Electricity

Electric Current and Simple Circuits

Key Concepts

- What is the relationship between electric charge and electric current?
- What are voltage, current, and resistance? How do they affect each other?

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.

Before	Statement	After
	3. When electric current flows in a wire, the number of electrons in the wire increases.	
	4. Electrons flow more easily in metals than in other materials.	

Study Coach

Create a Quiz Write a quiz question for each paragraph. Answer the question with information from the paragraph. Then work with a partner to quiz each other.

Read to Learn

Electric Current and Electric Circuits

You learned that transferring charge by contact occurs every time lightning strikes. How are a flash of lightning and a TV similar? They both transform the energy of moving electrons to light, sound, and thermal energy. *The movement of electrically charged particles is an* **electric current.**

A Simple Electric Circuit

The movement of electrons in a lightning strike lasts only a fraction of a second. In a TV, electrons continue moving as long as the TV remains on. An electric current flows in a closed path to and from a source of electric energy. *A closed, or complete, path in which an electric current travels is an* **electric circuit**. ✓

Reading Check

1. Identify What do circuits need to make electrons flow?

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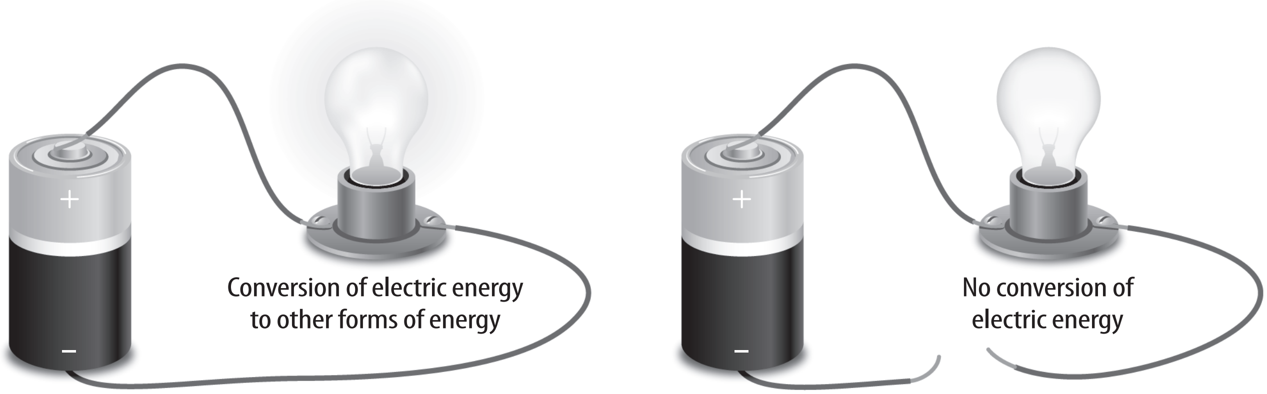
All electric circuits have one thing in common. They transform electric energy to other forms of energy. How do electric energy transformations affect you?

How Electric Charges Flow in a Circuit

On the left side of the figure on the next page, a battery, wires, and a lightbulb are connected in a circuit. The lightbulb glows as electrons flow from one end of the battery, through the wires and lightbulb, and back into the other end of the battery.

Current in a Simple Circuit



When the circuit is broken, or open, as shown on the right side of the figure above, the electrons stop flowing. The bulb stops glowing.

A current of electrons in a wire is somewhat like water pumped through a hose. The amount of water flowing into one end of a hose is the same as the amount of water flowing out the other end. Likewise, the number of electrons flowing into a wire from a power source equals the number of electrons flowing out of the wire, back into the source. The number of electrons in the wire does not change.

The Unit for Electric Current

Electric current is approximately measured as the number of electrons that flow past a point every second. Electrons are so tiny and a circuit has so many that you could never count them one at a time. So scientists count electrons by a quantity called the coulomb (KEW lahm). A coulomb is about 6×10^{18}, or 6,000,000,000,000,000,000. This large number is read as 6 quintillion.

The SI unit for electric current is the ampere (AM pihr), commonly called an amp. Its symbol is A. One ampere of current equals about one coulomb of electrons flowing past a point in a circuit every second. The electric current through a 120-W lightbulb is about 1 A. A hair dryer uses about 10 A, or 60,000,000,000,000,000,000 electrons per second.

What is electric resistance?

Look at the figure above. Suppose you replaced one wire in the circuit with a piece of string. The lightbulb would not glow because there would be no current in the circuit. Why do electrons flow easily in metal wire but not in string? The answer is that wire has much less electric resistance than string. **Electric resistance** *is a measure of how difficult it is for an electric current to flow in a material*.

