CHAPTER 8 OPENER, pp. 248–249

USING THE PHOTO AND TEXT

The opening photograph displays a CD. The centre of the CD acts like a "window" through which to view the electrical components of the CD player. This image provides a good example of electrical energy being converted into other forms of energy. Have students read and discuss the chapter-opening text. Invite students to think of an electronic device that requires batteries. Ask students to discuss the different forms of energy produced by this device. Discuss that modern technology, using the concepts of electricity learned in Chapter 7, has allowed us to control the transfer of electrical energy.

USING THE WHAT YOU WILL LEARN/WHY IT IS IMPORTANT/SKILLS YOU WILL USE

Encourage students to read the Skills You Will Use section. Take this opportunity to discuss how not all models in science are three-dimensional. In this chapter, the models will be in the form of diagrams. Circuit diagrams represent a universal "language" of symbols. As with all models in science, the purpose of these diagrams is to better understand a scientific concept. Ask students, "Why might we want to draw a sketch (model) of a circuit?" "What would be the advantage of using symbols to represent different components?" Sample responses might include the following:

- Symbols simplify the circuit.
- Symbols make it easier to share knowledge and help others better understand the circuit.
- Symbols make it easier to analyze possible problems with the circuit.
- Components that serve the same purpose may look physically different. Symbols would standardize all diagrams.
- By using symbols, the diagram would be simplified.

USING THE FOLDABLES™ FEATURE

See the Foldables section of this resource.

8.1 ELECTRIC POTENTIAL ENERGY

BACKGROUND INFORMATION

Electrical energy is called potential energy because it is energy that is stored. This type of energy is similar to gravitational potential energy. If a ball is lifted and held above the ground, the ball has energy because, if released, it will move (fall).

Electrons separated from the positive nucleus "want" to return to their original location, just like the ball "wants" to return to the ground. If the electrons are held separated, then these electrons have electric potential energy. The amount of energy possessed by the separated electrons is dependent on how far they have been separated and also on how many electrons have been separated. Potential difference, or voltage as it is more commonly called, is proportional to the distance that the charges have been separated.

The actual potential energy is the product of both the voltage and the amount of charge (Energy = Voltage × Charge).

When discussing electrochemical cells, the word "battery" is often used to describe a single cell. Technically, a battery consists of more than one cell. Early experiments involving electrochemical cells produced cells that had a maximum voltage of 1.5 V. Therefore, a 6.0 V battery consisted of four electrochemical cells connected together. Current technology produces electrochemical cells that have a voltage of over 2.0 V, and therefore it is hard to predict how many chemical cells a certain battery contains. It is now accepted language to refer to all electrochemical cells as "batteries," regardless of the number of cells involved.

Students may ask about alkaline batteries. Alkaline batteries use an alkaline electrolyte instead of an acidic electrolyte. Alkaline batteries are usually rechargeable. To recharge a battery, a current is forced to travel backward through the battery. That is, the battery is connected backward to a voltage that is slightly greater than the voltage of the battery. This process allows electrons to be replenished in both the electrolyte and the electrodes.

COMMON MISCONCEPTIONS

- Students often assume that the battery with the greater voltage will be able to do more work. It is both the voltage and the amount of charge that are used to produce energy. Cars need a 12 V battery in order to run; however, two 9.0 V batteries connected together would not be able to supply enough energy to start a car, because they would not be able to separate enough charge.

ADVANCE PREPARATION

- Voltmeters are required for all of the activities in this section. Digital multimeters, set as voltmeters, are preferable for these activities. Make sure you have tested all your meters prior to the activities. Digital meters need to have their internal batteries changed periodically.
- Activity 8-1B, on page 255 of the student textbook, requires different-sized batteries. Many of these batteries can be purchased at a local electronics or hardware store.

- Activity 8-1C, on page 256 of the student textbook, requires various fruits. Many grocery stores will donate overripe or damaged fruit for this purpose.

Useful research materials for advance preparation can be found at www.discoveringscience.ca.

INTRODUCING THE SECTION, pp. 250–251

Using the Text

Have students read page 250 of the student textbook. Create a chart on the board and ask students to list the differences and similarities between charge stored in a battery and charge stored by a storm cloud.

