# UNIT 1: DC CIRCUITS

Lecture 3

# Kirchhoff's Law

- Ohm's law by itself is not sufficient to analyze circuits.
- However, when it is coupled with Kirchhoff's two laws, we have a sufficient, powerful set of tools for analyzing a large variety of electric circuits.
- These laws are:

1. Kirchhoff's Current Law (KCL)
2. Kirchhoff's Voltage Law (KVL)

# Kirchhoff’s Current Law (KCL)

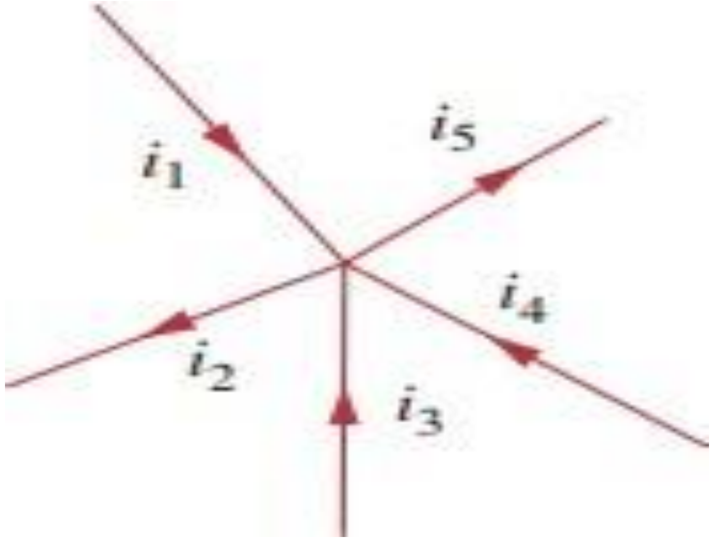
- It states that:

“the algebraic sum of currents entering a node is zero”.

OR

“ Sum of currents entering a node = Sum of currents leaving a node “

- Based on Law of Conservation of Charge.
- Mathematically, $\sum I = 0$



# QUICK QUIZ (Poll 1)

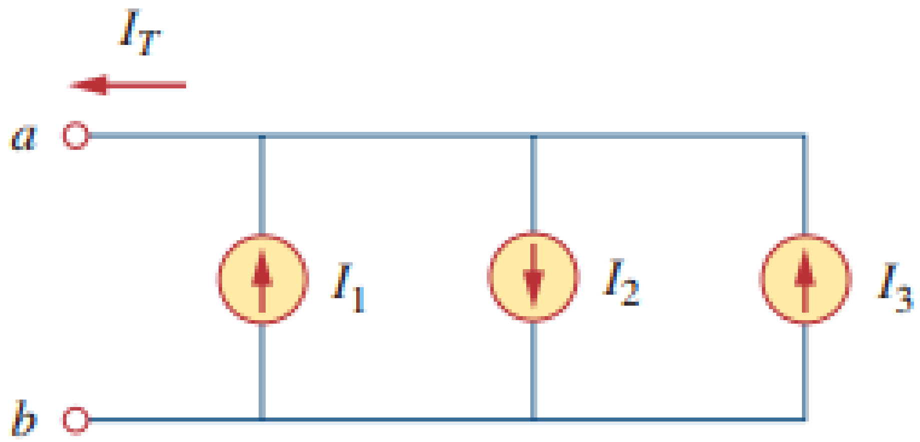
KCL equation for the given network is:

