Chapter 4

Ohm's Law, Power, and Energy

Ohm's Law

- Current in a resistive circuit
  - Directly proportional to its applied voltage
  - Inversely proportional to its resistance

$$I = \frac{E}{R}$$

Ohm's Law

- For a fixed resistance
  - Doubling voltage doubles the current
- For a fixed voltage
  - Doubling resistance halves the current

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Ohm's Law

- Also expressed as $E = IR$ and $R = E/I$
- Express all quantities in base units of volts, ohms, and amps or utilize the relationship between prefixes

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Ohm's Law in Graphical Form

- Linear relationship between current and voltage
- y = mx
  - y is the current
  - x is the voltage
  - m is the slope

5

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Ohm's Law in Graphical Form

- Slope (m) determined by resistor conductance

6

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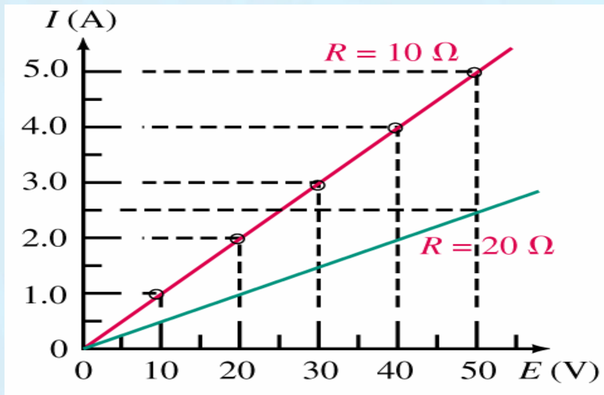
Ohm's Law in Graphical Form



7

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Open Circuits

- Current can only exist where there is a conductive path
- Open circuit
  - When there is no conductive path

8

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Open Circuits

- If $I = 0$
  - Ohm's Law gives $R = E/I = E/0 \rightarrow$ infinity
- An open circuit has infinite resistance

Voltage Symbols

- Voltage sources
  - Uppercase ***E***
- Voltage drops
  - Uppercase ***V***
- $V = IR$
  - IR drops

Voltage Polarities

- Polarity of voltage drops across resistors is important in circuit analysis
- Drop is + to – in the direction of conventional current
- To show this, place plus sign at the tail of current arrow

11

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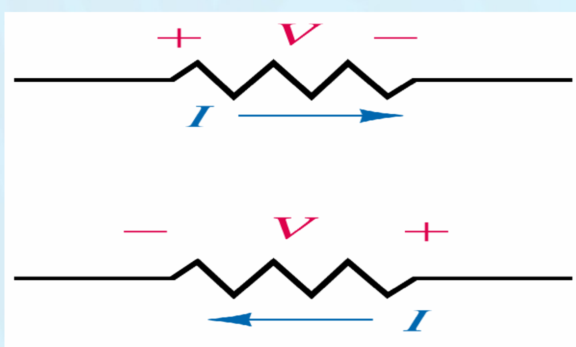
Voltage Polarities



12

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Current Direction

- Current usually proceeds out of the positive terminal of a voltage source
- If the current is actually in this direction, it will be supplying power to the circuit

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Current Direction

- If the current is in the opposite direction (going into the positive terminal), it will be absorbing power (like a resistor)

Current Direction

- See two representations of the same current on next slide
- Notice that a negative current actually proceeds in a direction opposite to the current arrow

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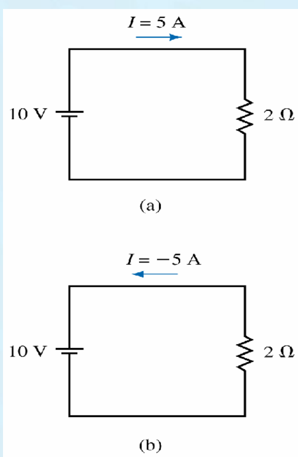
Current Direction



Power

- The greater the power rating of a light, the more light energy it can produce each second
- The greater the power rating of a heater, the more heat energy it can produce

Power

- The greater the power rating of a motor, the more mechanical work it can do per second
- Power is related to energy
  - Capacity to do work

Power

- Power is the rate of doing work
  - Power = Work/time
- Power is measured in **watts (W)**
- Work and energy measured in **joules (J)**
- One watt =
  - One joule per second

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Power in Electrical Systems

- From $V = W/Q$ and $I = Q/t$, we get

$$P = VI$$

- From Ohm's Law, we can also find that

$$P = I^2R \text{ and } P = V^2/R$$

- Power is always in watts

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Power in Electrical Systems

- We should be able to use any of the power equations to solve for *V*, *I*, or *R* if *P* is given
- For example:

$$I = \sqrt{\frac{P}{R}}$$

$$V = \sqrt{PR}$$

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Power Rating of Resistors

- Resistors must be able to safely dissipate their heat without damage
- Common power ratings of resistors are 1/8, 1/4, 1/2, 1, or 2 watts

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Power Rating of Resistors

- A safety margin of two times the expected power is customary
- An overheated resistor
  - Often the symptom of a problem rather than its cause

Energy

- Energy =
  - Power × time
- Units are joules
- Watt-seconds
  - Watt-hours or kilowatt-hours

Energy

- Energy use is measured in kilowatt-hours by the power company
- For multiple loads
  - Total energy is sum of the energy of individual loads

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Energy

- Cost =
  - Energy × cost per unit or
- Cost =
  - Power × time × cost per unit

Energy

- To find the cost of running a 2000-watt heater for 12 hours if electric energy costs $0.08 per kilowatt-hour:
  - Cost = 2kW × 12 hr × $0.08 Cost = $1.92

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Law of Conservation of Energy

- Energy can neither be created nor destroyed
  - Converted from one form to another
- Examples:
  - Electric energy into heat
  - Mechanical energy into electric energy

Law of Conservation of Energy

- Energy conversions
  - Some energy may be dissipated as heat, giving lower efficiency

Efficiency

- Poor efficiency in energy transfers results in wasted energy
- An inefficient piece of equipment generates more heat
  - Heat must be removed

Efficiency

- Efficiency (in %) is represented by η (Greek letter eta)
  - Ratio of power out to power

$$\eta = \frac{P_{out}}{P_{in}} \times 100 \ \%$$

- Heat removal requires fans and heat sinks

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Efficiency

- Always less than or equal to 100%
- Efficiencies vary greatly:
  - Power transformers may have efficiencies of up to 98%
  - Some amplifiers have efficiencies below 50%

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Efficiency

- To find the total efficiency of a system
  - Obtain product of individual efficiencies of all subsystems:

$$\eta_{Total} = \eta_1 \times \eta_2 \times \eta_3 \times \cdots$$