Using the Key Terms and Section Summary

At the beginning of each section in the student textbook are the Key Terms and section summary. Both can be used as a pre-reading strategy and a review tool. Before reading the text in the section, students should be able to define the Key Terms by scanning the text and using the Glossary. The Key Terms include terms from the curriculum outcomes and additional terms that are important for students to know and understand.

The section summary provides an overview of the key concepts being covered in the section. Students may not know all the concepts and terms described in the summary, but they can use this information to help guide them through their reading.

After reading the section, students can go back to the Key Terms and section summary to consolidate their understanding and identify areas that require clarification. At the end of the chapter or unit, students can use the Key Terms and section summary for review. BLM 3-2, Unit 3 Key Terms, and BLM 3-4 Chapter 8 Key Terms, can be used to assist students.

Using the Did You Know, p. 251

All early radios used batteries. These early sets had as many as three different-sized batteries. These batteries were known as A, B, and C. Size A and C batteries were quite low voltage, and variations of these batteries are still used today. The B battery was very high voltage (up to 48 V). This battery was used to control the vacuum tubes in the old radios. Improved technology allowed the radios to operate on just the A and C batteries, and that is why it is not common to see B cells today.

Using the Activity

Find Out Activity 8-1A

A Penny for a Battery, p. 251

Purpose

- Students investigate the electrochemical cell using common household materials.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 day before	Gather materials.	For each group: – aluminum foil – paper towel – penny – voltmeter – vinegar

Time Required

- 20 min

Science Background

This activity demonstrates the materials that make up a simple electrochemical cell. This simple electrochemical cell contains two dissimilar metals (aluminum and copper) and an electrolyte (acid–vinegar). When the paper towel is dry, students should not measure any voltage between the aluminum and copper. Once the paper is soaked in vinegar and placed between the two metals, students will measure a voltage. The electrolyte will allow electrons to be removed from the copper penny and electrons to be placed on the aluminum. This process will cause a potential difference or voltage.

Activity Notes

- This combination of copper, aluminum, and vinegar should produce a voltage of approximately 0.5 V.
- The copper penny used in this activity should be clean. Tarnished pennies may not work as well.
- Students should make sure that the paper towel is completely between the penny and aluminum. The penny and aluminum should not be in direct contact.
- When connecting the meters to the metal, the aluminum is the negative terminal and the copper is the positive terminal. If a digital meter is used, a meter connected backward will give a negative value. If an analogue meter is used, the meter must be connected correctly to get a reading.

Supporting Diverse Student Needs

- Pair students who require support following written instructions with students who have strong reading skills. As well, students could research the electromotive series of metals. From examining this series, they could choose their best combination of metals to produce the largest voltage.

What Did You Find Out? Answers

1. (a) The voltmeter in step 4 had no voltage, but there was a voltage in step 5.
   (b) The vinegar caused the difference.
2. (a) Students' answers may vary but could include citrus juice and cola.
   (b) The liquid they chose should also be an acid.
3. The voltmeter should measure an even higher voltage than before. Some students may suggest that the reading should be twice the original voltage.
4. Students' answers may vary but could include the following: Does the size of the foil change the voltage? Does the amount of vinegar change the voltage?

Using a Demonstration

- A simple demonstration can be used to examine the relationship of energy, charge, and voltage. Support a metre stick so that it is positioned vertically with the 0 cm end on the table and the 100 cm end in the air. Place several identical objects, perhaps golf balls or table tennis balls, on the table at the base of the metre stick. These objects represent the electrons. Lift one object and tape it to the 30 cm mark, then lift another object and adhere it to the 60 cm mark. Finally, lift a third object to the 100 cm height. Suggest to students that the height of each object (electron) represents the separation from the atom. This separation distance can be thought of as the potential difference or voltage. Then ask students, "Which object has the most potential energy?" Students will understand that the highest object has the most energy since it required the most energy to move it from the table to the highest position. Therefore, the greater the voltage, the greater the energy of a single charge.
- Lift and attach two more objects to the 60 cm height. Now ask the class, "What has more energy, the single object at 100 cm or the three objects at 60 cm?" It requires more work to lift three identical objects 60 cm than to lift one object 100 cm. The amount of energy also depends on the amount of charge at that particular voltage. To summarize this demonstration, state that the energy of electric charge is determined by both the amount of voltage and also how much charge is separated.

