LESSON 5

Electrical Circuits

Inquiries 2
Periods 3

CONCEPTS

A closed path in an electrical circuit is one that can be traced in a continuous path from the source of electrical energy, around the circuit, and back to the energy source.

An electrical circuit will transfer energy from the source to the user only if there is a closed path.

A series circuit has only one closed path connecting the electrical components.

Electrical components in series are on the same closed path; electrical components in series are on or off at the same time.

A parallel circuit has more than one closed path connecting the electrical components.

Electrical components in parallel are on separate closed paths; electrical components in parallel can simultaneously have one component turned on and another component turned off.

CONCEPTS (cont.)

Switches are used to open and close paths in circuits.

Schematic diagrams use symbols to represent the components of electrical devices and to show how these components are connected in electrical circuits.

STUDENT OBJECTIVES

Identify the components necessary for a closed circuit.

Build electrical circuits in which a lightbulb or a combination of lightbulbs will light in prescribed ways.

Draw schematics that represent electrical circuits.

Identify the differences between series and parallel circuits.

Use switches to turn lightbulbs on and off.

OVERVIEW

In this lesson, students begin their investigations of current electricity. In Lessons 2 and 3, which focused on static electricity, students saw that energy generated by static electricity could light a neon lightbulb briefly. Keeping a lightbulb lit continuously, however, requires a steady supply of electrical energy. Electrical circuits are a means of providing a steady supply of electrical energy to operate electrical devices. Lessons 5–12 are designed to develop students' understandings of electrical circuits. Students investigate electrical current and voltage and how they are related in closed circuits. They also learn how to calculate the electrical power of a device and the electrical energy that a device uses when it is operated for a certain period of time.

In this lesson, students use batteries, lightbulbs, and switches to build circuits that turn lightbulbs on and off in a variety of ways. In Inquiry 5.1, students build a simple circuit and identify the properties that make it a closed circuit. They also learn how to draw electrical diagrams, or schematics, for the circuits. In Inquiry 5.2, they build circuits in which they can turn lightbulbs on and off in different combinations. They draw schematics of these circuits and use their schematics to develop an understanding of series and parallel circuits.

BACKGROUND

An electrical circuit is a system that enables electrical energy to be distributed to devices that transform the electrical energy into other forms of energy. The energy systems that students explored in Lesson 1 were all electrical circuits. Students found that each system had an electrical energy source and an electrical energy user. Each

system also had wires or leads that connected the source to the user. All electrical circuits have the following components: an electrical energy source, an electrical energy consumer, and a means to connect the two. When the source and the user are connected in a continuous or unbroken path, charge flows in the wires. This charge flow, or current, provides the mechanism to transport electrical energy from the source to the user. A continuous charge flow enables a device to operate continuously.

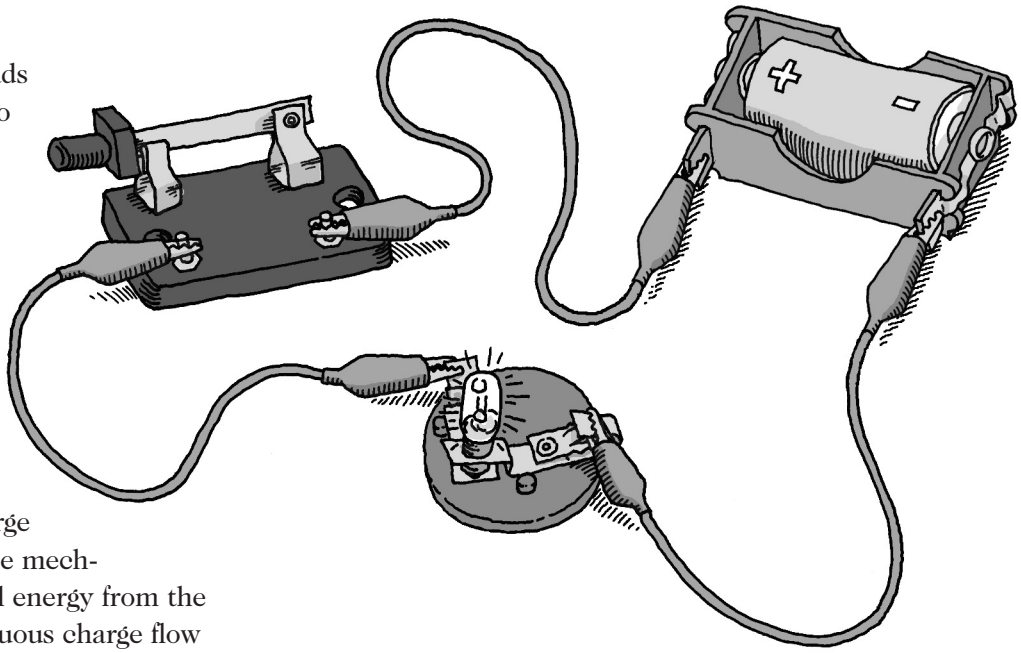

Figure 5.1 *Closed circuit: With the switch closed, there is a continuous path around the circuit, resulting in a charge flow.*

Open and Closed Circuits

A continuous charge flow occurs if a circuit is closed. A closed circuit is one that has an unbroken path for charge flow, as shown in Figure 5.1. This means that, starting at the energy source for the circuit, you can trace a continuous, unbroken path through the wires and devices in the circuit and return to the energy source.

