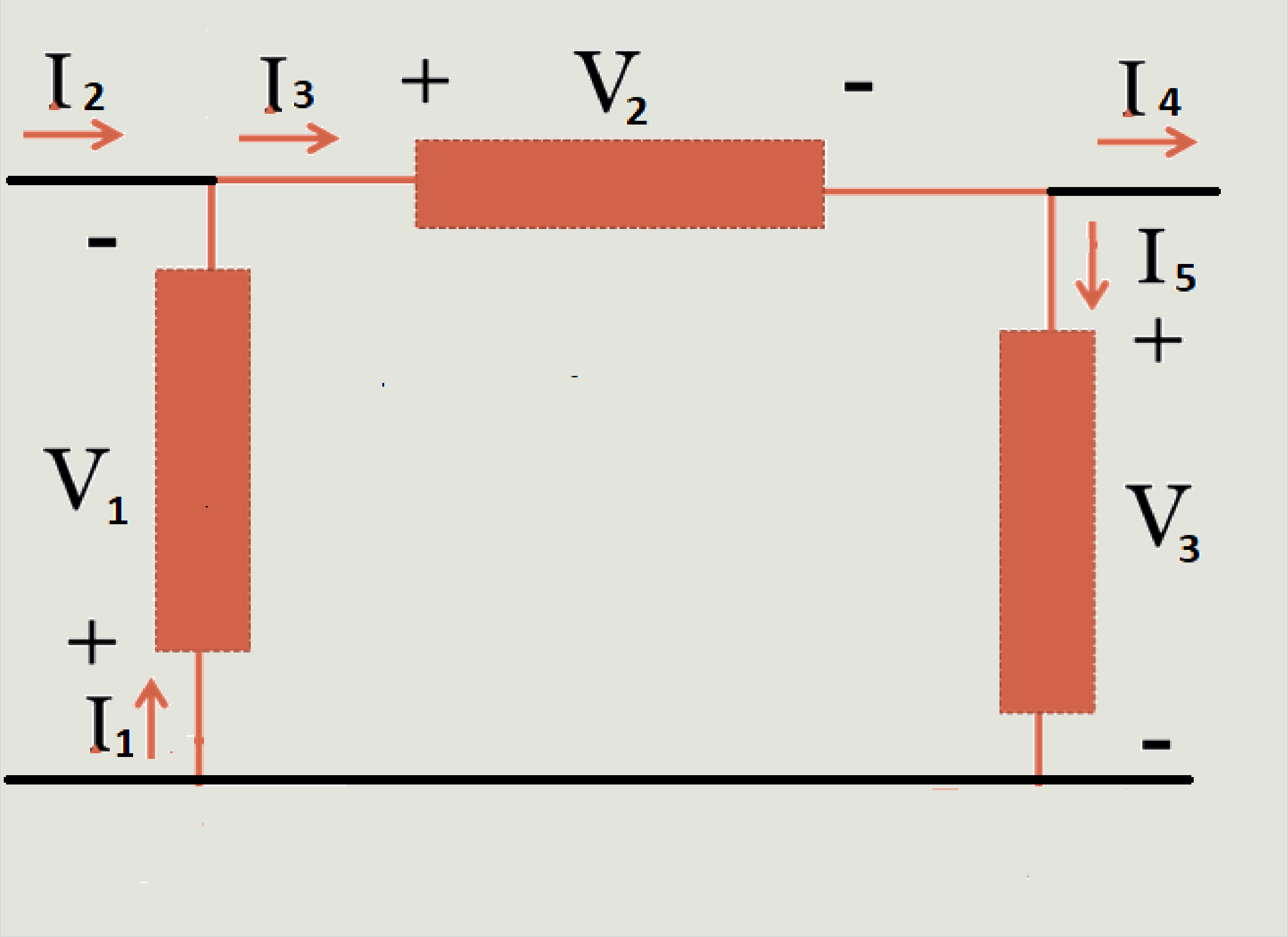
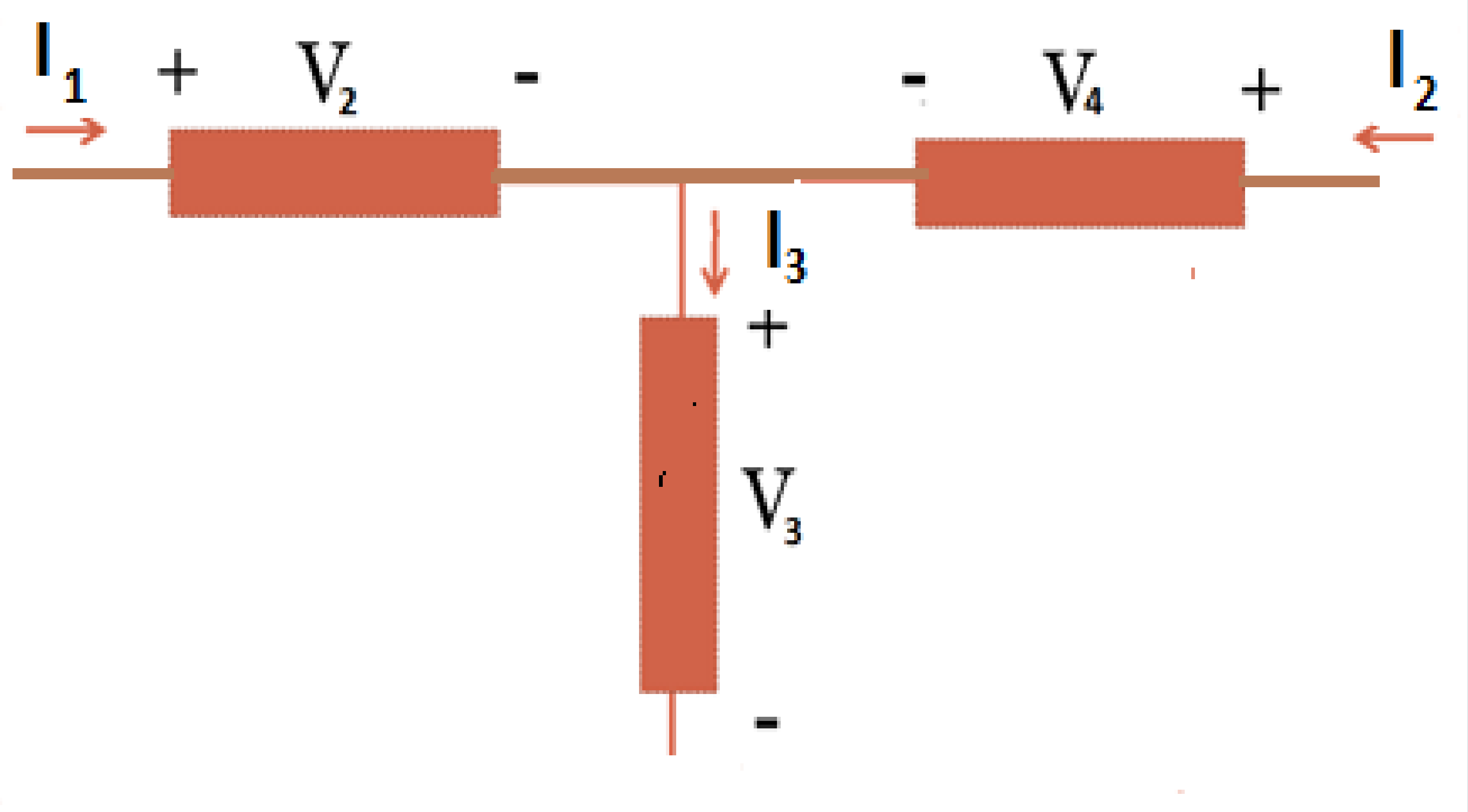
# Understanding Loop



# Understanding Node

- Two or more elements are interconnected at a point which is termed as Node.
- There may be several nodes in a  network.
- Potential at a node is node Voltage with respect to reference.
- Potential difference between two nodes is termed as voltage across the elements connected between the two nodes.