TEACHING THE SECTION, pp. 251–255

Using Reading

Pre-reading—Predict-Read-Verify

Break up the section into chunks, such as the following:
- Electric Potential Energy and Electric Potential Difference
- Producing Voltage
- Many Sources of Electrical Energy

Discuss the title of each chunk. Ask students what they think the title means, and have them make a prediction about what they will learn in each chunk. They can then read the sections and compare their predictions with what they learned.

During Reading—Note Taking

Encourage students to take notes as they read each of the chunks that you have suggested. As they read, have students place a sticky note beside any passage that they do not understand. Then, when they have finished reading that chunk, they can discuss these passages with a classmate, or you can discuss them as a larger group.

Supporting Diverse Student Needs

To help students understand the meaning of "potential energy" and "potential difference," draw students' attention to Figure 8.4, on page 252. Demonstrate the difference between the two terms by using the analogy of the stairs, which will particularly benefit visual-spatial learners. Explain that the height of the stairs is like potential difference, and the work done to get up the stairs is like potential energy. Understanding the two sentences in the figure caption is pivotal for appreciating the analogy. Body-kinesthetic learners may want to act out the situation.

Students may have a difficult time understanding the concepts and terms because they cannot see charges separating in a cell. The goal for this section is to understand the relationship between resistance, current, and voltage. A quiz-quiz-trade activity may be useful to help students review the terminology introduced throughout this section.

After Reading—Semantic Mapping

When students have completed taking notes, have them create a concept map that includes all of the Key Terms in this section and shows the relationships between them. Refer students to Science Skill 8, Organizing Your Learning: Using Graphic Organizers, on page 495 of the student textbook.

Reading Check Answers, p. 255

1. An electrochemical cell or battery uses chemical energy to produce electrical energy.
2. Energy is the ability to do work.

3. Kinetic energy is energy due to motion. Potential energy is a stored energy.
4. Voltage is a more common name for electric potential difference.
5. The amount of energy a charge possesses is due to the potential difference (voltage) and the amount of charge that has been separated.
6. A voltmeter is a device used to measure potential difference.
7. The two groups of batteries are dry cells and wet cells.
8. Electrodes are usually made of metals. These electrodes gain a positive or negative charge due to their contact with the electrolyte. The electrolyte is a substance that reacts with the electrodes to separate charge.
9. Students' answers may vary but could include the following: Forms of energy sources that can be transformed into electrical energy include friction, piezoelectric crystals, photo-electro-chemical cells, thermocouples, and generators.

USING THE ACTIVITIES

- Activity 8-1A, on page 251 of the student textbook, is best used as an introductory activity. Detailed information about this activity can be found in Introducing the Section.
- Activity 8-1B, on page 255 of the student textbook, is best used after students have studied the electrochemical cell on page 253.
- Activity 8-1C, on pages 256 and 257 of the student textbook, is best used as a summary activity for the section, after students have had an opportunity to study all of section 8.1.

Detailed notes on doing these activities follow.

Find Out Activity 8-1B

Using the Voltmeter, p. 255

Purpose

- Students will use a voltmeter to measure the potential difference of different batteries.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 day before	Gather materials and apparatus.	For each group: – voltmeter – various batteries: AA, AAA, lantern battery, watch battery, 9.0 V battery

Time Required

- 20 min

Safety Precautions

- Remind students to make sure that the positive lead is connected to the positive terminal of the battery and the negative lead is connected to the negative terminal.
- If any wires become hot, ensure that students disconnect the battery immediately.

Science Background

Not all batteries have the same voltage. The voltage of a battery has nothing to do with its physical size.

Point out to students that potential difference (voltage) is determined by the distance the charge is separated. However, it does not follow that the bigger the cell, the farther the charge can be separated, and therefore, the higher the potential difference.

This activity provides the opportunity for students to become familiar with the meter. Students start with the meter set to a higher scale than the predicted voltage. On this high scale, students will determine the magnitude of the voltage. Students can then switch to a lower scale to increase accuracy.

By connecting the meter's positive lead (red) to the positive terminal of the battery and the negative lead (black) to the negative terminal, electrons will flow through the meter in the correct direction. On a digital meter, connecting the meter backward will result in a negative reading but will not damage the meter. An analogue meter could be damaged by connecting it to the battery in a backward configuration.