An open circuit has a gap or break in the path as you move through the circuit (see Figure 5.2). In open circuits, there is no charge flow. Without the charge flow, electrical energy cannot be transported to the electrical devices, so they cannot operate.

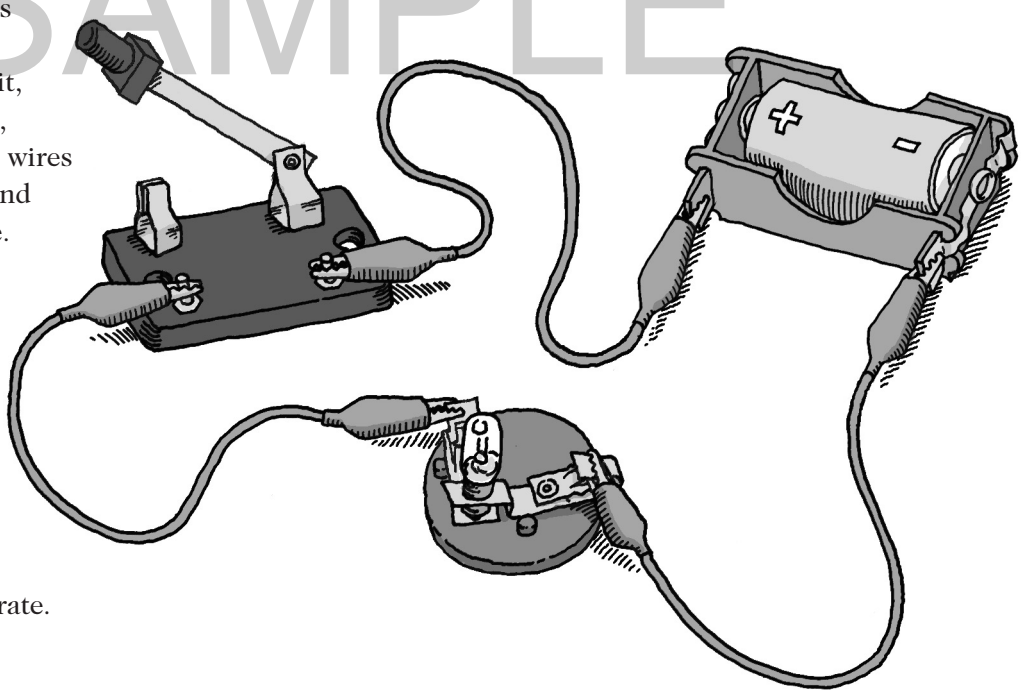

Figure 5.2 *Open circuit: With the switch open, there is a broken path, resulting in no charge flow.*

Switches

A switch is one device that is used to control circuits by controlling the flow of charge. Opening a switch creates a gap or break in the circuit that stops the charge flow. Closing a switch provides a continuous path that allows charge to flow in the circuit.

Series Circuits

A series circuit is one that has only one closed path that can be traced from the energy source through the devices in the circuit and back to the source (see Figure 5.3). All devices in a series circuit lie on the same path and have the same charge flow through them. If several devices are connected together in a series circuit and the charge flow is interrupted to one device, it is interrupted to all. Thus, devices in a series circuit are all on at the same time or all off at the same time.

Switches are usually connected in series with devices. Opening or closing a switch on a path turns devices on and off because the switch starts or stops the charge flow on the path. For example, in a typical home, you will find a wall switch in series with a ceiling light; opening and closing the switch turns the light on and off.