# Understanding Node

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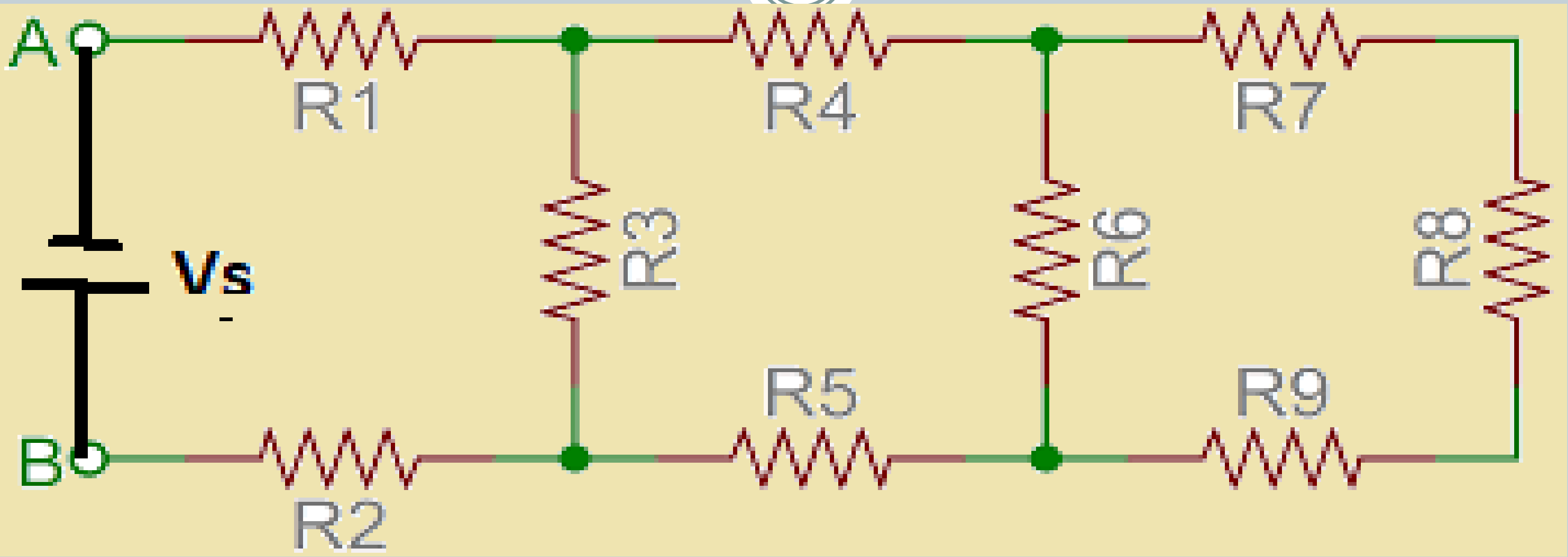
# Example of Network




Number of Elements: 10

Number of Branches:10(6)

Number of Nodes:6

Number of Loops:6

Number of Meshes:3

# Fundamental Laws of Network Theory

## Kirchoff's Laws

### Kirchoff's Voltage Law

### Kirchoff's Current Law

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# Kirchoff's Voltage Law

- **Kirchoff's Voltage Law states that,**

Around any loop of a network, the sum of all voltages, taken in the same direction, is zero:

$$\sum_{\text{Loop}} v_k = 0$$

# Kirchoff's Current Law

## Kirchoff's Current Law states that,

At any node of a network, the sum of all currents entering the node is zero:

$$\sum_{\text{Node}} i_k = 0$$

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# KVL and KCL

- KVL is a discrete version of Faraday's Law, valid to the extent that no time-varying flux links the loop.
- KCL is just conservation of current, allowing for no accumulation of charge at the node.

# Effect of Network Elements

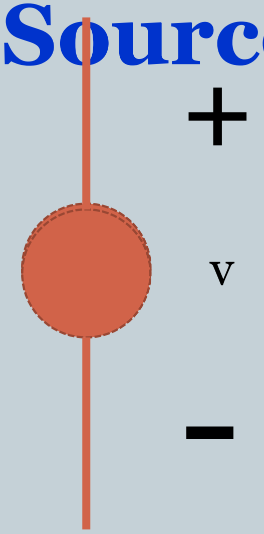
- Network elements affect voltages and currents in one of three ways:

1. Voltage sources maintains the potential difference across their terminals to be of some fixed value
2. Current sources maintains the current through the branch to be of some fixed value.
3. All other elements impose some sort of relationship, either linear or nonlinear, between voltage across and current through the branch.

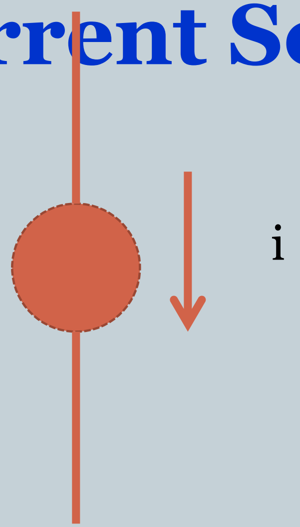
# Basic Electrical Sources

There are two types of Sources to enforce the elements of network in order to get some response