Activity Notes

- If you have enough meters and batteries, students could do this activity individually. If students are in small groups, make sure each student gets a chance to use the meter.
- Demonstrate the correct use of a voltmeter for the class before students perform this activity. Read Science Skill 7, Using Electric Circuit Symbols and Meters, on pages 492 and 493 of the student textbook, with students, paying particular attention to the section called "Reading a Meter".

Supporting Diverse Student Needs

- This is a good hands-on activity for body-kinesthetic and visual-spatial learners. Ensure that they follow the instructions in Science Skill 7 for connecting and reading a meter properly. This skill will be used throughout the chapter.
- AA and AAA batteries both have a potential difference of 1.5 V even though they are different physical sizes. For enrichment, have students suggest reasons for having batteries of the same voltage but different sizes. Students could research this topic.

What Did You Find Out? Answers

1. The positive lead of the voltmeter should be connected to the positive terminal of the battery so that you do not damage the voltmeter.
2. Always start with the meter on the high voltage scale so that you do not overload the meter. As well, if the scale setting is too low, you will not be able to take a measurement.
3. Physical size does not indicate the voltage in a battery. For example, 9.0 V batteries are smaller than 6.0 V lantern batteries.

Conduct an Investigation 8-1C

Fruit Battery, pp. 256–257

Purpose

- Students investigate the factors that produce voltage in an electrochemical cell.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 day before	Gather materials and apparatus. Purchase fresh fruit or have students bring in one piece of fruit each.	For each group: – 1 piece of fruit – aluminum strips – voltmeter – zinc strips – iron strips – copper strips – steel wool – 250 mL beaker – water

Time Required

- 60 min

Safety Precautions

- Remind students to be careful of sharp edges when inserting the metal strips into the fruit.
- Ensure that students handle and dispose of all lab materials using proper techniques.

Science Background

An electrochemical cell consists of two dissimilar metals and an electrolyte. In this activity, the electrolyte is provided by the juice contained in the fruit. If the two metals used are identical (for example, aluminum-aluminum), there should be no potential difference across the two strips. Both metals would have the same affinity to either accept or lose electrons and therefore would be at the same potential. Different combinations of metals will produce different voltage. This difference is because each metal has a different tendency to give up or accept electrons, and therefore a different pair of metals will create a different potential difference. If the electrolyte is removed, in the case of using water instead of juice, no electrons will be added or removed from the metal strips, and therefore there is no potential difference.

Activity Notes

- All the metal strips should be cleaned of any corrosion before this activity begins.
- This activity is best done in small groups. Having students bring their own fruit or having them choose the fruit that they think will provide the best voltage adds interest to this activity. You might want to hold a contest to see whose fruit suggestions produce the highest voltage.
- The voltage produced by a fruit battery is relatively small, 0.5 to 1.0 V. The meter should be able to measure these small voltages. Regardless of the type of meter used, the voltage will significantly fluctuate. This fluctuation is why the procedure asks students to count 5 s before recording their value.
- Some fruit is quite difficult to pierce. Making a small incision with a scalpel for the student may be beneficial.
- Using alligator clips to connect the meter to the metal strips makes for a better connection than if students try to touch the metal strips with the leads.

Supporting Diverse Student Needs

- You may wish to distribute BLM 3-15, Fruit Battery, for students to use when recording their data.
- Ensure that students who have difficulty following written instructions are in groups with students who are able to do this.
- For enrichment, students could experimentally investigate how to connect several different strips of metal so as to double the output voltage of their piece of fruit. Another enrichment activity is for students to suggest reasons why the voltage produced by their fruit battery continually fluctuated.

Analyze Answers

1. Students' answers may vary but can be verified by observing their data table.
2. Students' answers may vary, but identical metals should have produced very little voltage.
3. Combinations of two different metals produced higher voltages than two similar metals.
4. Using the same opening each time contributes to a controlled experiment. The distance between metals is the same for each pair.
5. The two metals in water will not produce a voltage. An acid (electrolyte) is needed to produce a voltage.

Conclude and Apply Answers

1. Two different metals and an acid (electrolyte) are needed to produce a high voltage in an electrochemical cell.
2. Students' answers may vary but could include more acidic fruit, larger electrodes, and connecting multiple electrodes together in series.

3. Students' answers may vary but could include size, short lifespan, low voltage, and mess.
4. Students' answers may vary but could include MP3 players, flashlights, and cars.