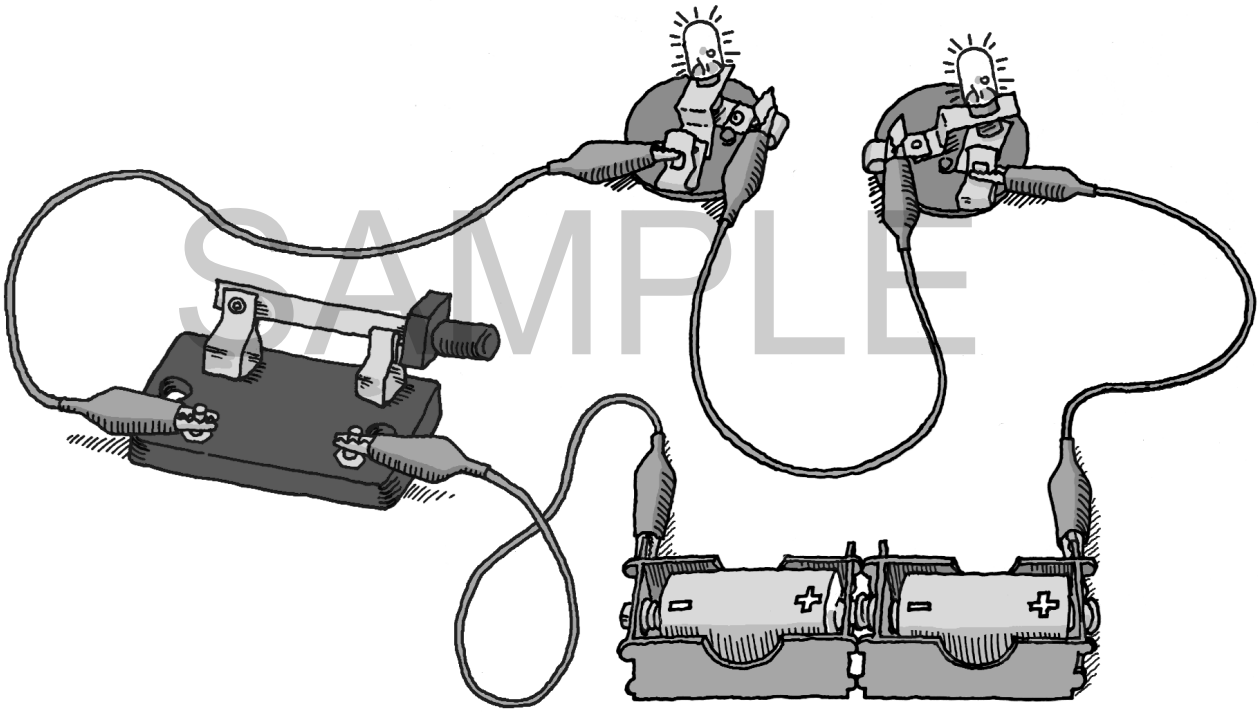

Figure 5.3 *Two lightbulbs in series in a circuit*

Parallel Circuits

A parallel circuit is one that has more than one closed path connecting devices to the energy source, as illustrated in Figure 5.4. Therefore, different devices can be connected to the energy source on different closed paths. Interrupting the charge flow for one path does not interrupt it for other closed paths. Devices connected in parallel can operate independently of one another; that is, one device can be off, while other devices are on, since each has its own closed path to the energy source. All homes contain parallel circuits, which allow some lights or appliances to be on while others are off.

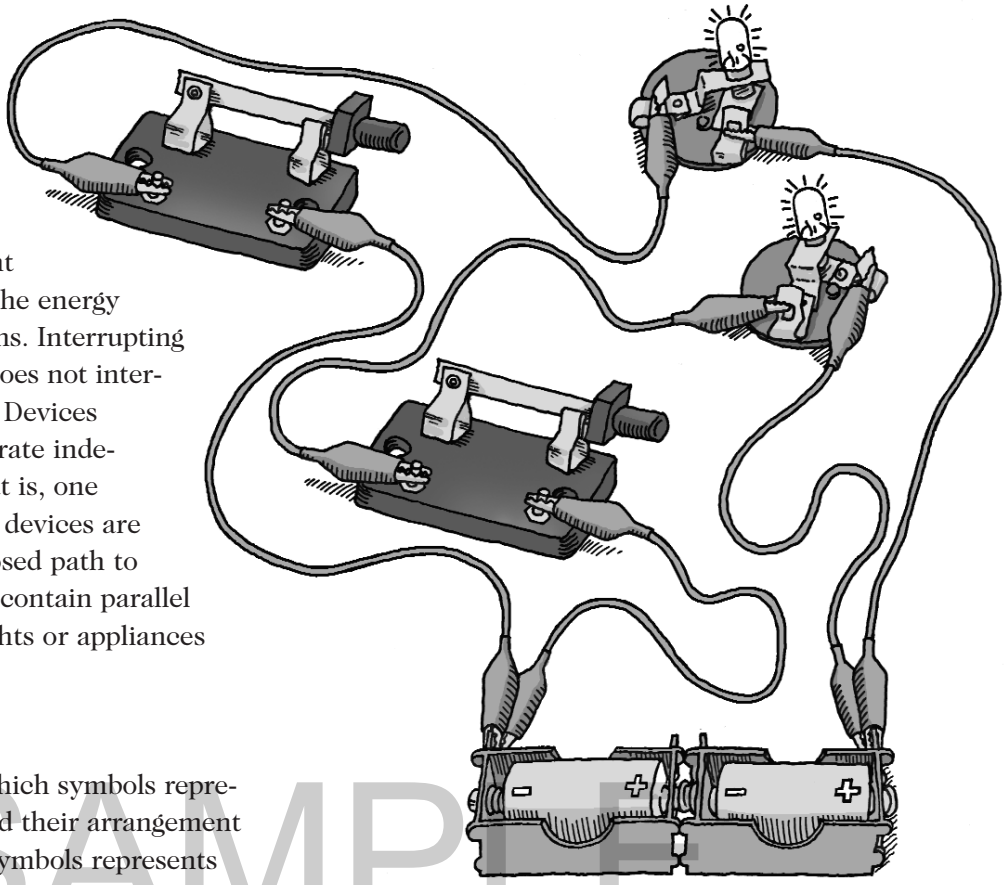

Figure 5.4 *Two lightbulbs connected in parallel in a circuit*

Schematics

Schematics are diagrams in which symbols represent electrical components and their arrangement in circuits. A standard set of symbols represents components such as batteries, switches, lightbulbs, and so on. These symbols portray complex circuits in an efficient way. Conventional drawing methods are limited: They do not allow for a clear portrayal of all the components of such devices as a radio, nor do they show how a device's components are arranged to make a complete circuit. Schematics simplify conventional drawings, which allows for easy identification of all of the components of a circuit. In addition, a schematic shows which items are in series with each other, which are in parallel, and which other connections are needed to make the circuit perform its desired function. Figures 5.5 and 5.6 show the schematics for, respectively, Figures 5.1 (circuit with closed switch) and 5.2 (circuit with an open switch).