**Voltage Source** and **Current Source**

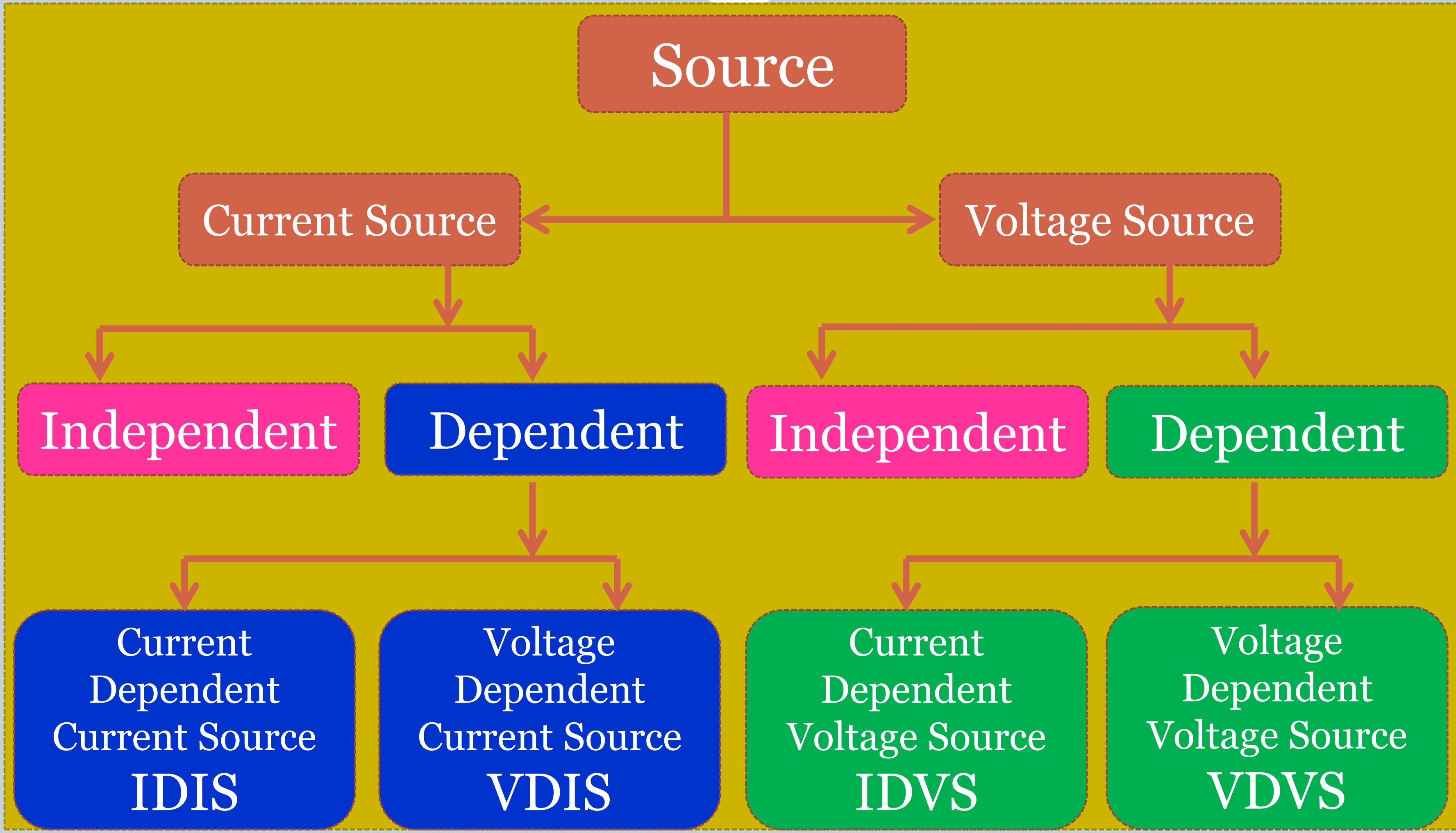



**Voltage Source Notation**

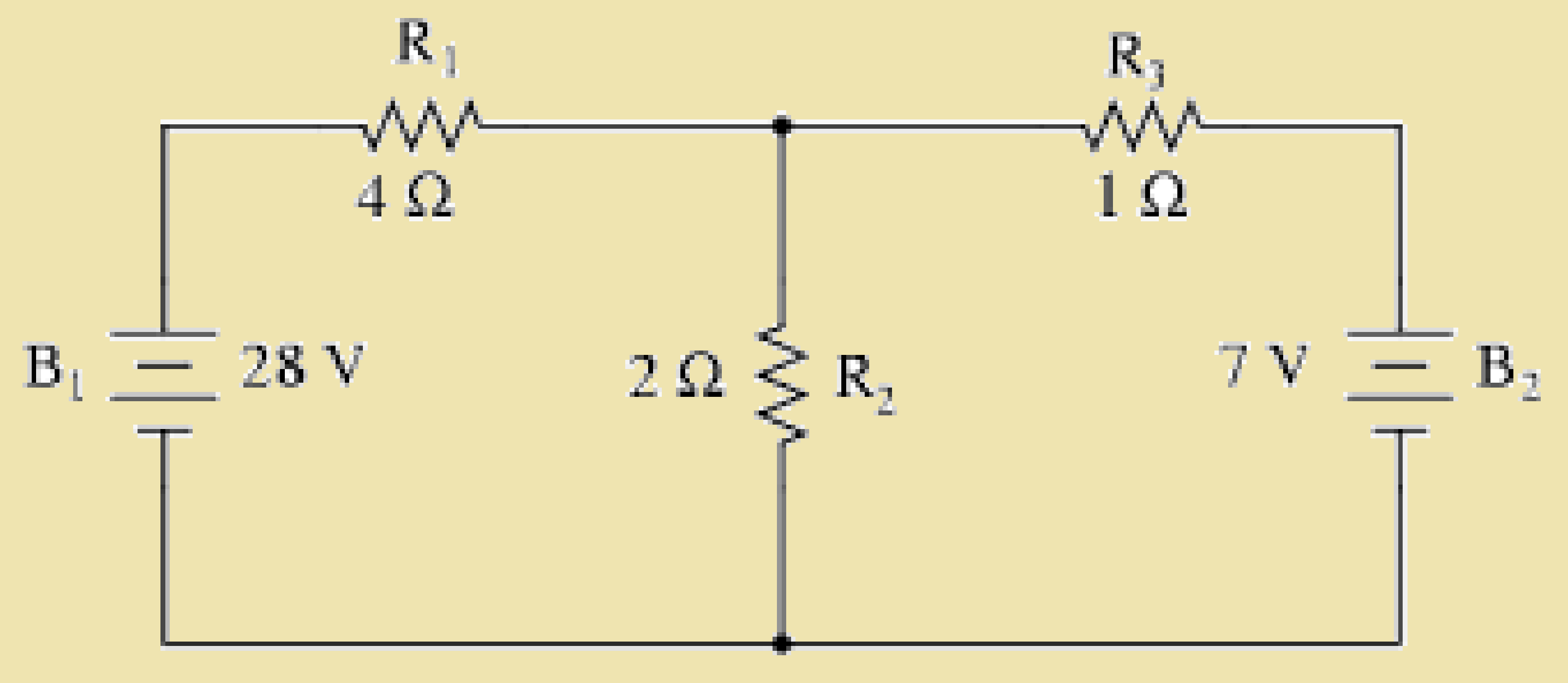



**Current Source Notation**

# Types of Electrical Sources



# Example 2

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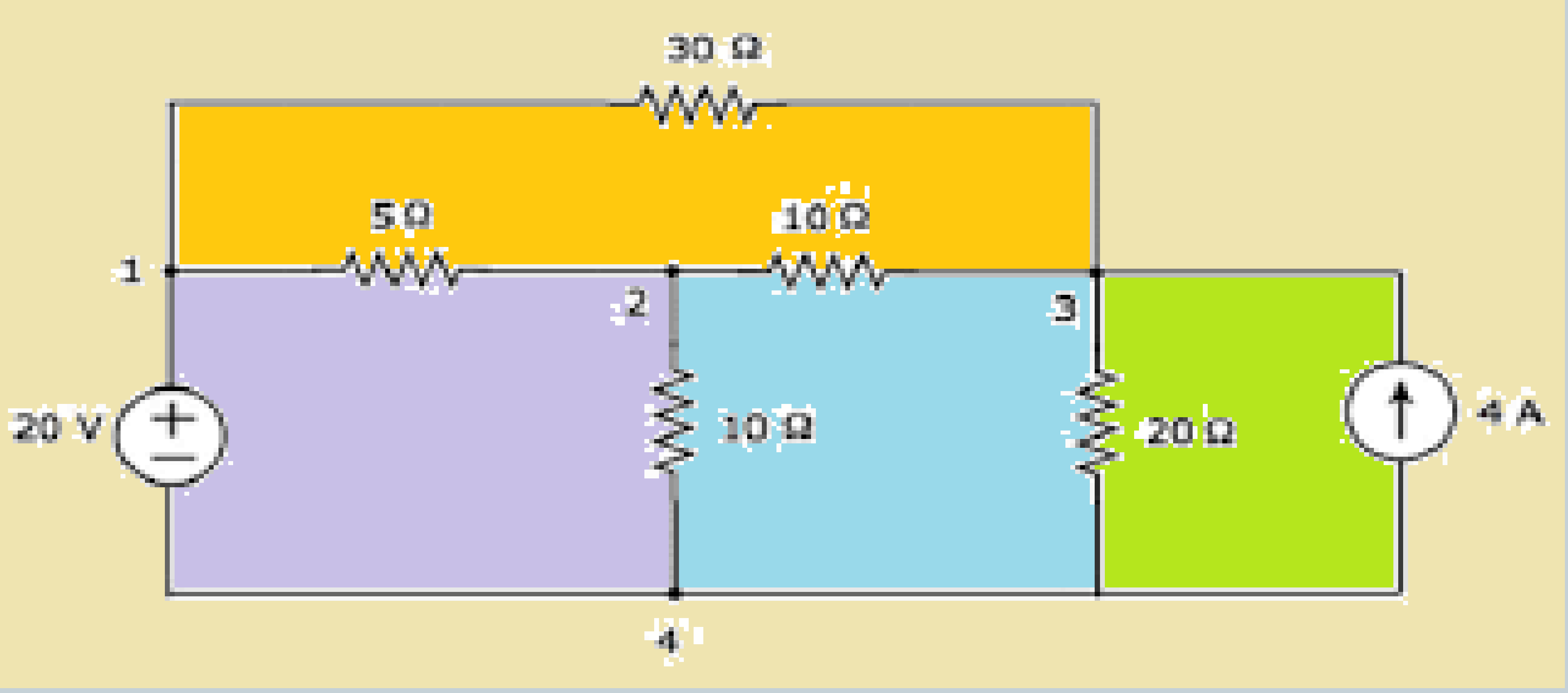
# Example 3

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# Linearity

A network is said to be Linear if it satisfies the following two conditions:

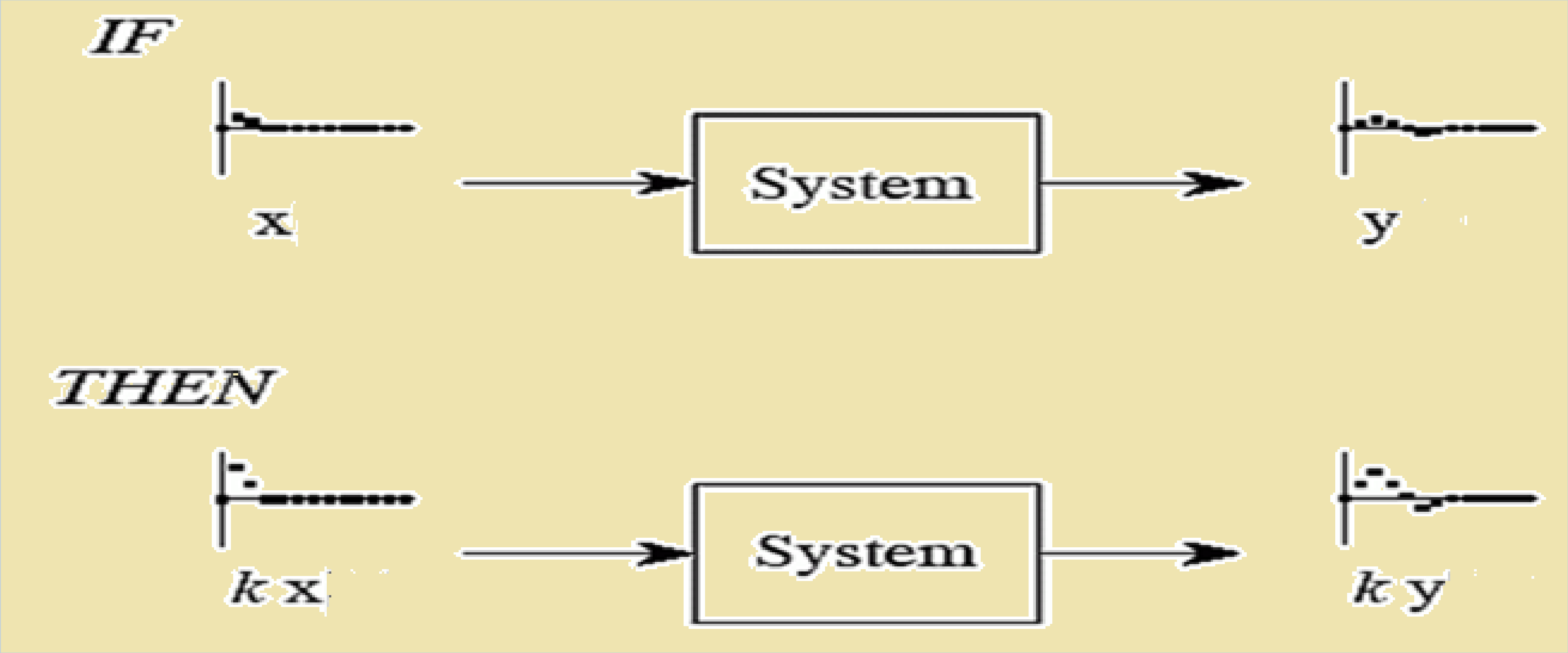
- Homogeneity

and

- Additivity

# Condition of Homogeneity

- For any single input x yielding output y, the response to an input kx is ky for any value of k.

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# Condition of Additivity

If, in a multi-input network
the input x1 by itself yields output y1
and
a second input x2 by itself yields y2,
then
the combination of inputs
x1 and x2 yields the output y = y1 + y2.

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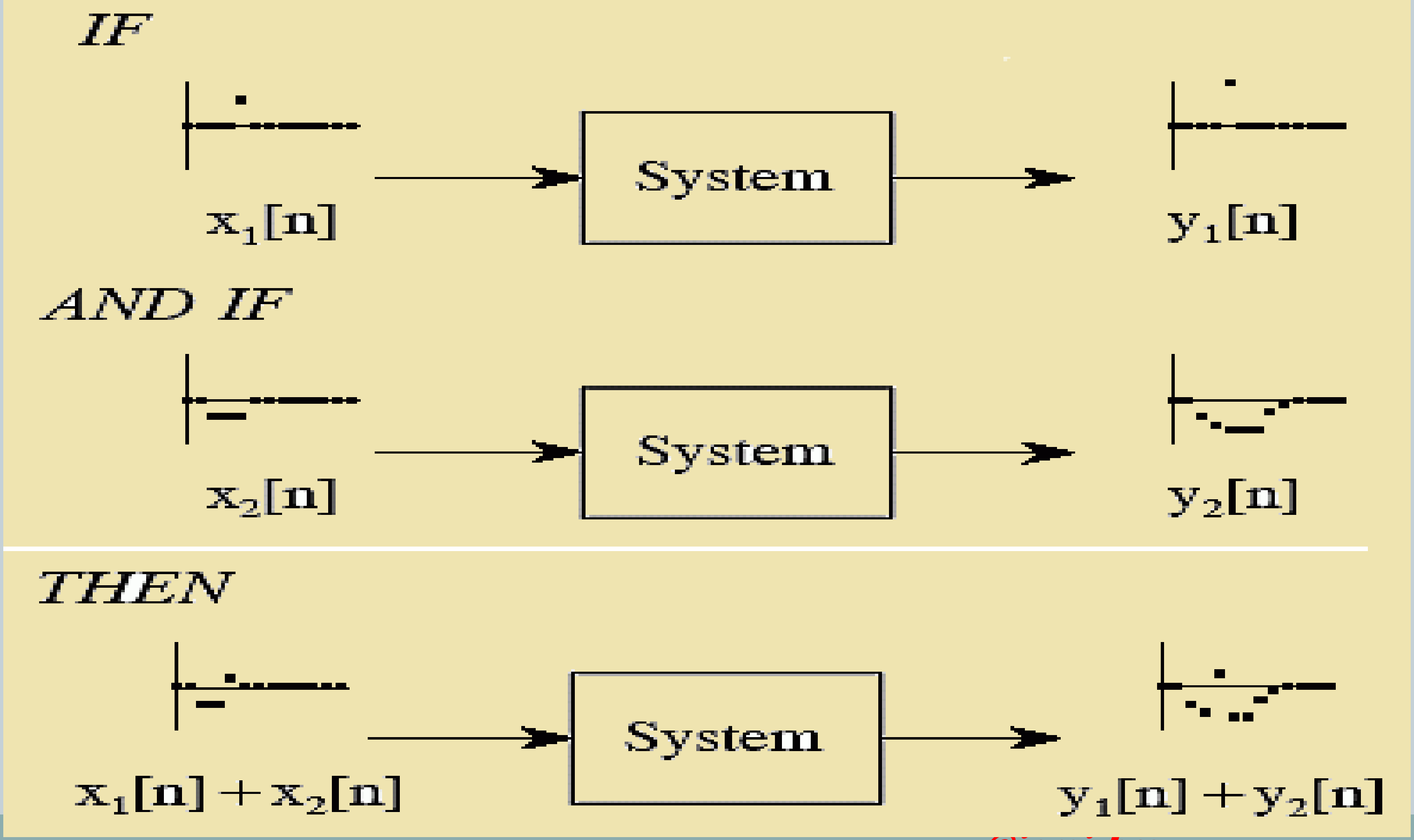
# Condition of Additivity

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# Linearity and Superposition