USING THE FEATURE

www Science: Electric Fish: The Shocking Truth, p. 258

This feature can be used to help engage students who show more of an interest in life sciences than in physics and to demonstrate one of the ways the strands of science are connected. This feature can also be used as extension material to challenge students in several ways. After reading the feature, students could be asked to do the following:

- Prepare a short report on the interesting facts about electric fish.
- Research other types of fish that have these electric properties.
- Visit www.discoveringscience.ca for more information about electric fish.

SECTION 8.1 ASSESSMENT, p. 259

Check Your Understanding Answers

Checking Concepts

1. The amount of energy per unit of charge is called electric potential difference or voltage.
2. The potential difference in a battery changes the electrons' electric potential energy. Likewise, a staircase can change a person's gravitational potential energy.
3. Voltage is a common word for potential difference.
4. The output energy of a battery is dependent on both the voltage and the amount of charge that the battery can separate.
5. A voltmeter can be used to measure potential difference.
6. Other methods of producing electrical energy could be any of the following: friction, piezoelectric crystals, photo-electrochemical cells, thermocouples, and generators.

Understanding Key Ideas

7. In an electrochemical cell, the electrolyte causes electrons to be either added or removed from the electrodes. Since one electrode will have more electrons and the other will have fewer electrons, a potential difference is created across the two electrodes.
8. The student will measure no voltage across the two silver electrodes. This result is because identical electrodes will both either want to give up electrons or accept electrons. No charge will be separated and therefore there is no potential difference.

Pause and Reflect Answer

You could not use two 9.0 V batteries to start a car because they do not have enough electrical energy. The electrical energy is due to both the voltage and the amount of charge that has been separated. The two 9.0 V batteries would not be able to separate enough charge to provide enough energy to start a car.

Other Assessment Opportunities

- Consult the Unit front matter for a list of applicable Assessment Blackline Masters.

8.2 ELECTRIC CURRENT

BACKGROUND INFORMATION

An electric circuit is any complete pathway that allows electrons to leave a source and eventually return to that source. When electrons leave a source like a battery, they have electric potential energy. Upon returning to the source, all of the electric potential energy in the charge must be converted to other forms of energy. The flow of electric charge through the circuit is called electric current. When Benjamin Franklin developed his theories on electricity, he had no knowledge of atomic structure. Franklin assumed that an electric "fluid" flowed from a positive object into a negative object. This theory opposes our modern knowledge of electron transfer. For this reason, conventional current describes Franklin's original ideas of positive flow. Today, when we use the term "current," we are describing electron flow, which is from negative to positive.

COMMON MISCONCEPTIONS

- Students often think that current is represented by how fast the charge is moving. Current is the amount of charge that passes a given point per second. A conductor with a large cross-sectional area can have a large amount of charge passing a given location without the charge moving quickly.
- Many students believe that it is the amount of voltage that causes harm when a person gets an electric shock. It is the current that passes through the body that represents the danger of electricity. A current as small as 70 mA can cause damage to the human body.

ADVANCE PREPARATION

- Activity 8-2D, on page 266 of the student textbook, requires several circuit components. The flashlight bulbs required need to be various sizes. Bulbs of different wattage or voltage can be ordered from a science supply company or may be purchased at a local electronic store.

Useful research materials for advance preparation can be found at www.discoveringscience.ca.

INTRODUCING THE SECTION, p. 260

Using the Text

Have students read page 260. Ask students why the computer would need so many different pathways. Ask, "What forms of energy does the electricity entering the computer get transformed into?" Students may suggest that the electrical energy becomes light energy, sound energy, thermal energy, and mechanical energy. Having an actual electronic device, such as a disassembled old radio or stereo, for students to view would also be useful.

Using the Key Terms and Section Summary

At the beginning of each section in the student textbook are the Key Terms and section summary. Both can be used as a pre-reading strategy and a review tool. Before reading the text in the section, students should be able to define the Key Terms by scanning the text and using the Glossary. The Key Terms include terms from the curriculum outcomes and additional terms that are important for students to know and understand.

The section summary provides an overview of the key concepts being covered in the section. Students may not know all the concepts and terms described in the summary, but they can use this information to help guide them through their reading.

