Section 4

Electric Circuits

Objectives

After this lesson, students will be able to

N.2.4.1 Explain what Ohm's law is.

N.2.4.2 Describe the basic features of an electric circuit.

N.2.4.3 Identify how many paths currents can take in series and parallel circuits.

Target Reading Skill

Comparing and Contrasting Explain that comparing and contrasting information shows how ideas, facts, and events are similar and different. The results of the comparison can help students' understanding.

Answers

Sample answers:

Series Circuit: Only one path for current to take

Overlap: Unbroken path that has a current

Parallel Circuit: There are several paths for current to take

All in One Teaching Resources

- Transparency N21

Preteach

Build Background Knowledge

L2

Experience With Circuits

Help students recall their experiences with electric circuits. Ask: **What happens if the wire is cut between the wall switch and a ceiling light at home?** *(The light cannot be turned on.)* **If that wire were cut between the switch and the light, would all the other lights in your home go out as well?** *(No. They could still be turned on.)*

Section 4

Electric Circuits

Reading Preview

Key Concepts

- What is Ohm's law?
- What are the basic features of an electric circuit?
- How many paths can currents take in series and parallel circuits?

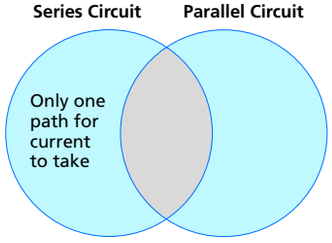
Key Terms

- Ohm's law
- series circuit
- ammeter
- parallel circuit
- voltmeter

Target Reading Skill

Comparing and Contrasting

As you read, compare and contrast series circuits and parallel circuits in a Venn diagram like the one below. Write the similarities in the space where the circles overlap and the differences on the left and right sides.



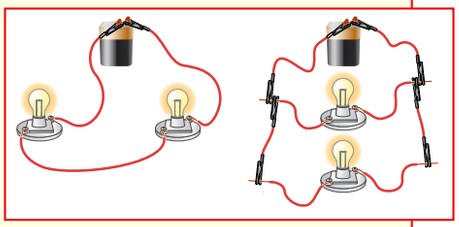
Lab zone Discover Activity

Do the Lights Keep Shining?

1. Construct both of the circuits shown using a battery, several insulated wires, and two light bulbs for each circuit.
2. Connect all wires and observe the light bulbs.
3. Now unscrew one bulb in each circuit. Observe the remaining bulbs.

Think It Over

Observing What happened to the remaining light bulbs when you unscrewed one bulb? How can you account for your observations?



It's a cool, clear night as you stroll along the river with your family. The city is brightly lit, and the river water sparkles with reflected light. In addition to the lights at the top of the lamp-posts, a string of lights borders the river path. They make a striking view.

As you walk, you notice that a few of the lights in the string are burned out. The rest of the lights, however, burn brightly. If one bulb is burned out, how can the rest of the lights continue to shine? The answer depends on how the electric circuit is designed.

Although most lights are shining, some lights are burned out. ▶

Lab zone Discover Activity

Skills Focus Observing

Materials 4 light bulbs with sockets, 2 dry cells with holders, several lengths of insulated wire, alligator clips

Time 15 minutes

Tips Remove insulation from ends of wire. You may want to have students include a switch in their circuits.

L2

Think It Over Sample answer: In one circuit, the remaining bulb went out. Current stopped because the circuit contained only one path. In the other circuit, the remaining bulb stayed lit. That circuit contained a second path for the current.

Ohm's Law

To understand electric circuits, you need to understand how current, voltage, and resistance are related to one another. In the 1800s, George Ohm performed experiments that demonstrated how those three factors are related. Ohm experimented with many substances while studying electrical resistance. He analyzed different types of wire in order to determine the characteristics that affect a wire's resistance.

Ohm's Results Ohm set up a circuit with a voltage between two points on a conductor. He measured the resistance of the conductor and the current between those points. Then he varied the voltage and took new measurements.

Ohm found that if the factors that affect resistance are held constant, the resistance of most conductors does not depend on the voltage across them. Changing the voltage in a circuit changes the current, but will not change the resistance. Ohm concluded that conductors and most other devices have a constant resistance regardless of the applied voltage.