**If a Linear network**

has

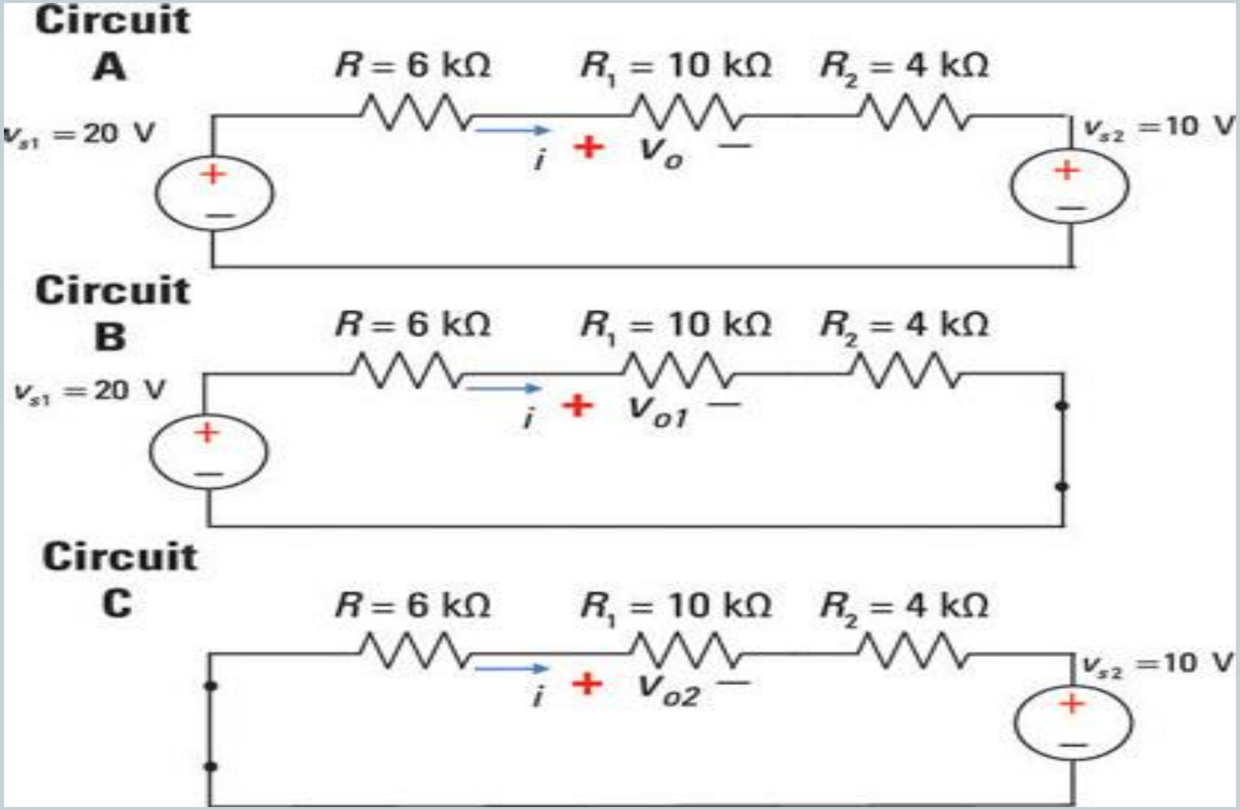
**multiple independent sources,**

it is possible to find the response to each source separately, then add up all of the responses to find total response.

**Note that this can only be done with independent sources!**

# Analyze Circuits with Two Independent Sources Using Superposition

## Two voltage sources Problem




Find the output voltage Vo across the 10-kΩ resistor

# One Voltage Source and One Current Source

$$v_o = v_{o1} + v_{o2}$$

$$v_{o1} = v_{s1}\left(\frac{R_1}{R + R_1 + R_2}\right)$$

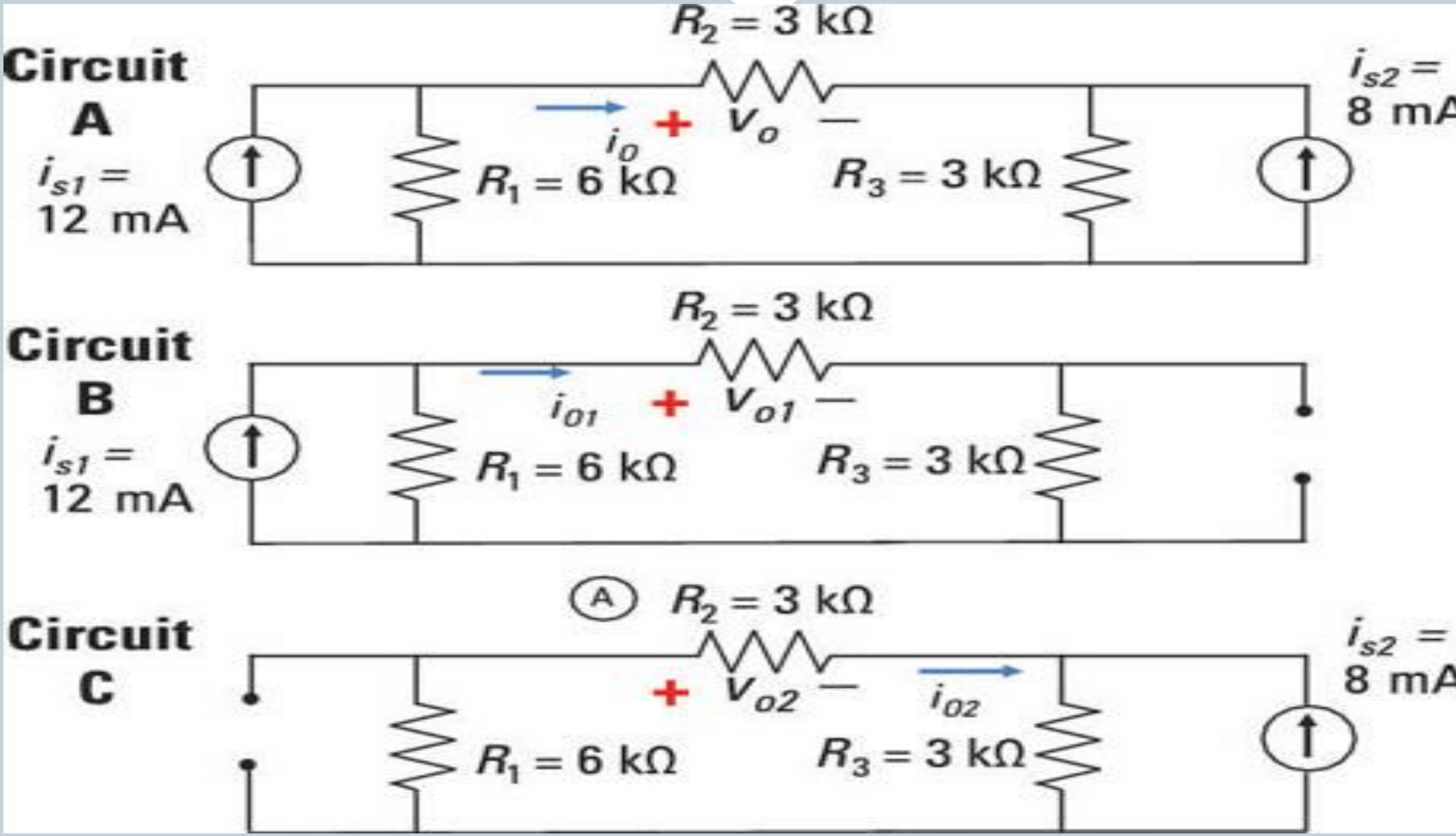
$$v_{o1} = (20\text{ V})\left(\frac{10\text{ k}\Omega}{6\text{ k}\Omega + 10\text{ k}\Omega + 4\text{ k}\Omega}\right) = 10\text{ V}$$

$$v_{o2} = -v_{s2}\left(\frac{R_1}{R + R_1 + R_2}\right)$$

$$v_{o2} = (-10\text{ V})\left(\frac{10\text{ k}\Omega}{6\text{ k}\Omega + 10\text{ k}\Omega + 4\text{ k}\Omega}\right) = -5\text{ V}$$

$$v_o = v_{o1} + v_{o2} = (10\text{ V} - 5\text{ V}) = 5\text{ V}$$

# Two Current Sources

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# Two Current Sources

$$i_o = i_{o1} + i_{o2}$$

$$i_{o1} = \frac{\left(\frac{1}{R_{eq1}}\right)}{\left(\frac{1}{R_1} + \frac{1}{R_{eq1}}\right)} \cdot i_{s1}$$

$$i_{o2} = \frac{\left(\frac{1}{R_{eq2}}\right)}{\left(\frac{1}{R_{eq2}} + \frac{1}{R_3}\right)} \cdot i_{s2}$$

$$i_{o1} = \left(\frac{\frac{1}{(3\text{ k}\Omega + 3\text{ k}\Omega)}}{\frac{1}{6\text{ k}\Omega} + \frac{1}{(3\text{ k}\Omega + 3\text{ k}\Omega)}}\right) \cdot (12\text{ mA}) = 6\text{ mA}$$

$$i_{o2} = \left(\frac{\frac{1}{(6\text{ k}\Omega + 3\text{ k}\Omega)}}{\frac{1}{(6\text{ k}\Omega + 3\text{ k}\Omega)} + \frac{1}{3\text{ k}\Omega}}\right) \cdot (-8\text{ mA}) = -2\text{ mA}$$

# 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 $V_{th}$ in series with a resistor $R_{th}$. It is known as Thevenin's equivalent circuit. A linear circuit may contain independent sources, dependent sources, and resistors.