After reading the section, students can go back to the Key Terms and section summary to consolidate their understanding and identify areas that require clarification. At the end of the chapter or unit, students can use the Key Terms and section summary for review. BLM 3-2, Unit 3 Key Terms, and BLM 3-4, Chapter 8 Key Terms, can be used to assist students.

Using the Did You Know, p. 260

Have students read the Did You Know? feature on page 260. Many students are familiar with the microchip. Microchips use semiconductors such as silicon and germanium. This is a good opportunity to review conductors and insulators from the last chapter. A semiconductor is a material that conducts electricity better than an insulator but not as well as a conductor. The microchip is actually layers of semiconductors separated by insulators, much like a sandwich. Conductors connect the separate layers together. This is how microchips control the flow of electrons. An excellent addition to this discussion would be to show students an old vacuum tube. In a vacuum tube, electron flow is controlled by the heated plates inside the tube. Since electrons inside the microchip are flowing through a solid semiconductor instead of a vacuum, this technology is called "solid state." The vacuum tube will demonstrate to students how technology has been able to "shrink" circuitry.

Using the Activity

Find Out Activity 8-2A

Lighting It Up, p. 260

Purpose

- Students investigate the concept of a circuit using a battery, conducting wire, and a light bulb.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 day before	Gather materials.	For each student/pair/group: – 1 D cell battery – 10 cm of insulated wire with both ends bare – one 2.0 V flashlight bulb

Time Required

- 20 min

Safety Precautions

- If the wire becomes hot, ensure that students disconnect it immediately.
- Remind students to not connect the wire directly across the cell. The flashlight bulb must be part of the circuit.

Science Background

In order for students to light the light bulb, the bulb and cell must be part of a complete circuit. That is, there must be one continuous pathway on which electrons can travel. The order of the circuit components does not matter. It does not matter if the bulb is touching the positive side of the battery or if it is touching the negative side of the battery.

Activity Notes

- This activity is meant to be conducted using a discovery style. Students are not provided with a step-by-step process, but rather discover what works themselves.
- Students will need to touch the light bulb directly to one side of the battery and use the wire to connect the other terminal of the battery to the bulb.

- The second circuit that students are required to draw will have the bulb connected to the opposite terminal of the battery.
- You may wish to distribute BLM 3-16, Making Light Bulbs Glow, for students to complete after they finish the activity.

Supporting Diverse Student Needs

- Students who have difficulty following written instructions could work with a partner.
- This is a good activity for students who are strong visual learners. Artistic students could use this activity as an opportunity to demonstrate their strengths; for example, by enhancing their diagrams to show electrons moving throughout.

What Did You Find Out? Answers

1. The circuit sketch in step 3 should show an incomplete (broken) pathway.
2. Sketches 1 and 2 should show a complete circuit.
3. Students' answers may vary but could include running a complete lap on the track, and the electricity flowing through any electrical component.

TEACHING THE SECTION, pp. 261–265

Using Reading

Pre-reading—Key Word Concept Maps

Consider discussing the Key Terms in this section with students before they commence reading. Doing so will clarify terms before students begin reading, allowing them to better link the terms to the concepts that they are studying.

During Reading—GIST

As students read this section, have them write short summaries of every chunk. Encourage them to keep their summaries short and to use diagrams, which will help students summarize adequately and succinctly. Emphasize the importance of using precise language.

Supporting Diverse Student Needs

- Have students who have trouble summarizing information that they read use Think-Pair-Share to create their summaries. Each student drafts a summary, then discusses it with a classmate, and uses what they talk about to complete and refine their own summary.

After Reading—Reflect and Evaluate

When students have completed taking notes, they can quietly review their notes and choose three interesting facts. Students can share these facts as a class or in a small-group discussion. Students could complete any or all of BLM 3-17, Make Your Own Dimmer Switch; BLM 3-18 Drawing Circuit Diagrams; BLM 3-19, Circuit Symbols; BLM 3-20, Calculate the Current; and BLM 3-21, Calculate the Potential Difference. Note that BLM 3-19 provides a summary of all the circuit symbols used in the section, so students should refer to the textbook pages for the ammeter symbol (p. 264) and the resistor symbol (p. 275).

Students may question the need for a switch in a circuit since a circuit can operate without one. A switch serves mainly as a control or safety role. For enrichment, ask students to add a component to the analogy that represents a switch. A possible reply could be a lifeguard at the top of the slide regulating the participants on the slide.