A. $I_1 + I_2 + I_3$

B. $I_1 + I_2 - I_3$

C. $I_1 - I_2 + I_3$

D. $-I_1 - I_2 + I_3$



# Kirchhoff's Voltage Law (KVL)

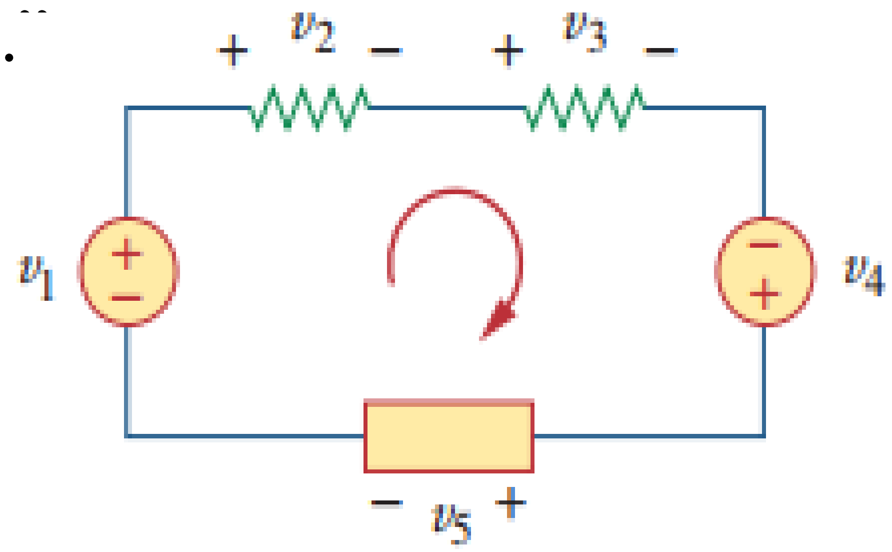
- It states that:

"algebraic sum of all voltages around a closed path (or loop) is zero."