Calculating With Ohm's Law The relationship between resistance, voltage, and current is summed up in **Ohm's law. Ohm's law says that the resistance is equal to the voltage divided by the current.**

This relationship can be represented by the equation below:

$$\text{Resistance} = \frac{\text{Voltage}}{\text{Current}}$$

The units are ohms (Ω) = volts (V) ÷ amps (A). You can rearrange Ohm's law as follows:

$$\text{Voltage} = \text{Current} \times \text{Resistance}$$

You can use the formula to see how changes in resistance, voltage, and current are related. For example, what happens to current if voltage is doubled without changing the resistance? For a constant resistance, if voltage is doubled, current is doubled as well.

Math Skills

Decimals

When calculating voltage, you often use decimals. When you multiply two decimals, the number of decimal places in the product is the sum of the number of decimal places in each decimal you multiply.

If a circuit has a resistance of 30.5 ohms and a current of 0.05 amps, what is its voltage?

$$30.5 \text{ ohms} \times \frac{0.05 \text{ amps}}{1.525 \text{ volts}}$$

Practice Problems Use Ohm's law to calculate the voltage of a circuit with a resistance of 15.2 ohms and a current of 0.10 amps.

FIGURE 16
Measuring Factors in a Circuit
You can use a meter to measure voltage, current, and resistance. **Measuring** *What units are used to measure current and voltage?*

Math Skills

Math Skill Decimals

Focus Ask students to look at the equations for Ohm's Law.

Teach Remind students that when multiplying decimals to calculate voltage the number of decimal places in the product is the sum of the number of decimal places in each number being multiplied. Refer students who need additional help to the Decimals review section of the Skills Handbook.

Answer 1.52 volts

Instruct

Ohm's Law

Teach Key Concepts L2

Resistance, Voltage, and Current

Focus Explain to students that Ohm's law is about how resistance, voltage, and current are related to one another.

Teach Recall for students that the amount of charges that pass through a wire in a unit of time is the rate of electric current. Ask: **What is the unit for the rate of current?** *(Ampere, or amp)* **How does changing the voltage—the potential difference—in a circuit affect the current and the resistance in the circuit?** *(Changing the voltage changes the current, but will not change the resistance.)* **What does Ohm's law say?** *(Resistance is equal to the voltage divided by the current.)*

Apply Explain that by manipulating the values in the equation used to represent Ohm's law, any of the three values can be calculated as long as you know the other two. Ask: **What is the equation you would use to find voltage?** *(V = IR)* **What is the equation you would use to find current?** *(I = V/R)*

learning modality: logical/mathematical

Independent Practice L2

All in One Teaching Resources

- Guided Reading and Study Worksheet: *Electric Circuits*

Student Edition on Audio CD

Monitor Progress L2

Writing Ask students to write the formulas they would use to calculate each of three values in a circuit: resistance, voltage, and current.

Answer

Figure 16 Current is measured in amps, and voltage is measured in volts.

Math Sample Problem

Math Skill Formulas and equations

Focus Tell students that to calculate the resistance in a circuit, they will divide the voltage by the current. This often involves dividing a whole number by a decimal number. Review this skill by solving a division problem on the board, such as 6 divided by 0.3 *(6 ÷ 0.3 = 20)*.

Teach Some students might understand the problem better if they make a drawing of a car, with a battery, a brake light, and a wire in between. Have students label the battery as 12 volts and label the wire as 0.40 amps. Ask: **What is being calculated in this problem?** *(Resistance)* **What values are given?** *(Current and voltage)* **What is the formula used to solve the problem?** *(R = V/I)* **What is the unit used for the answer?** *(Ohms)* **Why is the answer greater than either number in the fraction?** *(You are dividing the voltage by a fraction.)*

Math Practice

Answers

1. 8.0 Ω *(4.0 V ÷ 0.5 A)*

2. 120 V *(12 A × 10 Ω)*

All in One Teaching Resources

- Transparency N22

Features of a Circuit

Teach Key Concepts L2

Basic Features of a Circuit

Focus Tell student that there are three basic features that all electric circuits have.