Visual Check

2. Analyze Why isn't electric energy being converted to light energy in the figure on the right?

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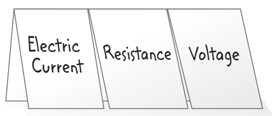
FOLDABLES®

Make a horizontal three-tab book to organize your notes about the flow of electric charge.



Key Concept Check

3. Describe What is the relationship between electric charge and electric current?

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Interpreting Tables

4. Evaluate Can electric current flow more easily in iron or gold?

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Reading Check

5. Define What is an ohm?

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Reading Check

6. Compare How does resistance vary in conductors and insulators?

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Electric Resistance of Different Materials	
Material (20 cm × 1 mm)	**Resistance (ohms)**
Copper	0.004
Gold	0.006
Iron	0.025
Carbon	8.9
Rubber	2,500,000,000,000,000,000

The unit of electric resistance is the ohm (OHM). The symbol for the ohm is the Greek letter Ω (omega). An electric resistance of 20 ohms is written 20 Ω. The table above lists the electric resistances of some materials.

Electric Resistance of Conductors and Insulators

Electric conductors are materials in which electrons easily move. A good conductor has low electric resistance. Usually electric wires are made of copper because copper is one of the best conductors. Recall that electrons cannot easily move through insulators, such as plastic, wood, or string. A good electric insulator has high electric resistance. Atoms of an insulator hold electrons tightly. This prevents electric charges from easily moving through the material. Therefore, replacing a wire in a circuit with string prevents electrons from flowing in a circuit.

Resistance—Length and Thickness

A material's electric resistance also depends on the material's length and thickness. Imagine two copper wires of the same length. One wire is thicker than the other. When two copper wires are the same length, the thicker wire will have less electric resistance. Because the thick wire has less resistance, it will conduct better.

Increasing the length of a conductor also increases its electric resistance. Imagine two copper wires of the same thickness. One is shorter than the other. When two copper wires have the same thickness, the shorter wire will have less electric resistance. Therefore, it will conduct better.

What is voltage?

You probably have heard the term *volt*. You use 1.5-V batteries in a flashlight. You plug a hair dryer into a 120-V outlet. But, what does this mean?

Battery Voltage

In the figure below, a battery creates an electric current in a closed circuit. Energy stored in the battery moves electrons in the circuit. As the electrons move through the circuit, the amount of energy transformed by the circuit depends on the battery's voltage. **Voltage** *is the amount of energy the source uses to move one coulomb of electrons through the circuit*. A circuit with a high voltage source transforms more electric energy to other energy forms than a circuit with a low voltage source. For example, a lightbulb connected to a 9-V battery produces about six times more light and thermal energy than the same lightbulb connected to a 1.5-V battery.

Voltage

Higher voltage across lightbulb — Lower voltage across wire

Voltage in Different Parts of a Circuit

Electric energy transforms to other forms of energy in all parts of a circuit. For example, the lightbulbs in the figure above transform electric energy to light and thermal energy. Even the wires and batteries produce a small amount of thermal energy. In other words, different amounts of energy transform in different parts of a circuit. The voltage measured across a portion of a circuit indicates how much energy transforms in that portion of the circuit.

For example, the voltmeter in the figure above shows where most of the battery's energy is used. The voltmeter shows that voltage is greater across the lightbulb than across the wire. This means that the lightbulb transforms more energy to other forms, such as light and thermal energy, than the wire. ✓

✓ Visual Check

7. Assess Why is the voltage reading across the lightbulb higher than across the segment of wire?

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✓ Reading Check

8. Explain What happens to the energy flowing in an electric circuit?

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Reading Check

9. Relate How is the resistance of a circuit calculated?

Key Concept Check

10. Name How do voltage, current, and resistance affect each other?

Visual Check

11. Identify Circle the equation used to calculate current.

Ohm's Law

When designing electrical devices, engineers choose materials based on their electric resistance. For example, the heating coils in a toaster must be made of a metal with very high electric resistance. This allows the coils to transform most of the circuit's energy to thermal energy. But, how much resistance should a conductor have? The answer is found with Ohm's law.

Using Ohm's Law

Named after German physicist Georg Ohm, **Ohm's law** *is a mathematical equation that describes the relationship between voltage, current, and resistance*. The law states that as the voltage of a circuit's electric energy source increases, the current in the circuit increases, too. Also, as the resistance of a circuit increases, the current decreases. The following equation expresses Ohm's law.