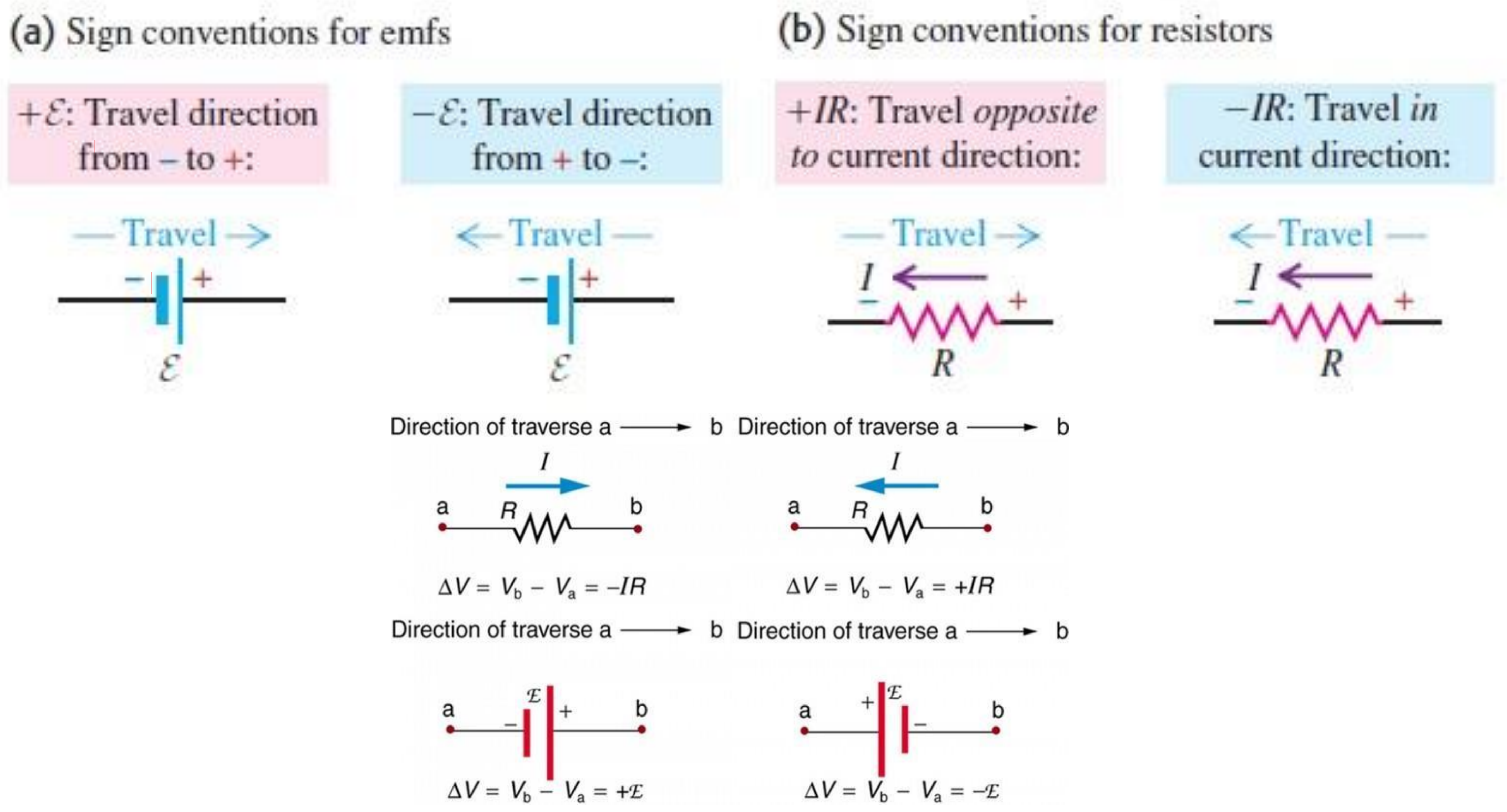
OR

" Sum of voltage drops = Sum of voltage rises."