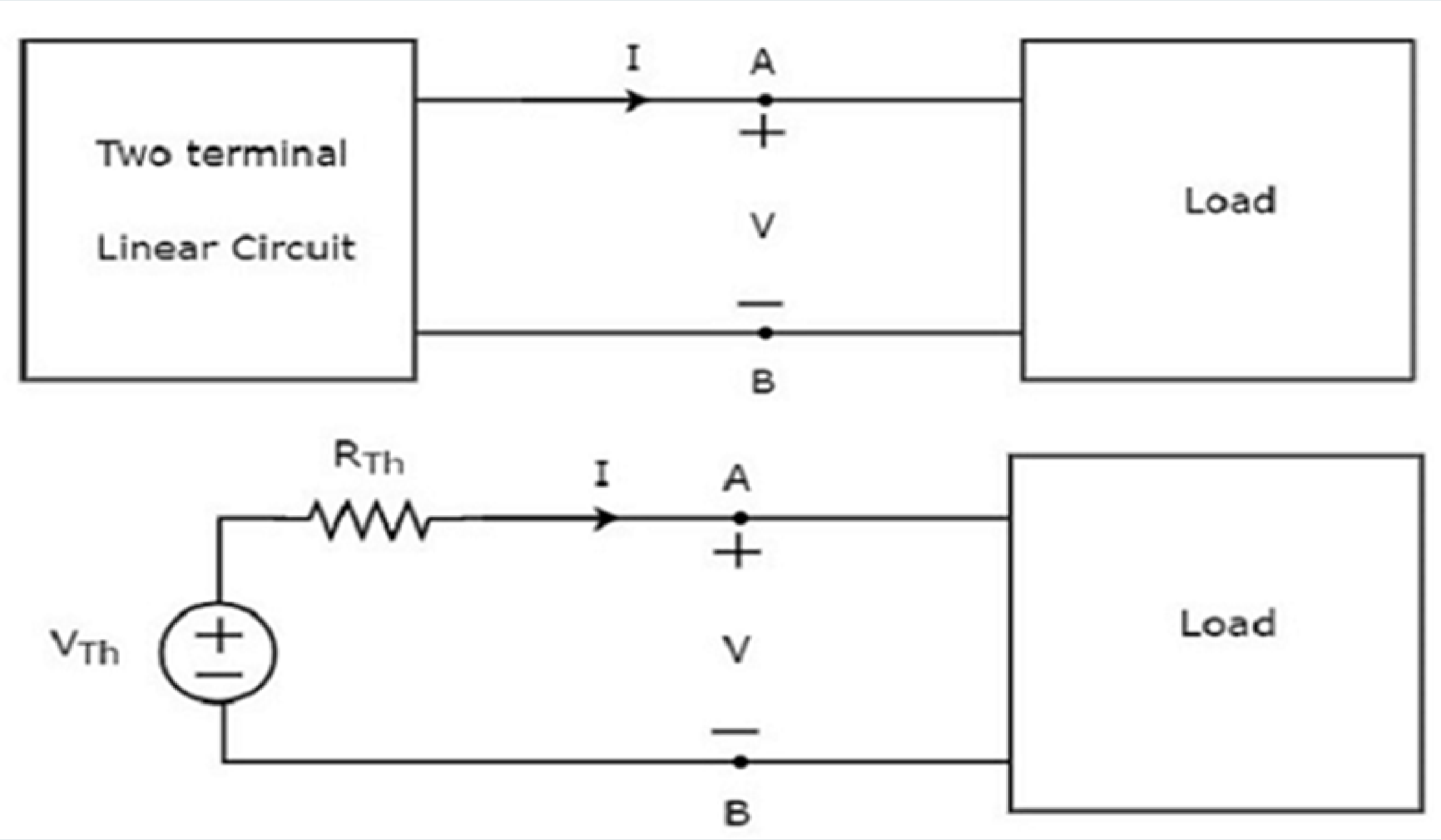
# $R_{th}$ and $V_{th}$

- $R_{th}$ is resistance looking into the open circuited terminals, measured with all active sources deactivated (to be replaced by their internal impedances) and
- $V_{th}$ is the Voltage across open circuited terminals

# Thevenin's Theorem : Steps to follow

- 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 $R_{Th}$.

# Thevenin's Equivalent Circuit

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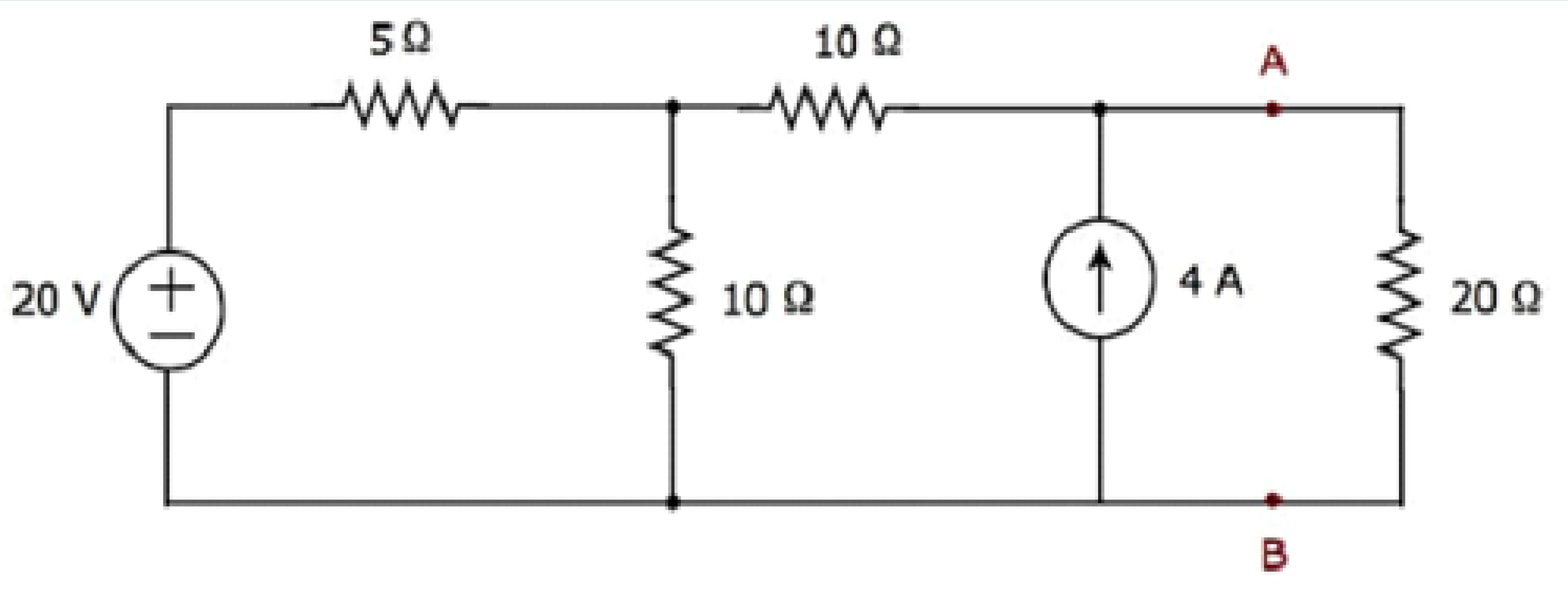
# Thevenin's Theorem Example