Ohm's Law Equation

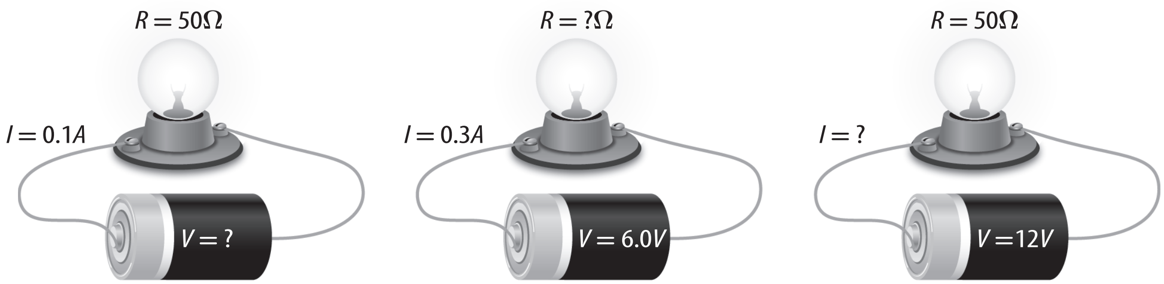
$$\text{voltage } (V) = \text{current } (I) \times \text{resistance } (R)$$

$$V = IR$$

V is the symbol for voltage, measured in volts (V). I is the symbol for electric current, which is measured in amperes (A). And, R is the symbol for electric resistance, measured in ohms (Ω). If you know the value of two of the variables in the equation, you can determine the third, as described in the figure below.

Ohm's Law

Calculate the voltage across the lightbulb. | **Calculate the resistance of the lightbulb.** | **Calculate the current flowing through the lightbulb.**



To find the voltage, start with Ohm's law:

$$V = IR$$

Substitute the known values into the equation:

$$V = 0.1A \times 50\Omega$$
$$V = 5V$$

To find the resistance, start with this form of Ohm's law:

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

Substitute the known values into the equation:

$$R = \frac{6V}{0.3A}$$
$$R = 20\Omega$$

To find the current, start with this form of Ohm's law:

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

Substitute the known values into the equation:

$$I = \frac{12V}{50\Omega}$$
$$I = 0.2A$$

Voltage, Resistance, and Energy Transformation

Often more than one device and a battery are connected as a series circuit. Recall that every part of a series circuit has the same electric current. How can you tell if one device in the circuit has greater electric resistance than the others? Devices with more resistance transform more energy.

You determine which device has more electric resistance with a voltmeter and an understanding of Ohm's law. According to Ohm's law, with equal current, the voltage is greater across the device with a greater resistance. The device with the greater electric resistance has the greater voltage across it. A higher-resistance device transforms more electric energy to other forms of energy.

For example, two lightbulbs and a battery are connected as a series circuit. One lightbulb has a voltage reading of 10 V, and the other lightbulb in the circuit has is a voltage reading of 2 V. The lightbulb with the higher resistance transforms more electric energy to light.

Math Skills

The current through a lightbulb is 0.5 A, and the resistance of the lightbulb is 220 Ω. What is the voltage across the lightbulb?

a. This is what you know:

current: $I = 0.5$ A

resistance: $R = 220\ \Omega$

b. This is what you need to find:

voltage V

c. Use this formula:

$V = IR$

d. Substitute the values for I and R into the formula and multiply:

$V = (0.5\text{ A}) \times (220\ \Omega)$

$= 110\text{ V}$

Answer: The voltage is 110 V.

12. Use a Simple Equation What is the voltage across the ends of a wire coil in a circuit if the current in the wire is 0.1 A and the resistance is 30 Ω?

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Mini Glossary

electric circuit: a closed, or complete, path in which an electric current travels

electric current: the movement of electrically charged particles

electric resistance: a measure of how difficult it is for an electric current to flow in a material

Ohm's law: a mathematical equation that describes the relationship between voltage, current, and resistance

voltage: the amount of energy the source uses to move one coulomb of electrons through the circuit

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that describes how voltage affects the amount of energy that is transformed.

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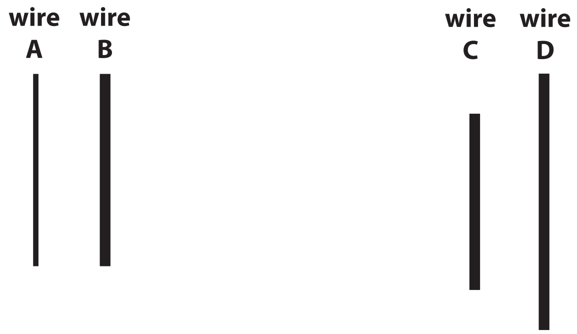
2. For each pair of copper wires below, identify which wire will have more electrical resistance and which wire will be the better conductor.



most electrical resistance: ____________________ ____________________

best conductor: ____________________ ____________________

3. Explain how the terms *ampere* and *coulomb* are related.

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What do you think NOW?

Reread the statements at the beginning of the lesson. Fill in the After column with an A if you agree with the statement or a D if you disagree. Did you change your mind?

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Log on to ConnectED.mcgraw-hill.com and access your textbook to find this lesson's resources.

END OF LESSON