Chapter 6

Parallel Circuits

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Parallel Circuits

- House circuits contain parallel circuits
- The parallel circuit will continue to operate even though one component may be open
- Only the open or defective component will no longer continue to operate

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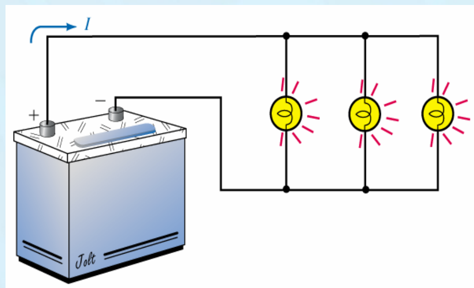
Parallel Circuits



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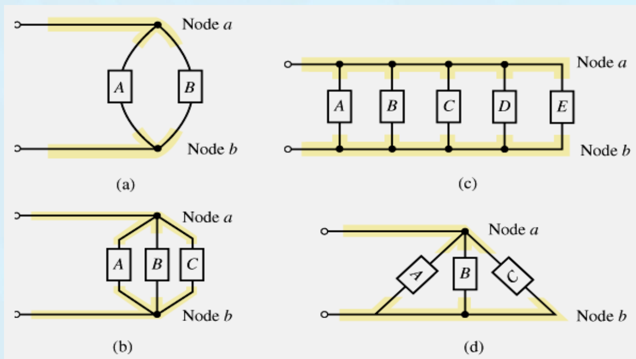
Parallel Circuits

- Elements in parallel
  - When they have exactly two nodes in common
- Elements between nodes
  - Any device like resistors, light bulbs, etc.
- Elements connected in parallel
  - Same voltage across them

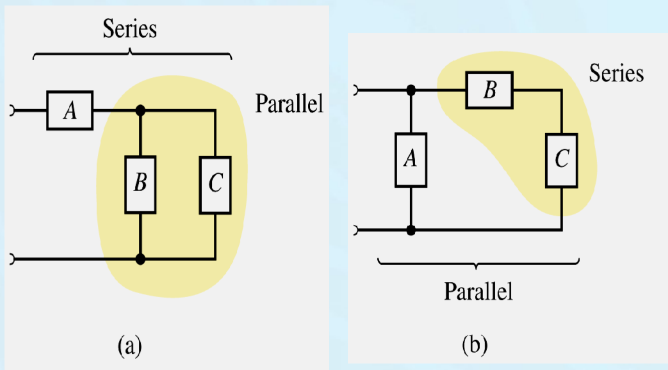
Parallel Circuits



Series - Parallel Circuits

- Circuits may contain a combination of series and parallel components
- Being able to recognize the various connections in a network is an important step in analyzing these circuits

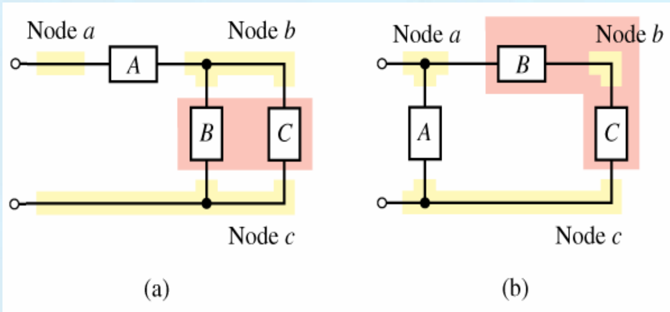
Series - Parallel Circuits



Parallel Circuits

- To analyze a particular circuit
  - First identify the node
  - Next, label the nodes with a letter or number
  - Then, identify types of connections

Parallel Circuits



Kirchhoff's Current Law (KCL)

- The algebraic sum of the currents entering and leaving a node is equal to zero

$$\sum I = 0$$

Kirchhoff's Current Law (KCL)

- Currents entering the node are taken to be positive, leaving are taken to be negative
- Sum of currents entering a node is equal to the sum of currents leaving the node

$$\sum I_{\text{in}} = \sum I_{\text{out}}$$

Kirchhoff's Current Law (KCL)

- An analogy:
  - When water flows in a pipe, the amount of water entering a point is the amount leaving that point

Direction of Current

- If unsure of the direction of current through an element, assume a direction
- Base further calculations on this assumption

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Direction of Current

- If this assumption is incorrect, calculations will show that the current has a negative sign
- Negative sign simply indicates that the current flows in the opposite direction