Teach Ask: **What are some examples of devices that are run by electrical energy?** *(Sample answer: Radio, CD player, light bulb)* **What are sources of electrical energy we use to supply energy to those devices?** *(Batteries, generators, and electric plants)* **What connects electric circuits?** *(Wires)*

Apply Have students look at the circuit in Figure 17, and ask: **What is the device, or resistor, in this circuit?** *(The light bulb)* **What is the source of electrical energy?** *(The battery)* **What connects this electric circuit?** *(Wires)* **learning modality: visual**

Math Practice

1. In a circuit, there is a 0.5-A current in the bulb. The voltage across the bulb is 4.0 V. What is the bulb's resistance?
2. A waffle iron has a 12-A current. If the resistance of the coils is 10 Ω, what must the voltage be?

Math Sample Problem

Calculating Resistance

The brake light on an automobile is connected to a 12-volt battery. If the resulting current is 0.40 amps, what is the resistance of the brake light?

1 Read and Understand

What information are you given?

Battery Voltage = 12 V

Current = 0.40 A

2 Plan and Solve

What quantity are you trying to calculate?

The resistance of the brake light.

What formula contains the given quantities and the unknown quantity?

$$\text{Resistance} = \frac{\text{Voltage}}{\text{Current}}$$

Perform the calculation.

$$\text{Resistance} = \frac{12\ \text{V}}{0.40\ \text{A}} = 30\ \Omega$$

3 Look Back and Check

Does the answer make sense?

The answer makes sense because you are dividing the voltage by a decimal. The answer should be greater than either number in the fraction, which it is.

Features of a Circuit

All electric circuits have the same basic features. **First, circuits have devices that are run by electrical energy.** A radio, a computer, a light bulb, and a refrigerator are all devices that transform electrical energy into another form of energy. A light bulb, for example, transforms electrical energy into electromagnetic energy by giving off light. The light bulb also produces thermal energy by giving off heat. By making fan blades rotate, electric fans transform electrical energy to mechanical energy. Devices such as light bulbs and fans resist the flow of electric current. They are therefore represented as resistors in a circuit.

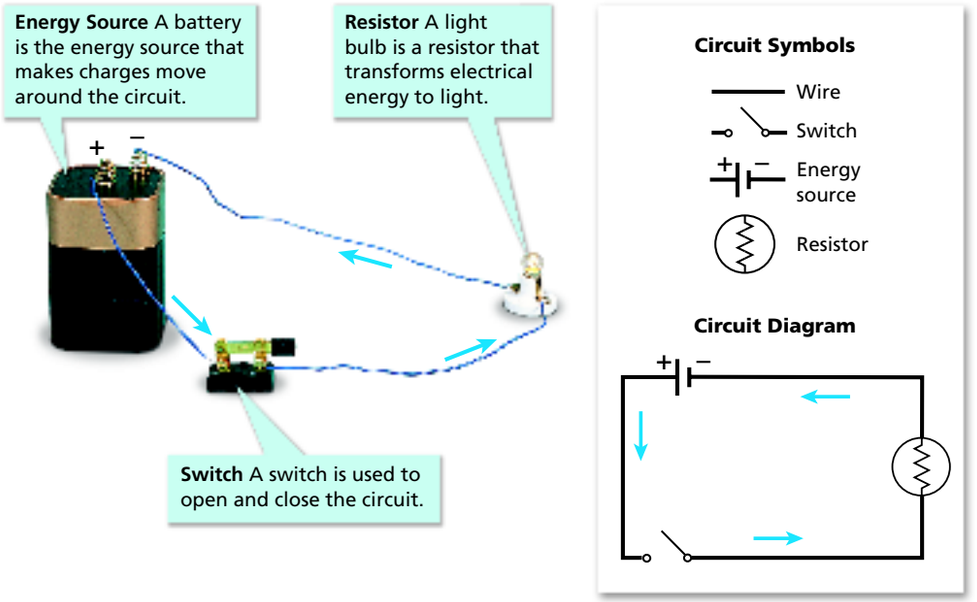
Second, a circuit has a source of electrical energy. Batteries, generators, and electric plants all supply energy to circuits. Recall that energy is the ability to do work. The source of electrical energy makes charges move around a circuit, allowing the device to do work.