- Based on Law of Conservation of Energy
- Mathematically, $\sum V = 0$

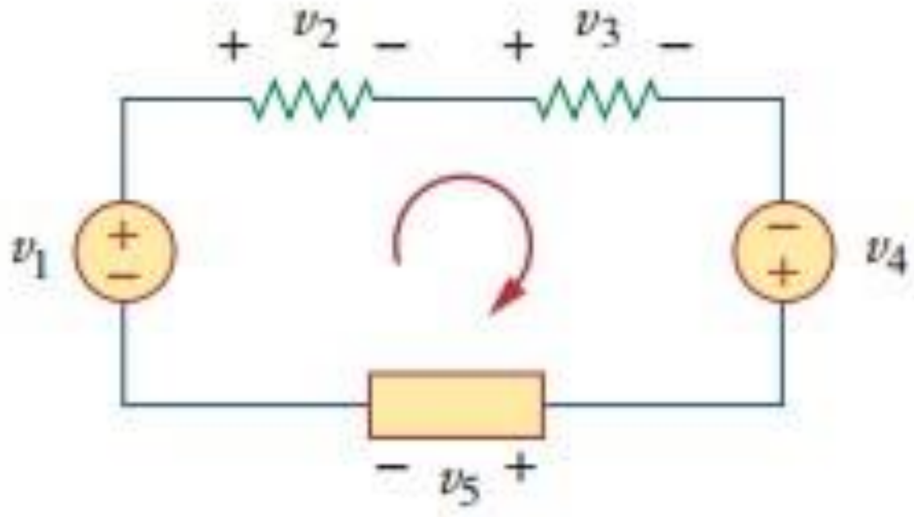


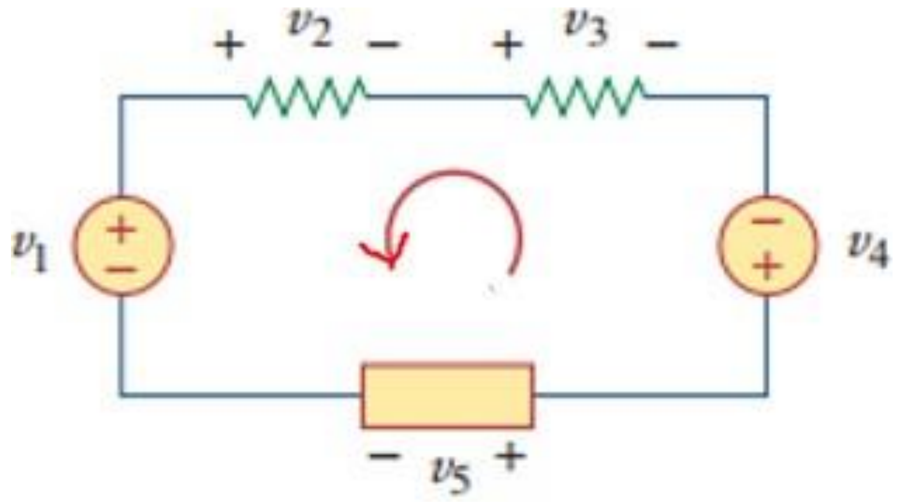
# Sign Convention for KVL



# Let us Recall!

- Taking Clockwise direction (Def. 1):
  $$+V_1 - V_2 - V_3 + V_4 - V_5 = 0$$
- Taking Anti-clockwise direction(Def. 1):
  $$-V_4 + V_3 + V_2 - V_1 + V_5 = 0$$
- Voltage rise = Voltage drop
  $$+V_1 + V_4 = V_2 + V_3 + V_5$$



# QUICK QUIZ (Poll 2)

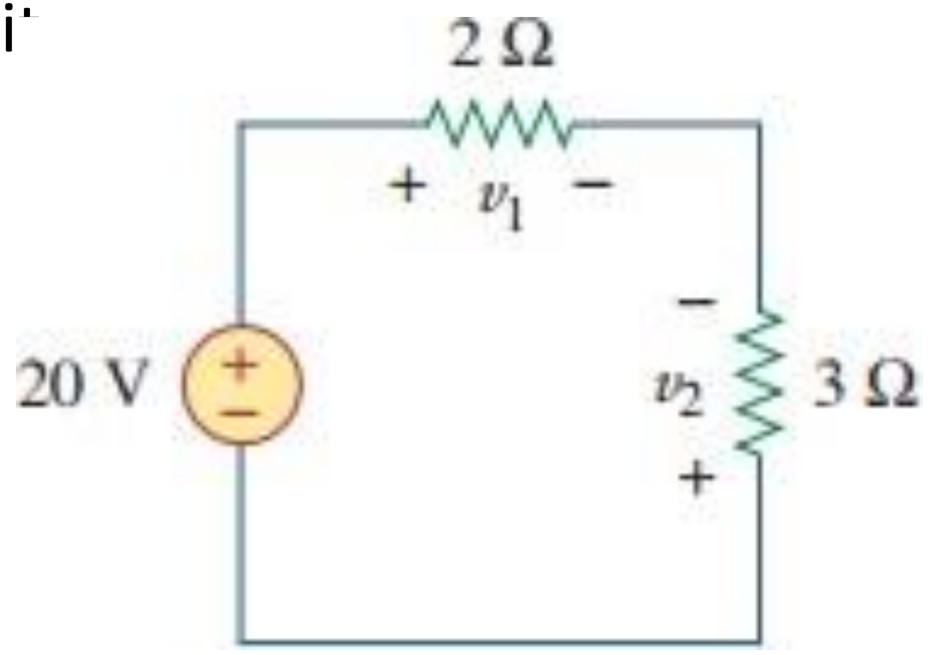
Find voltages $V_1$ and $V_2$ in the given circui