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

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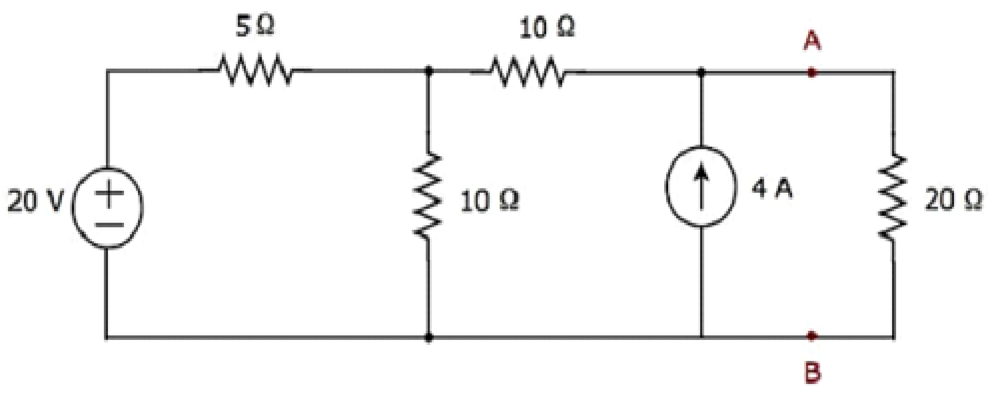
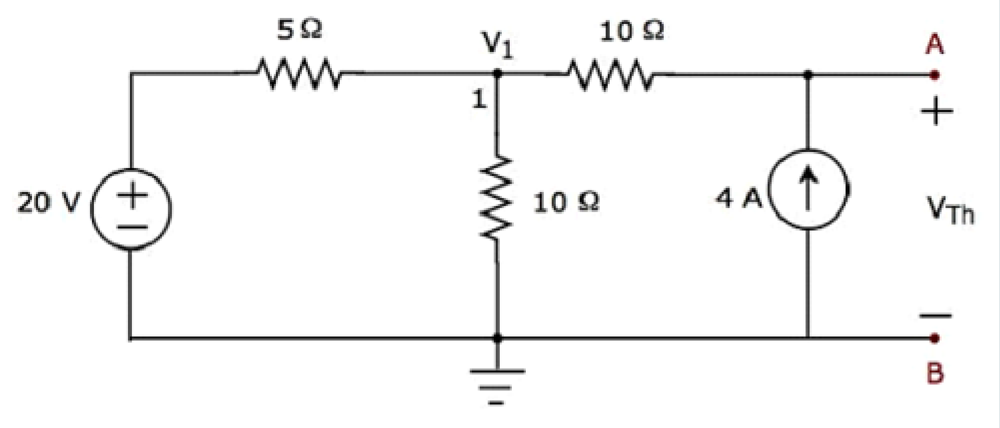
# Applying Thevenin's Theorem

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# Applying Thevenin's Theorem

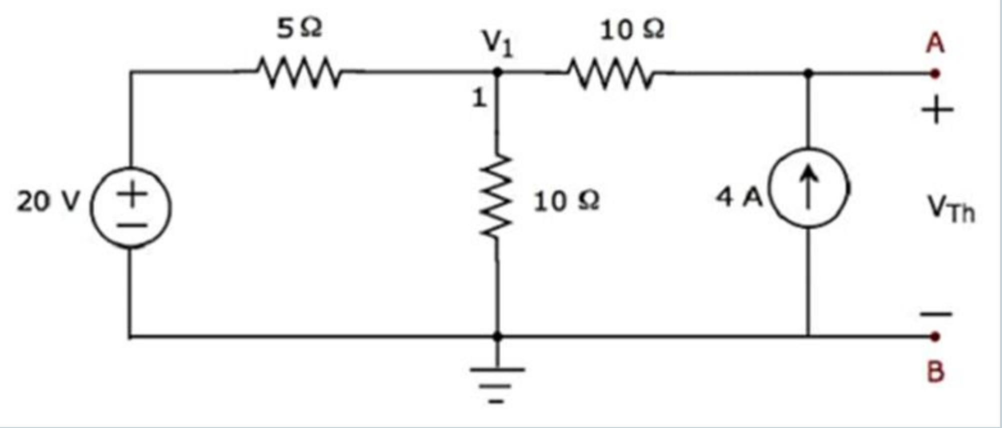
- The nodal equation at node 1 is

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

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

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

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



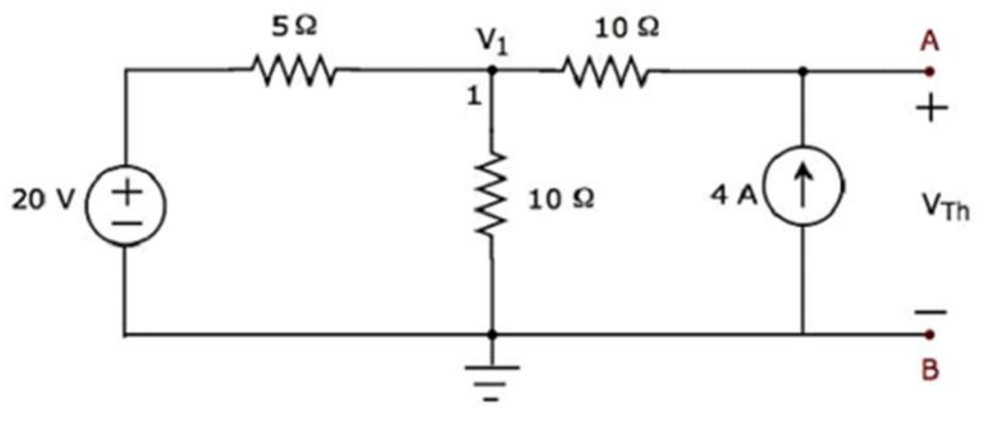
# Applying Thevenin's Theorem

The voltage across series branch 10 Ω resistor is

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

The **KVL equation** around second mesh

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




$V_1$ $V_{10\Omega}$

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

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

$$V_{Th} = \frac{200}{3} V$$

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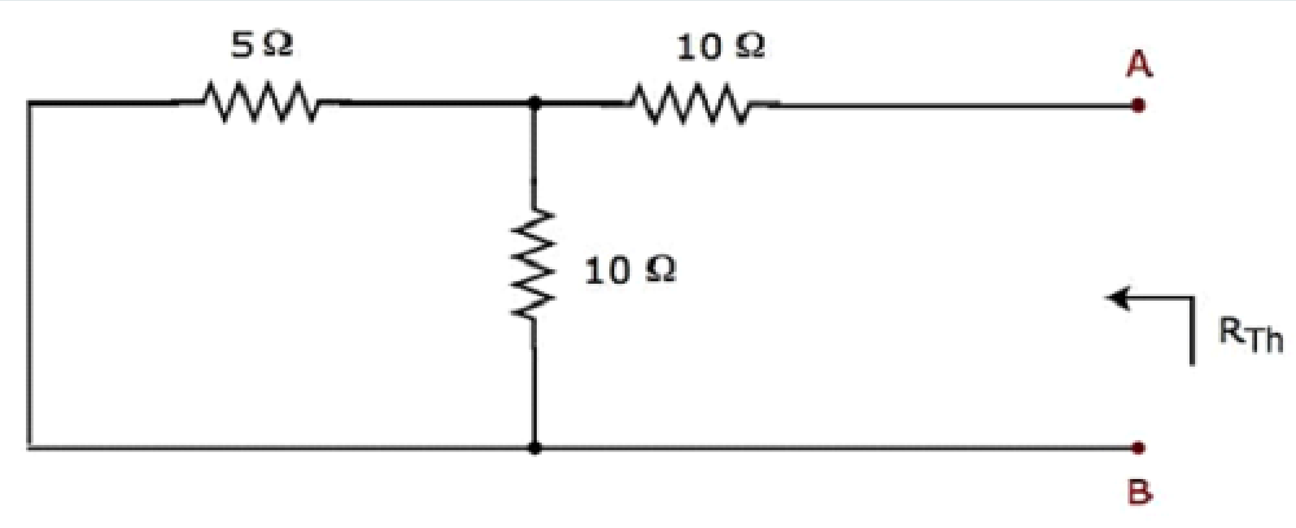
# Calculation of Thevenin's resistance $R_{Th}$

Short circuit the voltage source

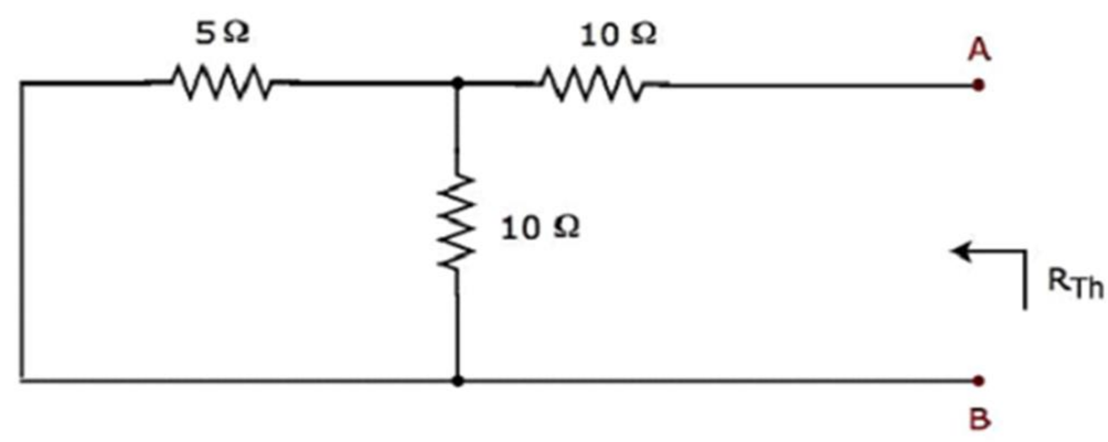
Open circuit the current source of the above circuit