Third, electric circuits are connected by conducting wires. The conducting wires complete the path of the current. They allow charges to flow from the energy source to the device that runs on electric current and back to the energy source. A switch is often included in a circuit to control the current in the circuit. Using a switch, you can turn a device on or off by closing or opening the circuit.

Notice that all the parts of a circuit are shown in Figure 17. Each part shown in the photograph is represented in the diagram by a simple symbol. Arrows indicate the direction of current, which flows from positive to negative. The + and – on the battery indicate the positive and negative terminals.

Reading Checkpoint **What is the function of conducting wires in a circuit?**

FIGURE 17
Diagraming a Circuit
Simple symbols make it easy to diagram a circuit. The resistor represents the device that is being run by the current. Resistors include light bulbs, appliances, and huge machines.
Interpreting Diagrams *Which symbol is used to represent a battery?*



Lab zone Teacher Demo L1

A Switch in an Electric Circuit

Materials 3 wires (20 cm long with insulation stripped from the ends), contact switch, light bulb, bulb holder, D-cell (1.5 volt)

Time 5 minutes

Focus Tell students this demonstration will allow them to observe how a switch is used in an electric circuit.

Teach Make a circuit using the contact switch, bulb, battery, and wires. Ask: **How does the switch operate to light the bulb?** *(Sample answer: The switch is a conductor that, when closed, allows charges to flow, lighting the bulb.)* **What happens when the switch is opened?** *(The switch breaks the circuit, stopping the electric current.)*

Apply Have students draw a diagram of the circuit you made that incorporates all the components, including the switch, used in the circuit. Suggest students consult the Circuit Symbols inset in Figure 17 for the symbols to use in their diagrams. **learning modality: visual**

All in One **Teaching Resources**

- Transparency N23

Differentiated Instruction

English Learners/Beginning L1
Comprehension: Link to Visual Guide students in using Figure 17 to learn about the features of a circuit. Explain the labels in the figure, and point out the relevant parts of the pictured circuit. Also, direct their attention to the list of circuit symbols used. **learning modality: visual**

English Learners/Intermediate L2
Comprehension: Ask Questions After students have read the information on features of an electric circuit, ask them to explain in their own words why circuits have devices, need a source of electrical energy, and are connected by conducting wires. If students make any errors, direct them to reread the relevant labels in Figure 17. **learning modality: verbal**

Monitor Progress L2

Writing Ask students to write a description of an electric circuit that includes the three basic features that all electric circuits have.

Answers

Figure 17 The symbol for energy source represents a battery.

Reading Checkpoint The conducting wires complete the path of the current.

Series Circuits

Teach Key Concepts L2

A Circuit With One Path

Focus Tell students that there are two main types of electric circuits, the series circuit and the parallel circuit.

Teach Ask: **In a series circuit, how many paths can the current take?** *(One)* Explain that a disadvantage of a series circuit is that the more resistors there are in the circuit, the less the current, given the same voltage. Ask: **What device is used to measure current?** *(An ammeter)*

Apply Have students use their fingers to trace the path current can take in the series circuit diagram in Figure 18. Ask: **How many resistors are there in this circuit?** *(Three)* **What happens if one of the resistors stops working, such as when a bulb burns out?** *(The circuit would be broken, and the other resistors would stop working.)*

Extend The ***Active Art*** will show students that a series circuit provides only one path for the flow of electrons. **learning modality: visual**

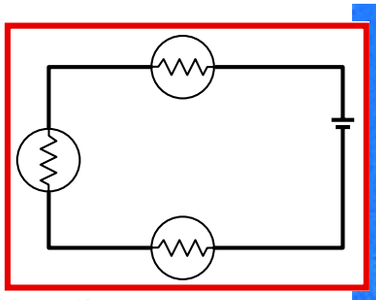
Go Online active art

For: Series and Parallel Circuit activity
Visit: PHSchool.com
Web Code: cgp-4023

Students can interact with the art of series and parallel circuits online.