A. $V_1 = 16\,V\ and\ V_2 = 12\,V$

B. $V_1 = 16\,V\ and\ V_2 = -8\,V$

C. $V_1 = 8\,V\ and\ V_2 = -12\,V$

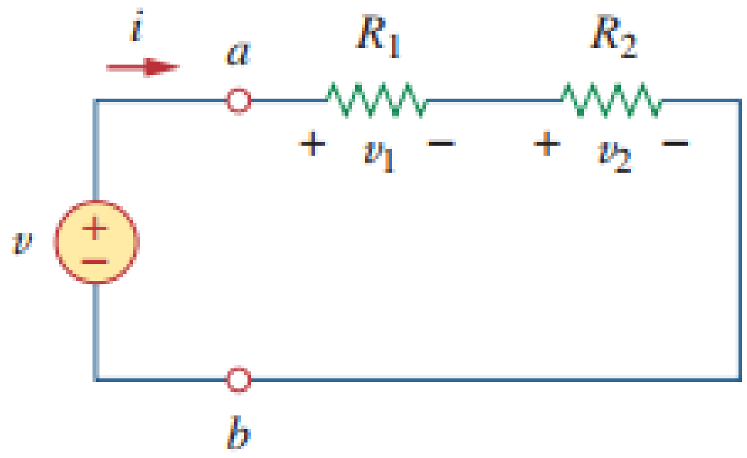
D. $V_1 = -12\,V\ and\ V_2 = 8\,V$



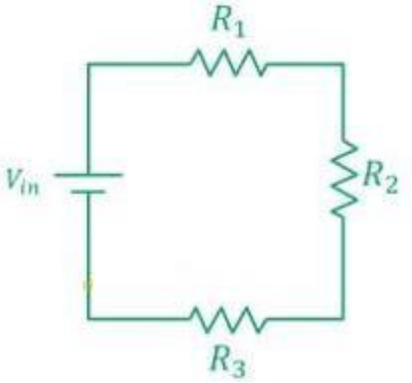
# Voltage Division Rule

- The important relations are:

$$v_1 = \frac{R_1}{R_1 + R_2} v, \qquad v_2 = \frac{R_2}{R_1 + R_2} v$$




**VOLTAGE DIVISION RULE FOR 3- RESISTORS**




$$V_1 = \frac{R_1}{R_1 + R_2 + R_3} \cdot V_{in}$$

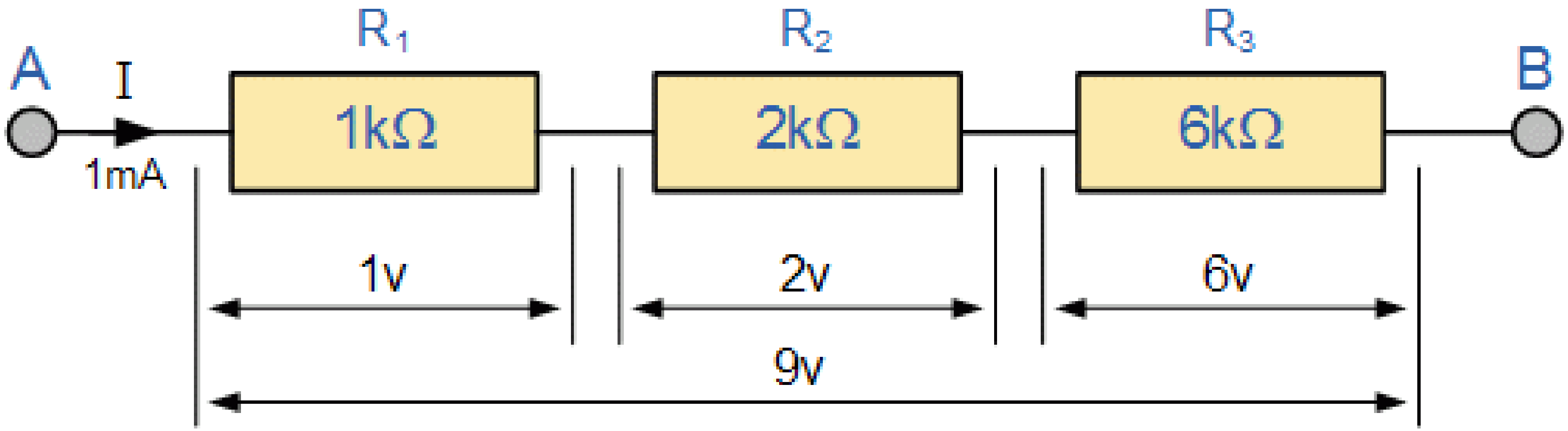
$$V_2 = \frac{R_2}{R_1 + R_2 + R_3} \cdot V_{in}$$