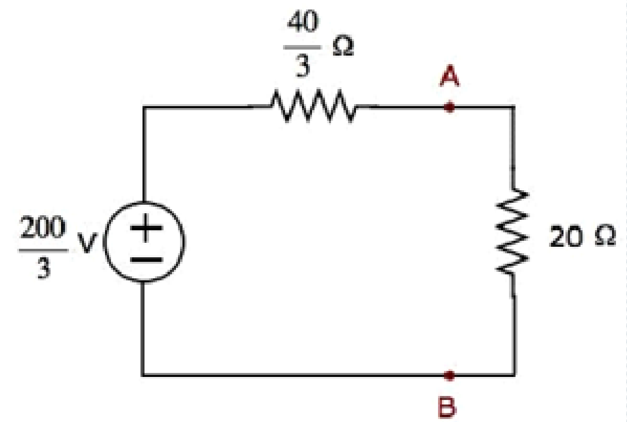
in order to calculate the Thevenin's resistance $R_{Th}$ across the terminals A & B.



# Final Solution

$$V_{Th} = \frac{200}{3} V$$




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 $\mathbf{R_{Th} = \frac{40}{3}\Omega}$.

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

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

# Norton's Theorem

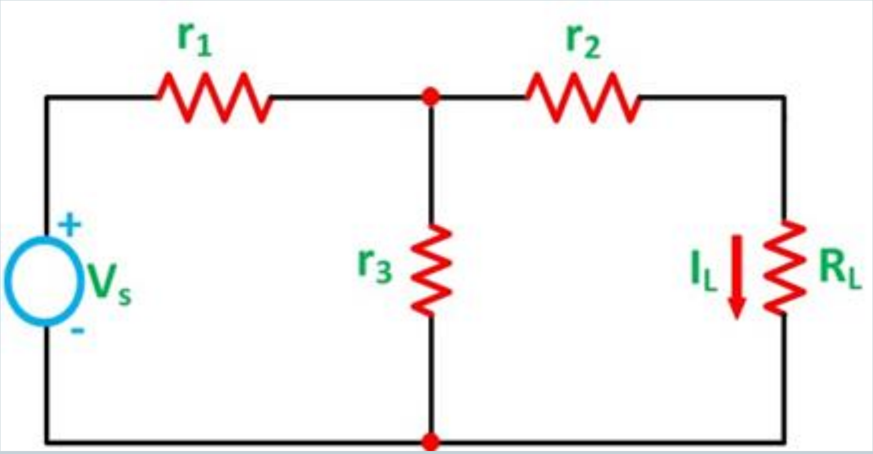
The Thevenin's and Norton's equivalent networks have the same impedance. Further, the equivalent sources are related by the simple relationship:

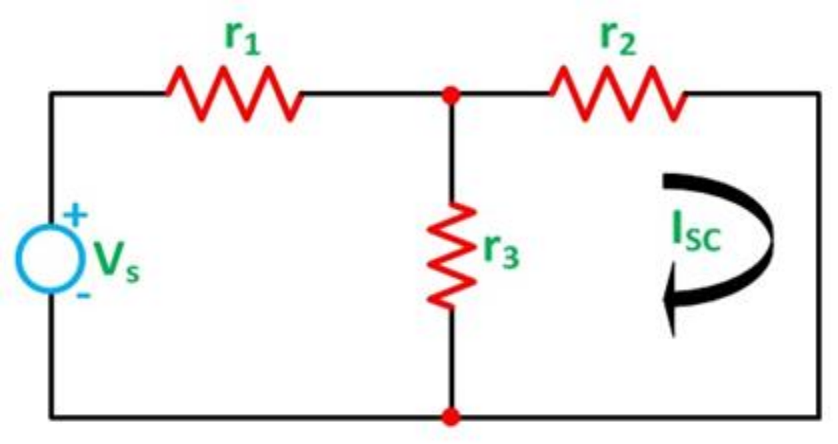
$V_{Th} = R_{eq} \times I_N$

# Norton's Theorem

- A linear active network consisting of independent or dependent voltage source and current sources and the various circuit elements can be substituted by an equivalent circuit consisting of a current source in parallel with a resistance.
- The current source being the short-circuited current across the load terminal and the resistance being the internal resistance of the source network.

# Norton's Theorem




Now, the value of current I flowing in the circuit is found out by the equation

$$I = \frac{V_S}{r_1 + \frac{r_2 r_3}{r_2 + r_3}}$$

And the short-circuit current ISC is given by the equation shown below

$$I_{SC} = I \frac{r_3}{r_3 + r_2}$$

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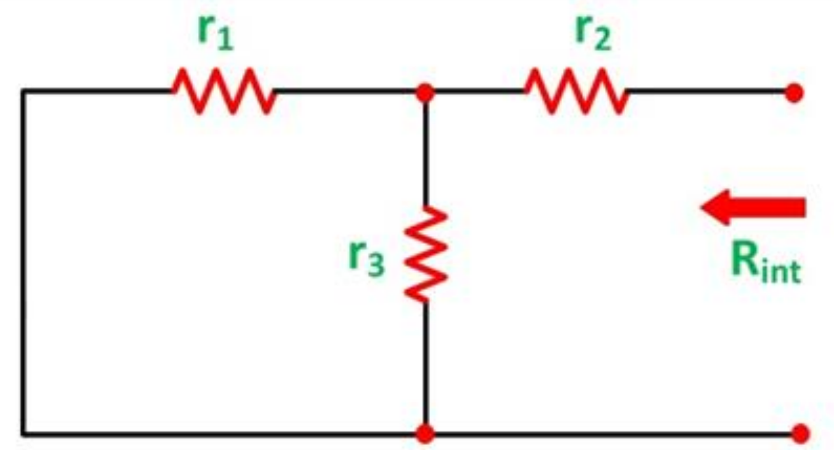
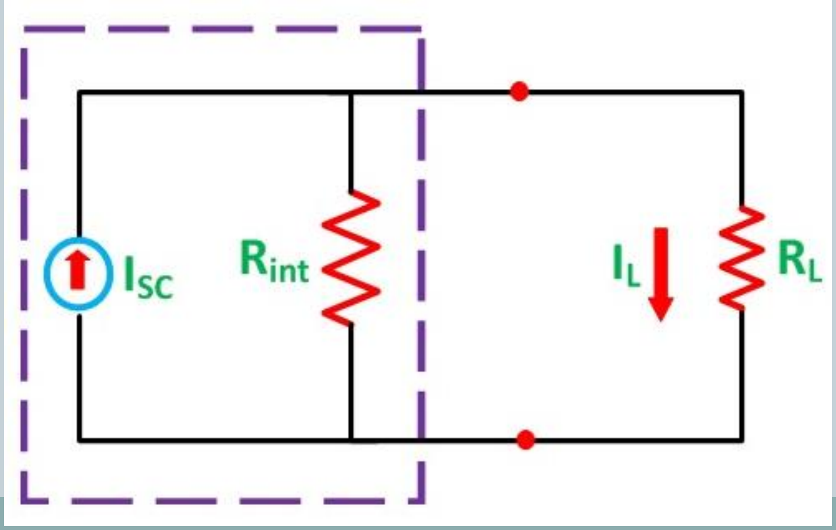
# Norton's Theorem




$$R_{int} = r_2 + \frac{r_1 r_3}{r_1 + r_3}$$




$$I_L = I_{sc} \frac{R_{int}}{R_{int} + R_L}$$

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# Norton's Theorem

- Step 1 – Remove the load resistance of the circuit.
- Step 2 – Find the internal resistance $R_{int}$ of the source network by deactivating the constant sources.
- Step 3 – Now short the load terminals and find the short circuit current $I_{SC}$ flowing through the shorted load terminals using conventional network analysis methods.
- Step 4 – Norton's equivalent circuit is drawn by keeping the internal resistance $R_{int}$ in parallel with the short circuit current $I_{SC}$.
- Step 5 – Reconnect the load resistance $R_L$ of the circuit across the load terminals and find the current through it known as load current $I_L$.