Electric Circuits

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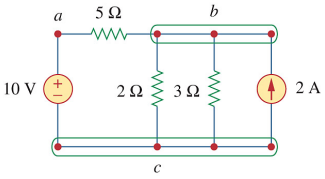
Lecture 3 (Nodes and Branches)

Overview

- Circuit topology and the voltage and current laws will be introduced.

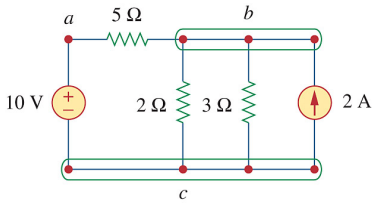
Nodes Branches and Loops

- Circuit elements can be interconnected in multiple ways.
- To understand this, we need to be familiar with some network topology concepts.
- A branch represents a single element such as a voltage source or a resistor.



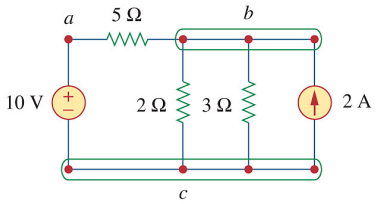
Nodes Branches and Loops

- A node is the point of connection between two or more branches.



Nodes Branches and Loops

- A loop is any closed-path in a circuit.
- A loop is independent if it contains at least one branch not shared by any other independent loops.



- Here, abca, bcb through the 3 Ω resistor and the current source, and bcb through the 2 Ω and 3 Ω resistors form independents loops.

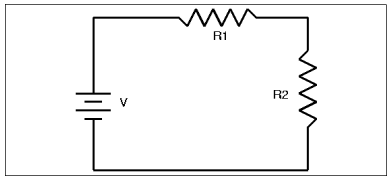
Network Topology

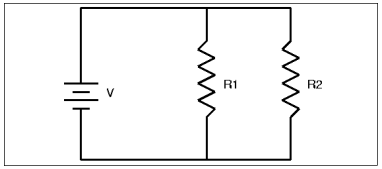
- A network with *b* branches, *n* nodes, and *l* independent loops will satisfy

$$b=l+n-1$$

Network Topology

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





Solved Problem

Kirchoff's Laws

- Ohm's law is not sufficient for circuit analysis
- Kirchoff's laws complete the needed tools
- There are two laws:
  - Current law
  - Voltage law

KCL

- Kirchoff's current law is based on conservation of charge
- It states that the algebraic sum of currents entering a node (or a closed boundary) is zero.
- It can be expressed as:

$$\sum_{n=1}^{N} i_n = 0$$

Solved Problem

KVL

- Kirchoff's voltage law is based on conservation of energy
- It states that the algebraic sum of voltages around a closed path (or loop) is zero.
- It can be expressed as:

$$\sum_{m=1}^{M} v_m = 0$$

Solved Problem

Solved Problem

Solved Problem

Solved Problem

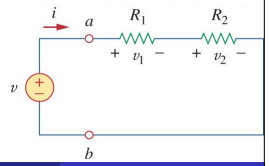
Series Resistors

- Two resistors are considered in series if the same current pass through them
- Take the circuit shown:
- Applying Ohm's law to both resistors

$$v_1 = iR_1 \quad v_2 = iR_2$$

- If we apply KVL to the loop we have:

$$-v + v_1 + v_2 = 0$$



Series Resistors II

- Combining the two equations:

$$v = v_1 + v_2 = i\left(R_1 + R_2\right)$$

- From this we can see there is an equivalent resistance of the two resistors:

$$R_{eq} = R_1 + R_2$$

- For N resistors in series:

$$R_{eq} = \sum_{n=1}^{N} R_n$$

Voltage Division

- The voltage drop across any one resistor can be known.
- The current through all the resistors is the same, so using Ohm's law:

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

- This is the principle of voltage division

Parallel Resistors

- When resistors are in parallel, the voltage drop across them is the same

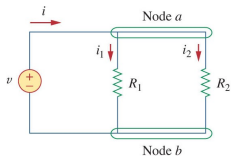
$$v = i_1 R_1 = i_2 R_2$$

- By KCL, the current at node *a* is

$$i = i_1 + i_2$$

- The equivalent resistance is:

$$R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$$



Solved Problem

Current Division

- Given the current entering the node, the voltage drop across the equivalent resistance will be the same as that for the individual resistors

$$v = iR_{eq} = \frac{iR_1R_2}{R_1 + R_2}$$

- This can be used in combination with Ohm's law to get the current through each resistor:

$$i_1 = \frac{iR_2}{R_1 + R_2} \quad i_2 = \frac{iR_1}{R_1 + R_2}$$

Solved Problem

Solved Problem

Solved Problem

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