$$V_3 = \frac{R_3}{R_1 + R_2 + R_3} \cdot V_{in}$$

**Voltage Division Rule for N-Resistors**

$$v_n = \frac{R_n}{R_1 + R_2 + \cdots + R_N} v$$

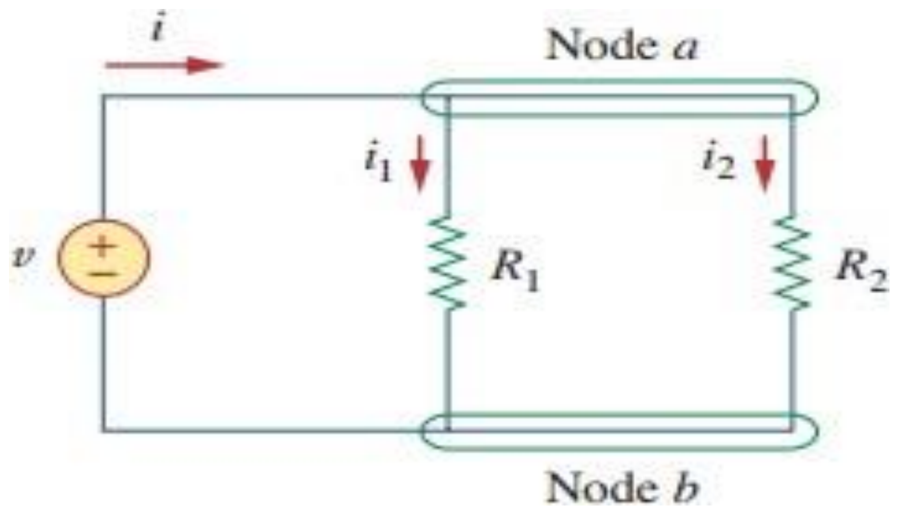
# Example for Voltage Division Rule



# Current Division Rule

- The important relations are:

$$i_1 = \frac{R_2\, i}{R_1 + R_2}, \qquad i_2 = \frac{R_1\, i}{R_1 + R_2}$$



# QUICK QUIZ (Poll 3)

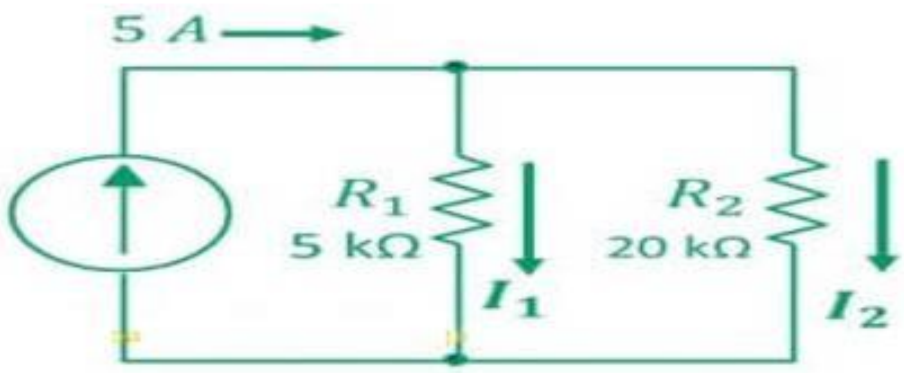
Find current across two resistors?