The electrical symbols chart, shown in SG Figure 5.3 and TG Figure 5.17, shows the symbols for the electrical components used in this module. A poster of this chart is included in your materials kit. Allow students to refer to this chart as needed when drawing schematics in future lessons.

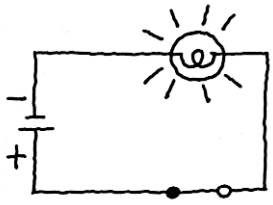

Figure 5.5 *Schematic for circuit with the switch closed, as shown in the conventional drawing in Figure 5.1.*

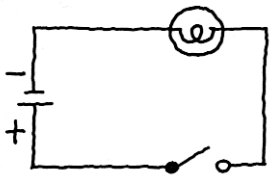

Figure 5.6 *Schematic circuit with the switch open, as shown in the conventional drawing in Figure 5.2.*

IMPLEMENTING LESSON 5

This lesson requires three periods. Complete "Getting Started" and Inquiry 5.1 in the first period and Inquiry 5.2 during the second. Use the third period to discuss "Reflecting on What You've Done" and the reading selections.

Getting Started

In "Getting Started," students examine their circuit systems kit and identify its components. This gives them a chance to become familiar with and make an inventory of the kit's contents. They should keep an inventory in their science notebooks and update the inventory as they add additional components to the kit in succeeding lessons. Keeping an inventory aids in equipment management and provides a means of holding students accountable for the contents of their kits.

Students must have secure connections for their circuits to function properly. SG Figures 5.1 and 5.2 and TG Figures 5.7 and 5.8 show how to produce the best connections by attaching wire leads to the batteries and to the switches properly.

Inquiry 5.1

In Inquiry 5.1, students build a simple circuit and draw in their science notebooks a picture that shows the materials they used and the connections that make the lightbulb light. Expect students' skill in building circuits to vary. Some will bring prior experience with circuits to the module; others will have to learn in class. To turn the lightbulb off, students may disconnect a wire from the lightbulb or battery, or they may put a switch in the circuit, using it to open and close the circuit. Both solutions are acceptable means of controlling the circuit and of turning the lightbulbs on and off.

By examining other groups' circuits, students should recognize that each diagram makes a complete loop or closed path from the energy source to the lightbulb and back to the source. They can then use these observations to write, in their own words, the definition of an electrical circuit.

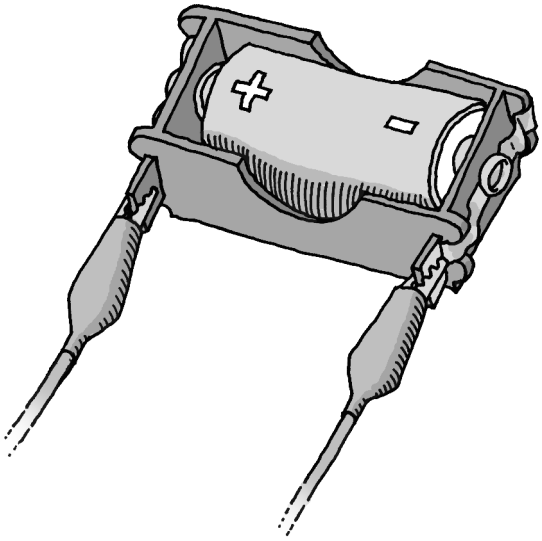

Figure 5.7 *How to securely connect wire leads to a battery*

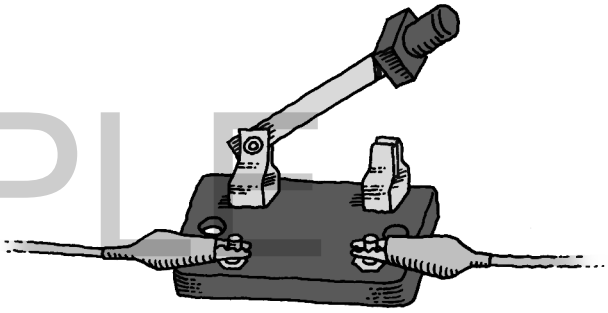

Figure 5.8 *How to securely connect wire leads to a switch*

Initially, students are asked to draw a picture of their circuit and its components. When students discover how time consuming this step is, they should see the time-saving value of electrical diagrams, or schematics. After they read about schematics, they can learn to use symbols to represent the components in their drawings. Working with the schematics helps students develop an appreciation for the value of symbols, allowing them to simplify their diagrams and communicate information more efficiently.

Inquiry 5.2

In Inquiry 5.2, students explore how to connect batteries, lightbulbs, and wires to make a set of bulbs light in different combinations. They build both series and parallel circuits. Procedure Step 2 in the Student Guide describes the different lightbulb combinations that students are to build. Students must figure out how to make the bulbs light as directed using only the equipment in their circuit systems kit. Students turn a lightbulb on and off by using switches, unscrewing bulbs, or simply disconnecting a wire from a lightbulb. Allow students to use or try all of these methods.

SAFETY TIP

Students should not screw the lightbulbs too tightly into the holders, which may cause the seal between the lightbulb globe and base to break. Students should turn the lightbulb gently until it makes contact with the base of the holder.