All in One Teaching Resources

- Transparency N24



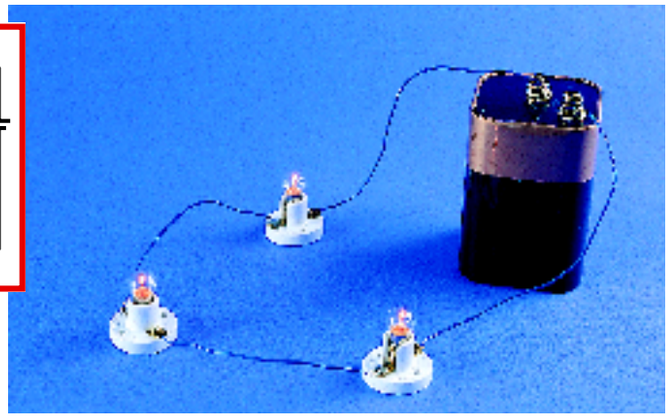


FIGURE 18
A Series Circuit
A series circuit provides only one path for the flow of electrons. **Predicting** *What will happen in a series circuit if one bulb burns out?*

Go Online active art

For: Series and Parallel Circuits Activity
Visit: PHSchool.com
Web Code: cgp-4023

Series Circuits

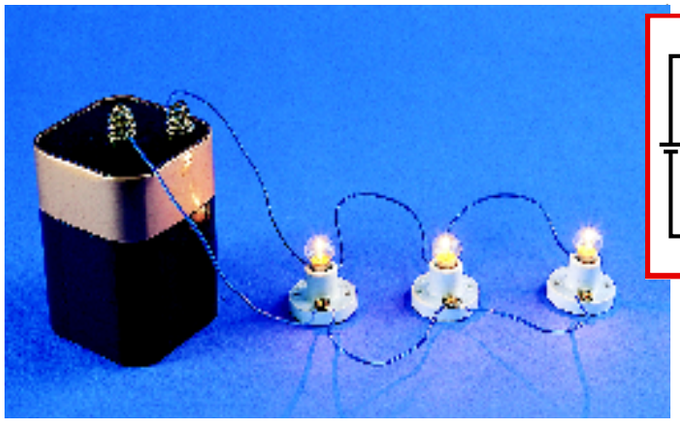
If all the parts of an electric circuit are connected one after another along one path, the circuit is called a **series circuit**. Figure 18 illustrates a series circuit. **In a series circuit, there is only one path for the current to take.** For example, a switch and two light bulbs connected by a single wire are in series with each other.

One Path A series circuit is very simple to design and build, but it has some disadvantages. What happens if a light bulb in a series circuit burns out? A burned-out bulb is a break in the circuit, and there is no other path for the current to take. So if one light goes out, the other lights go out as well.

Resistors in a Series Circuit Another disadvantage of a series circuit is that the light bulbs in the circuit become dimmer as more bulbs are added. Why does that happen? A light bulb is a type of resistor. Think about what happens to the overall resistance of a series circuit as you add more bulbs. The resistance increases. Remember that for a constant voltage, if resistance increases, current decreases. So as light bulbs are added to a series circuit, the current decreases. The result is that the bulbs burn less brightly.

Measuring Current An **ammeter** is a device used to measure current. If you want to measure the current through some device in a circuit, the ammeter should be connected in series with that device.

Reading Checkpoint **How does resistance change as you add bulbs to a series circuit?**



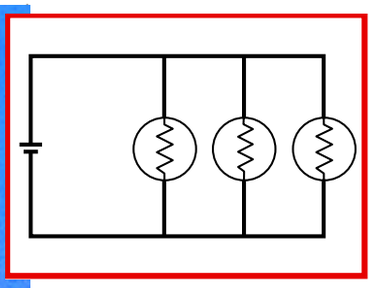


FIGURE 19
A Parallel Circuit
A parallel circuit provides several paths for the flow of electrons. **Predicting** *What will happen in a parallel circuit if one bulb burns out?*

Parallel Circuits

As you gaze at a string of lights, you observe that some bulbs burn brightly, but others are burned out. Your observation tells you that these bulbs are connected in a parallel circuit. In a **parallel circuit,** the different parts of the circuit are on separate branches. Figure 19 shows a parallel circuit. **In a parallel circuit, there are several paths for current to take.** Each bulb is connected by a separate path from the battery and back to the battery.