A. $I_1 = 4\ A\ and\ I_2 = 16\ A$

B. $I_1 = -2\ A\ and\ I_2 = 1\ A$

C. $I_1 = 4\ A\ and\ I_2 = 1\ A$

D. $I_1 = 1\ A\ and\ I_2 = 4\ A$



# Applications of Kirchhoff's Laws

- They can be used to analyze any electrical circuit.
- Computation of current and voltage of complex circuits.

# Limitations of Kirchhoff's Laws

- The limitation of Kirchhoff's both laws is that it works under the assumption that there is no fluctuating magnetic field in the closed loop and the current flows only through conductors and wires.

$$\frac{\partial \phi_B}{\partial t} = 0$$ Outside elements

$$\frac{\partial q}{\partial t} = 0$$ Inside elements

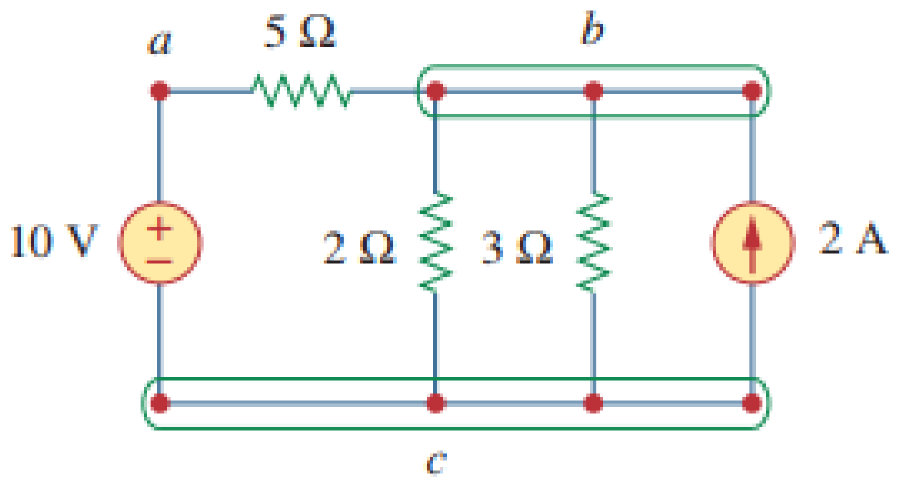
wires resistors sources

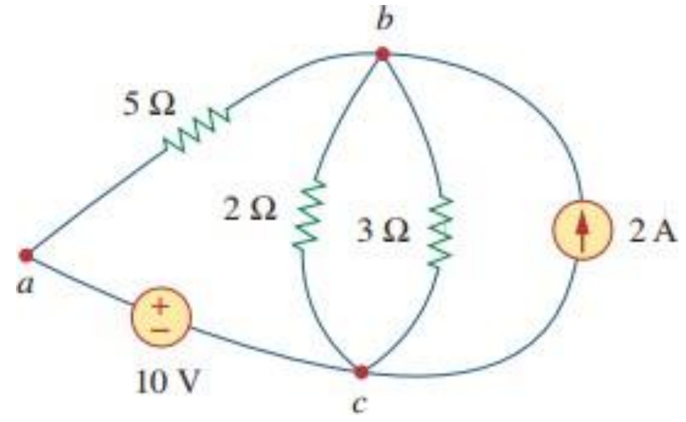
# Nodes, Branches, and Loops

- A branch represents a single element such as a voltage source or a resistor. 5
- A node is the point of connection between two or more branches. 5
- A loop is any closed path in a circuit 3

**NOTE:**

- Two or more elements are in series if they exclusively share a single node and consequently carry the same current.
- Two or more elements are in parallel if they are connected to the same two nodes and consequently have the same voltage across them.



# QUICK QUIZ (Poll 4)

How many branches, nodes and independent loops are present in the given circuit?

A. b=3, n=5, l=6

B. b=5, n=3, l=6

C. b=5, n=3, l=3

D. b=3, n=5, l=3