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Resistors in Parallel

- Voltage across all parallel elements in a circuit will be the same

Resistors in Parallel

- For a circuit with 3 resistors: $I_T = I_1 + I_2 + I_3$

$$\frac{E}{R_T} = \frac{E}{R_1} + \frac{E}{R_2} + \frac{E}{R_3}$$

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$G_T = G_1 + G_2 + G_3$$

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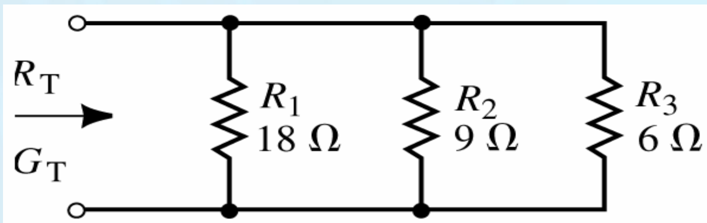
Resistors in Parallel

- Total resistance of resistors in parallel will always be less than resistance of smallest resistor



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Equal Resistors in Parallel

- For *n* equal resistors in parallel, each resistor has the same conductance *G*
- $G_T = nG$
- $R_T = 1/G_T = 1/nG = R/n$

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Equal Resistors in Parallel

- Total resistance of equal resistors in parallel is equal to the resistor value divided by the number of resistors

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Two Resistors in Parallel

- For only two resistors connected in parallel, the equivalent resistance may be found by the product of the two values divided by the sum

$$R_T = \frac{R_1 R_2}{R_1 + R_2}$$

- Often referred to as "product over the sum" formula

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Three Resistors in Parallel

- For three resistors in parallel:

$$R_T = \frac{R_1 R_2 R_3}{R_1 R_2 + R_1 R_3 + R_2 R_3}$$

- Rather than memorize this long expression
  - Use basic equation for resistors in parallel

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Voltage Sources in Parallel

- Voltage sources with different potentials should never be connected in parallel
- When two equal sources are connected in parallel
  - Each source supplies half the required current

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Voltage Sources in Parallel

- Jump starting automobiles
- If two unequal sources are connected
  - Large currents can occur and cause damage

Current Divider Rule

- Allows us to determine how the current flowing into a node is split between the various parallel resistors

Current Divider Rule

$$I_x R_x = I_y R_y$$

$$I_x = \frac{G_x}{G_y} I_y$$

$$I_x = \frac{R_y}{R_x} I_y$$

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Current Divider Rule

- For only two resistors in parallel:

$$R_T = \frac{R_1 R_2}{R_1 + R_2}$$

$$I_1 = \frac{I_T R_T}{R_1}$$

$$I_1 = \frac{R_2}{R_1 + R_2} I_T$$

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Current Divider Rule

- If current enters a parallel network with a number of equal resistors, current will split equally between resistors
- In a parallel network, the smallest value resistor will have the largest current
  - Largest resistor will have the least current

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Current Divider Rule

- Most of the current will follow the path of least resistance

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Analysis of Parallel Circuits

- Voltage across all branches is the same as the source voltage
- Determine current through each branch using Ohm's Law
- Find the total current using Kirchhoff's Current Law

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Analysis of Parallel Circuits

- To calculate the power dissipated by each resistor, use either VI, I^2R, or V^2/R
- Total power consumed is the sum of the individual powers
- Compare with $I_T^2R_T$

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Ammeter Design

- Coil of the meter can only handle a small amount of current
- A shunt resistor in parallel allows most of current to bypass the coil

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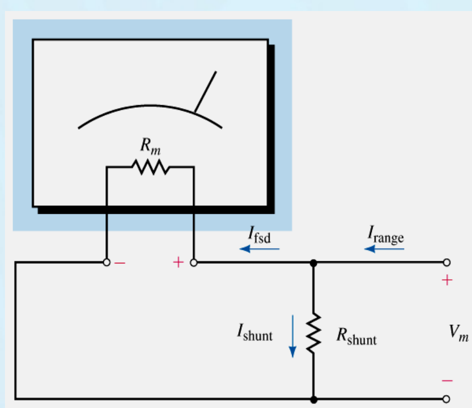
Ammeter Design



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Voltmeter Loading Effects

- A voltmeter
  - Meter movement in series with a current-limiting resistance
- If resistance is large compared with the resistance across which the voltage is to be measured, the voltmeter will have a very small loading effect

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Voltmeter Loading Effects

- If this resistance is more than 10 times the resistance across which the voltage is being measured, the loading effect can generally be ignored.
- However, it is usually much higher.