Several Paths What happens if a light burns out in a parallel circuit? If there is a break in one branch, charges can still move through the other branches. So if one bulb goes out, the others remain lit. Switches can be added to each branch to turn lights on and off without affecting the other branches.

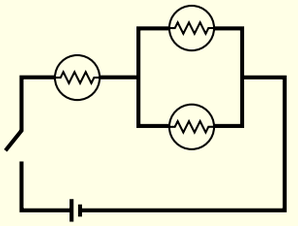
Resistors in a Parallel Circuit What happens to the resistance of a parallel circuit when you add a branch? The overall resistance actually decreases. To understand why this happens, consider blowing through a single straw. The straw resists the flow of air so that only a certain amount of air comes out. However, if you use two straws, twice as much air can flow. The more straws you have, the more paths the air has to follow. The air encounters less resistance. As new branches are added to a parallel circuit, the electric current has more paths to follow, so the overall resistance decreases.

Remember that for a given voltage, if resistance decreases, current increases. The additional current travels along each new branch without affecting the original branches. So as you add branches to a parallel circuit, the brightness of the light bulbs does not change.

Lab zone Skills Activity

Predicting

1. Look at the circuit diagram below. Predict whether all three light bulbs will shine with the same brightness.



2. Construct the circuit using a battery and three identical light bulbs. Observe the brightness of the bulbs.

Does this circuit behave like a parallel circuit or a series circuit? Explain.

Lab zone Skills Activity

Skills Focus Predicting L2

Materials dry cell, 3 light bulbs, insulated wire, switch

Time 15 minutes

Tips Help students recognize that this circuit contains one bulb in series and two bulbs in parallel.

Expected Outcome Sample answer: The circuit behaves like both types because it contains one bulb in series and two bulbs in parallel. The series bulb is brighter than the two parallel bulbs because the series bulb carries the same amount of current that the two parallel bulbs share.

Extend Have students predict what would happen if another bulb were added to the parallel circuit. **learning modality: logical/mathematical**

Parallel Circuits

Teach Key Concepts L2

A Circuit With Several Paths

Focus Tell students that in a parallel circuit, different branches allow the current to take any of several paths to complete the circuit.

Teach Ask: **How is a parallel circuit different from a series circuit?** *(In a series circuit, there is only one path for the current to take. In a parallel circuit, there are several paths.)* **If you add another branch to a parallel circuit, why does the resistance decrease?** *(An added branch decreases the resistance because the electric current has one more path to follow.)*

Apply Have students use their fingers to trace the path current can take in the parallel circuit diagram in Figure 19. Ask: **How many resistors are there in this circuit?** *(Three)* **What happens if one of the resistors stops working, such as when a bulb burns out?** *(The circuit would not be broken because there is more than one path for the current to take. The other resistors would still keep working.)* **learning modality: visual**

Monitor Progress L2

Oral Presentation Call on students to name one advantage and one disadvantage each for a series circuit and a parallel circuit.

Answers

Figure 18 The other lights will go out as well.

Figure 19 The other bulbs will remain lit.

Reading Checkpoint The total resistance increases as you add bulbs to a series circuit.

Monitor Progress L2

Answer

Reading Checkpoint A parallel circuit

Assess

Reviewing Key Concepts

1. a. Ohm investigated resistance, voltage, and current. **b.** Resistance is equal to voltage divided by current. **c.** The current will be multiplied four times, too.

2. a. An electric circuit has one or more devices run by electrical energy, a source of electrical energy, and conducting wires. **b.** Students should represent each feature of the circuit using the appropriate symbol. **c.** Students' circuit diagrams should be much like the one shown in Figure 18, except that the resistor will be located between the switch and the positive terminal of the energy source.