Students are not given the definitions of closed and open circuits; instead, they are encouraged to construct a meaning for these circuits from their experiences with the circuits in these inquiries. They should begin to realize that the circuits must have a closed path for the lightbulbs to light. Likewise, they are not given definitions for series and parallel circuits; instead, they should analyze the circuits they built. From their observations of how the lightbulbs can be turned on and off, they can begin to recognize that lightbulbs on the same path (series lightbulbs) must be both on or both off at the same time. They should see that lightbulbs on separate closed paths (parallel lightbulbs) can be on and off independently of one another. The separate closed paths in the circuit are called parallel lines and the circuits with parallel lines are called parallel circuits.

Use the questions in "Reflecting on What You've Done" to initiate a class discussion that focuses on what students have discovered about circuits in this lesson. Students are not asked to describe what they observe in terms of charge flow. They will investigate charge flow in Lesson 6.

ANTICIPATED OUTCOMES

In Inquiry 5.1, students are asked to find different ways to light a bulb. Figures 5.9 and 5.10 show methods that students can use to connect a battery with a lightbulb to light the bulb. Figure 5.11 is a schematic that shows a circuit with a switch in it. Figure 5.12 shows the schematic for Figure 5.9.

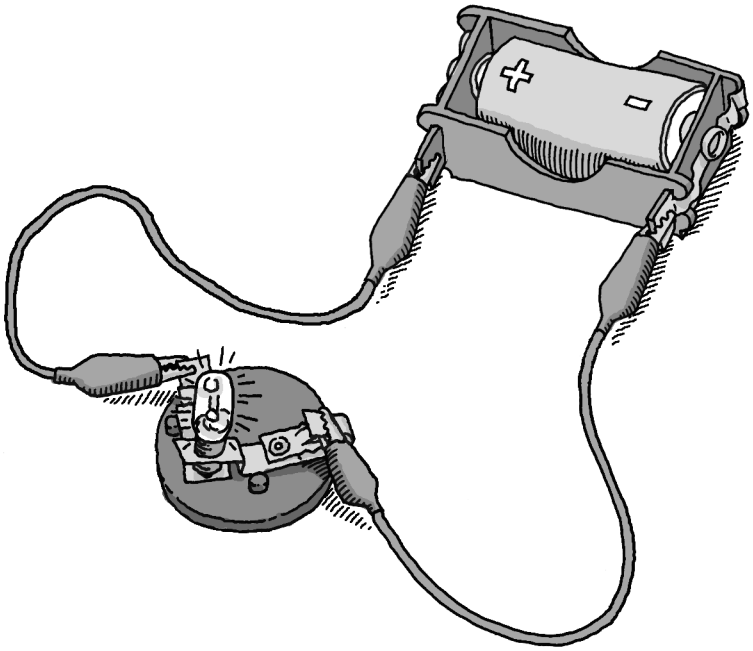

Figure 5.9 *Method 1—lighting the lightbulb*

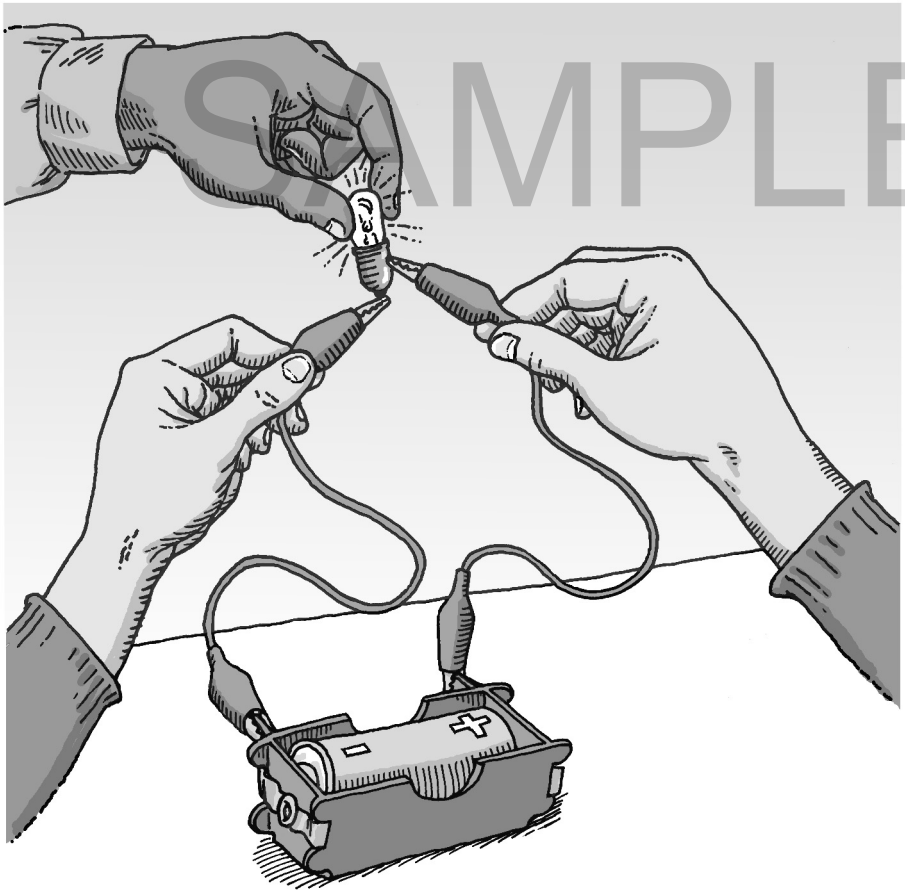

Figure 5.10 *Method 2—lighting the lightbulb*

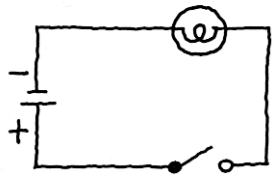

Figure 5.11 *A circuit with a switch*

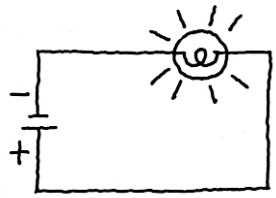

Figure 5.12 *Schematic for a simple circuit with no switch, as drawn conventionally in Figure 5.9*

Figures 5.13–5.16 show schematics for the student-built circuits in Inquiry 5.2. These circuit illustrations include switches. Students may draw diagrams without switches if they choose unscrewing the lightbulbs as their method of turning them on and off.

Circuit A

A circuit with two lightbulbs connected so that both must be on at the same time or both must be off at the same time

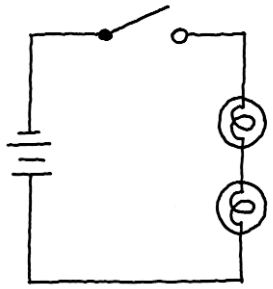

Figure 5.13 *Schematic for Circuit A*

Circuit B

A circuit with two lightbulbs connected so that one lightbulb can be turned off but the other lightbulb stays on

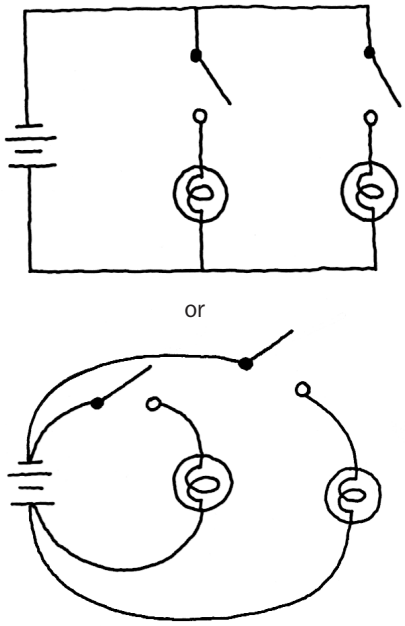

Figure 5.14 *Schematic for Circuit B*

Circuit C

A circuit with three lightbulbs connected so that any one lightbulb can be turned off but the other two lightbulbs stay on

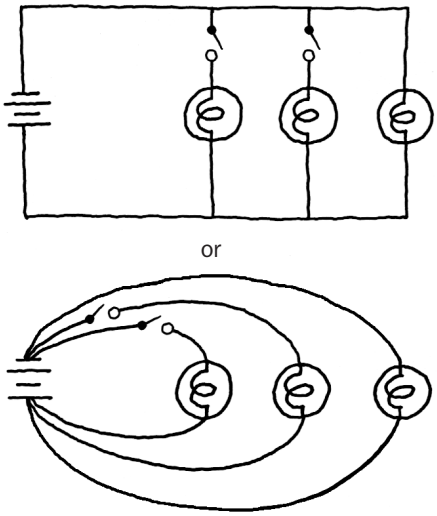

Figure 5.15 *Schematic for Circuit C*

Circuit D

A circuit with three lightbulbs connected so that turning off one lightbulb turns off another lightbulb, but the third lightbulb stays on

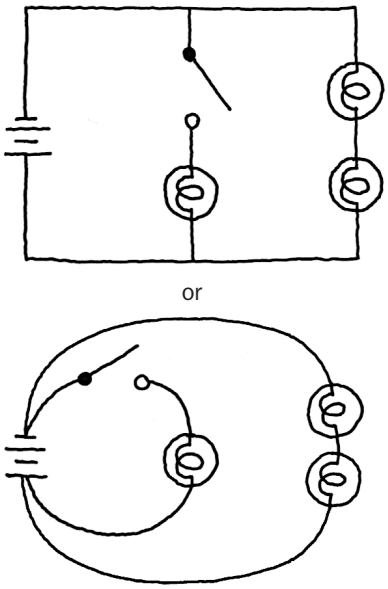

Figure 5.16 *Schematic for Circuit D*

READING SELECTIONS

Three reading selections accompany this lesson. The background reader "Drawing Electrical Diagrams" describes the advantages of using schematic diagrams to show the components of circuits and how they are connected and introduces the standard symbols for most electrical components. Students will not use all these symbols in this lesson, and they will not recognize some of the components for which symbols appear. Inform them that they will learn about these components as they progress through the module. Assure them that they can refer to the electrical symbols chart later, as needed.

"Electricity at Home: Safety Means 'Don't Touch!'" offers students guidelines for the safe use of electricity in their homes. "Get Wired" explains household wiring and how it supplies electrical current to appliances.

MATERIALS FOR LESSON 5

For the class

1 Electrical Energy and Circuit Design poster

For each student

1 copy of Student Sheet 5.2: Lighting More Lightbulbs

For each group

1 circuit systems kit
- 1 clear plastic box with lid
- 3 D-cell batteries
- 3 plastic D-cell battery holders
- 1 pack of connector wires with alligator clips (pack of 10)
- 2 knife switches, single-pole/single-throw
- 3 mini lightbulbs, 2.5 V
- 3 mini bulb holders
- 1 electric buzzer

PREPARATION

1. Make sure students have adequate space at their inquiry stations to set up the circuits for this lesson. They should have a clear table surface so that they can set up their circuits and clearly see the connections.
2. Put the materials for the circuit systems kits in the plastic boxes provided. Students will use these materials over the course of several lessons, during which time they will add other components to the boxes.
3. Designate a storage space where students can return their circuit systems kits at the end of the period or at the end of the day.