3. a. A series circuit is one in which the current can take only one path. A parallel circuit is one in which the current can take several paths. **b.** The lights are in a series circuit. The current stops because part of its path has been removed.

Reteach L1

Draw circuit diagrams on four different cards—two series circuits and two parallel circuits. Make sure that the components of each diagram are only in series or only in parallel. Hold up one card at a time, and ask students to identify the type of circuit shown.

Performance Assessment L2

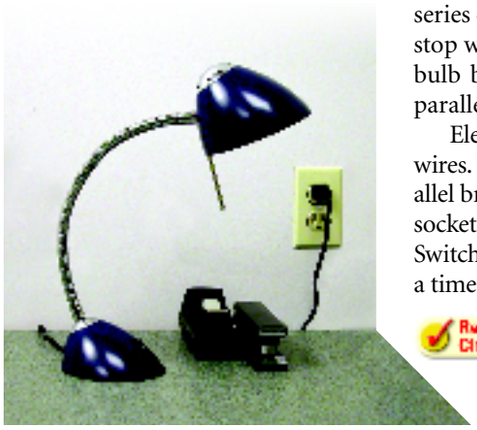
Drawing Have students draw two circuit diagrams—one that shows three bulbs in a series circuit and one that shows three bulbs in a parallel circuit.

Students can save their circuit diagrams in their portfolios. Portfolio

All in One Teaching Resources

- Section Summary: *Electric Circuits*
- Review and Reinforce: *Electric Circuits*
- Enrich: *Electric Circuits*

FIGURE 20
Household Circuits
Homes and businesses are wired with parallel circuits. That means that other appliances will stay on if the bulb in one light burns out.



Measuring Voltage A **voltmeter** is a device used to measure voltage, or electrical potential energy difference. When you measure the voltage of a device, the voltmeter and the device should be wired as a parallel circuit.

Household Circuits Would you want the circuits in your home to be series circuits? Of course not. With a series circuit, all the electrical devices in your home would stop working every time a switch was turned off or a light bulb burned out. Instead, the circuits in your home are parallel circuits.

Electrical energy enters a home through heavy-duty wires. These heavy-duty wires have very low resistance. Parallel branches extend out from the heavy-duty wires to wall sockets, and then to appliances and lights in each room. Switches are installed to control one branch of the circuit at a time. The voltage in most household circuits is 120 volts.

Reading Checkpoint **The wiring in your house forms what kind of circuit?**

Section 4 Assessment

Target Reading Skill **Comparing and Contrasting** Use the information in your Venn diagram about series and parallel circuits to help you answer Question 3.

Reviewing Key Concepts

1. a. **Reviewing** What three related electrical factors did Georg Ohm investigate?

b. **Explaining** What did Ohm discover about the relationship between these three factors?

c. **Predicting** In a circuit with a constant resistance, what will happen to the current if the voltage is multiplied four times?

2. a. **Listing** List three basic features of an electric circuit.

b. **Interpreting Diagrams** Use Figure 17 to show how each feature is represented in a circuit diagram.

c. **Applying Concepts** Draw a diagram of a circuit that includes one resistor. The resistor is located between the switch and the positive terminal of the energy source.

3. a. **Comparing and Contrasting** Compare and contrast series and parallel circuits.

b. **Relating Cause and Effect** If you remove one bulb from a string of lights, all the remaining lights will go out. Are the lights in a series circuit or parallel circuit? Explain.

Math Practice

4. **Calculating Resistance** The current through a resistor of unknown value is 0.025 A when it is connected to a 10.0-V source. What is the value of the resistor?

5. **Calculating Resistance** Suppose that the voltage remains the same as in Question 4, and the current changes to 0.031 A. What is the new value of the resistor?

Math Practice

Answers

4. 400 Ω *(10.0 V ÷ 0.025 A)*

5. 322.58 Ω *(10.0 V ÷ 0.031 A)*

Lab zone Chapter Project

Keep Students on Track Check to see that students have begun to test their alarm circuits. If students are having a hard time getting their switches to work properly, help them by providing hints on how to get the two ends of the wires to make electrical contact. Most completed circuits will be in a primitive form on a desktop. Encourage students to improve these designs.