Getting Started

1. Distribute the circuit systems kits and have students examine the contents of each box and identify each item using the equipment list. Remind them that they will use this kit for many of the investigations that follow.

2. Have students make a list of the kit's components in their science notebooks and tell them to leave room to add components to these inventory lists in future lessons. Or you can create one template inventory list of the kit's components and make enough copies of the list for each group. To ensure that their kits are complete when they start a lesson, students can then check off every component on the inventory list each time they use the kit.

3. Have students look at Figures 5.1 and 5.2 in the Student Guide. These illustrations show the best way to securely connect the wire leads to the battery holders and switches. Demonstrate, if necessary, how to use the alligator clips to attach the wires to the battery holders and switches.

Inquiry 5.1
Lighting a Lightbulb

PROCEDURE

1. Challenge students to use the materials in the circuit systems kit to build a circuit that will light a single lightbulb.

2. Once they have succeeded in lighting the bulb, have students draw in their science notebook a picture of their circuit that shows how the components are connected. Students' ability to draw the circuit will vary. Some will find it difficult to draw a picture of their circuit, while others with more drawing ability may take time to make a more detailed picture.

3. Have students discuss the following questions:

   What one thing could you do to turn your lightbulb off?

   How would that change your drawing?

4. Visit each group and have them demonstrate for you what they would do to turn the lightbulb off.

5. Encourage students to compare their drawings with those of other groups, and ask them to list what is common to all. They should recognize that the drawings show the same components and that wires connect the components to each other. Some will notice that all the paths are closed loops.

6. Have students write in their science notebooks their definition of the term "electrical circuit." After they compare their definitions, encourage the class to reach agreement on what makes an electrical circuit.

7. Have students read "Drawing Electrical Diagrams."

8. Have students convert their drawings to schematic diagrams using the electrical symbols chart, as shown in SG Figure 5.3 and TG Figure 5.17. Circulate among them as they draw to see that they are using the symbols correctly. You might have a student put a correctly drawn schematic on the board or on an overhead transparency for students to compare with their own schematics.

9. Initiate a class discussion to help students recognize that schematics provide a convenient and efficient way to represent an electrical circuit. You may want to collect student schematics and review them before the next class to see how well students are completing their diagrams.

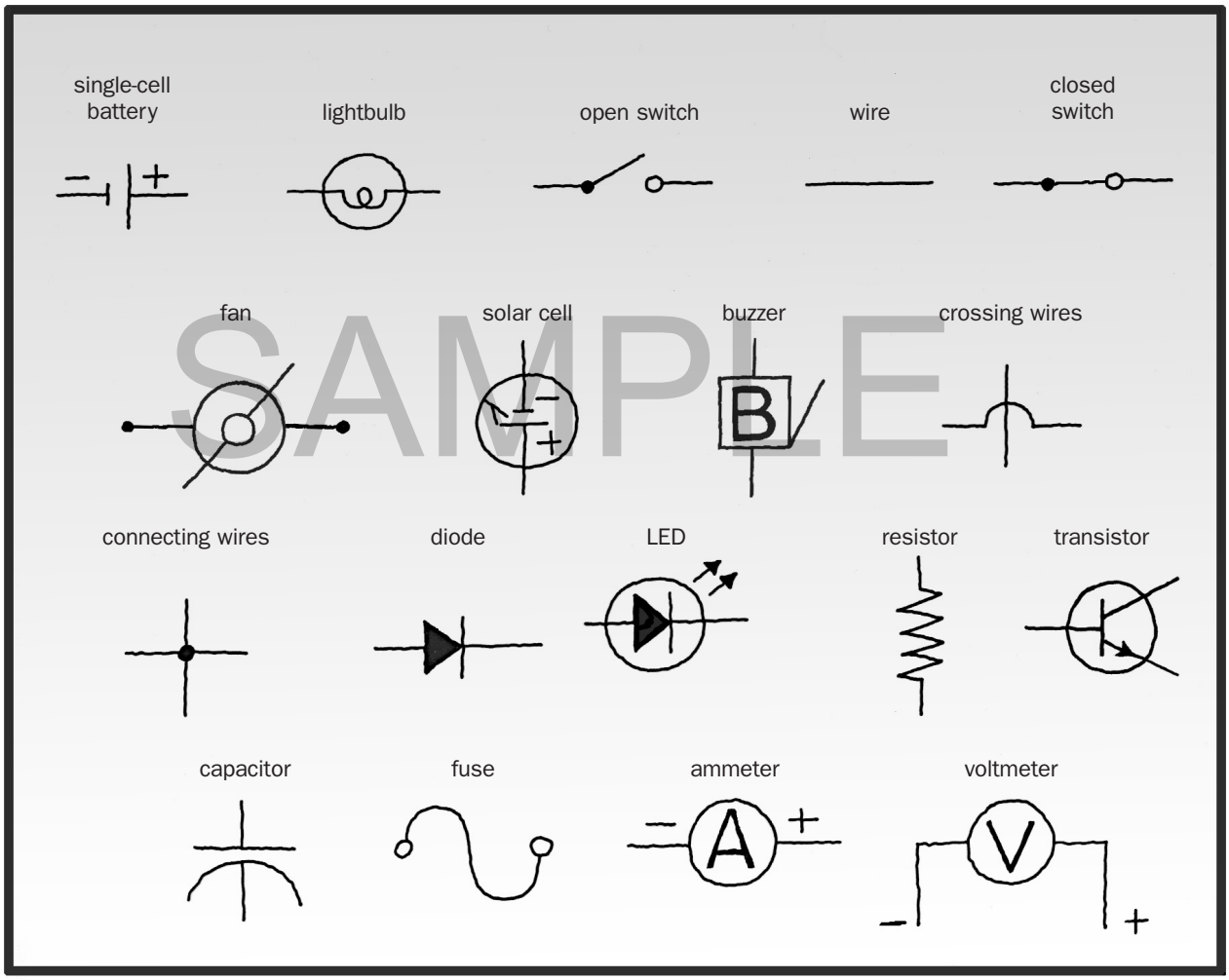

Figure 5.17 *Electrical symbols chart*

Inquiry 5.2
Lighting More Lightbulbs

PROCEDURE

1. Have students read the directions for Inquiry 5.2. Make sure they understand that they are to build four circuits, one at a time, as described in Procedure Step 2 of the Student Guide. After they have successfully built each circuit, they should draw its schematic on the student sheet.

2. Observe groups as they build the circuits. Make sure all students are involved in making the connections and drawing the diagrams.

3. Invite students who successfully build the circuits to draw their schematics on the board. Try to have at least one student-drawn schematic on the board for each of the four circuits.

4. Allow students time to answer the following questions on the student sheet. Then use these questions to initiate a discussion about why these circuits work to light the lightbulbs:

   A. What kind of path is needed for a lightbulb to stay on continuously?

   B. How is it possible for one lightbulb to be on while another in the same circuit is off?

REFLECTIONS

Have students answer the following questions and discuss their answers with the class.

A. Why is an electrical circuit that lights a lightbulb called a "closed" circuit? (The path is continuous with no breaks as you trace the path from the energy source, move through the circuit, and come back to the source. There are no open switches or breaks to interrupt the path.)

B. How can you tell that a circuit is closed? (The electrical device works properly.)

C. In an electrical diagram or schematic, how could you check to see if a circuit is closed? (Use a pencil and start at any point in the circuit. If you can go around the circuit and return to the starting point with no gaps or breaks in the path that you trace, then the circuit is closed.)

D. What does each of the following items do in a circuit: battery, lightbulb, switch, and wire? (A battery provides energy for the circuit. A lightbulb transforms electrical energy to other useful forms—light and heat. A switch opens and closes a circuit or lines in a circuit. The wires connect circuit components to each other and provide paths for charge flow).

E. A series circuit is one that has only one closed path around the circuit. Which of the circuits that you built in Inquiry 5.2 are series circuits? (Circuit A is a series circuit.)

F. A parallel circuit is one that has more than one closed path around the circuit. Which of the circuits that you built in Inquiry 5.2 are parallel circuits? (Circuits B and C are parallel circuits. Circuit D is a series/parallel combination: Two lightbulbs are in series, and the third one is in parallel with the other two.)

HOMEWORK

Period 1

Have students read "Electricity at Home: Safety Means 'Don't Touch!'"

Period 2

Have students answer the questions on the student sheet and review the questions in "Reflecting on What You've Done" in preparation for discussion in the next class.

EXTENSIONS

Technological Design

1. Have students use a computer circuit-simulation program to build electrical circuits.

Technological Design

2. Have students examine a blueprint for a house. Ask them to describe how a blueprint is like a schematic.

Technological Design

3. Have students read "Get Wired," which describes how houses are wired.

Technological Design

4. Have groups of students set up a working circuit of their own, and have them draw its schematic. Then have them exchange their schematic with another group. Have that group build the circuit by referring to the schematic and have the original group check to see that they have built it correctly and that it functions properly.

Technological Design

5. Give students a schematic of a circuit and have them identify the components in the circuit as well as which components are in series and which components are in parallel.

ASSESSMENT

- Assess students' understanding of circuit diagrams using the following criteria:
  - Students' pictures and diagrams include all components (an electrical energy source, an electrical energy user, wires, switch).
  - Students use correct symbols in their schematics.
  - Students' pictures and schematics show proper connections that produce the desired result.
- Assess students' understanding, via their oral and written responses, of the following concepts:
  - Closed circuits have a continuous path that can be traced around the circuit.
  - Series circuits have only one closed path around the circuit.
  - Components in series must be either both on at the same time or both off at the same time.
  - Parallel circuits have more than one closed path around the circuit.
  - Components in parallel can be on and off independently of one another.
  - Switches control devices by opening and closing paths.

Name: _____

Class: _____ Date: _____

Student Sheet 5.2
Lighting More Lightbulbs

Directions After building each circuit in Inquiry 5.2, draw a schematic for each circuit. Then answer the questions that follow by examining your schematics.

Circuit A

Circuit B

(continued)

Student Sheet 5.2 (continued)

Circuit C

Circuit D

Examine your schematics to answer the following questions:

A. What kind of path is needed for a lightbulb to stay on continuously?

B. How is it possible for one lightbulb to be on while another in the same circuit is off?