Reading Check Answers, p. 262

1. Students' answers may vary but may include light, heat, sound, and motion.
2. A complete pathway that allows electrons to flow is called an electric circuit.
3. The person (the electron) climbs the stairs (voltage of the battery) to the waterslide where he descends down the slide (dropping potential energy) and transforms potential energy into movement (transforming electrical energy into another kind as it passes through a load).
4. The four basic components of a circuit are the source, conductor, load, and switch.
5. Circuit diagrams give an organized representation of the actual circuit.

Reading Check Answers, p. 265

1. Electrons leave the negative side of the battery.
2. Each free electron in the circuit pushes the next electron with an action-at-a-distance force. Because of this process, all the free electrons experience a force at the same time.
3. The charge in the battery is not an example of static electricity because, when the battery is connected to a complete circuit, charge will flow continuously through the circuit.
4. Static electricity is charge that remains stationary, and current electricity is charge that moves.
5. Electric current is the amount of charge passing a point in a conductor every second.
6. Electric current is measured in amperes (A).
7. An ammeter is a device used to measure current.

USING THE ACTIVITIES

- Activity 8-2A, on page 260 of the student textbook, is best used as an introductory activity. Detailed information about this activity can be found in Introducing the Section.

- Activity 8-2B, on page 263 of the student textbook, is best used after students have learned about drawing circuit diagrams on page 262.
- Activity 8-2C, on page 265 of the student textbook, is best used as an introduction to, or a reinforcement of, the action-at-a-distance force that electrons in a circuit apply on each other. This activity is best used in conjunction with the Electrons Are So Pushy section on page 263.
- Activity 8-2D, on page 266 of the student textbook, is best used after students have learned about current on page 264.
- Activity 8-2E, on page 267 of the student textbook, is best used as a summary activity for the concepts learned in this section. Students can begin preparing for this investigation several days in advance.

Detailed notes on doing the activities follow.

Think About It Activity 8-2B

Drawing Circuit Diagrams, p. 263

Purpose

- Students draw and analyze circuit diagrams.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
Day of instruction	No advance preparation necessary.	For each student: – 1 ruler

Time Required

- 15 min

Science Background

Closed circuits are those that have one complete pathway. A "break" in the circuit would indicate an open circuit. Each of the components has its own circuit symbol. Refer to BLM 3-19, Circuit Symbols.

Activity Notes

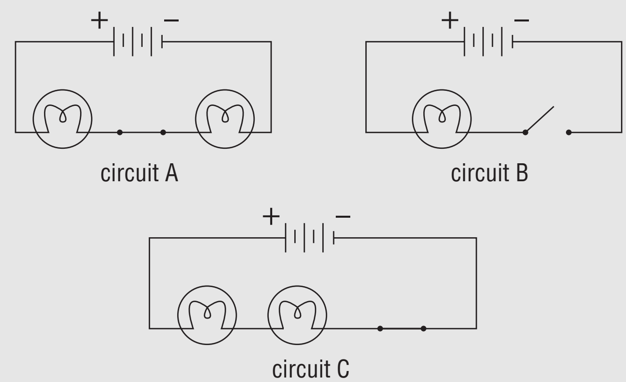
- All circuits should be drawn using a ruler. All turns in the circuit should be drawn at 90° angles.
- Not all students' circuit diagrams will be identical. The size and spacing of the components is not important, but the components should be in the same order as the initial illustration.
- The battery in this circuit may be symbolized as either a battery or a cell. Modern convention is to use the cell symbol to represent both cells and batteries.

Supporting Diverse Student Needs

- Some students may have trouble with the concept of open and closed circuits. For example, an open door lets people enter, yet an open circuit does not allow charge to pass. Extra explanation may be needed to help these students understand this concept.
- Visual-spatial learners will relate well to this activity. Students who have difficulty representing each circuit as a diagram can compare their answers with a classmate's. You can provide additional practice by setting up a few simple circuits and asking students to draw them. This could be modelled on the chalkboard. Students could also be asked to construct a model from a drawing.
- For enrichment, students can research circuit symbols that are not provided in the textbook.

What to Do Answer

1.



What Did You Find Out? Answers

1. Circuits A and C are closed circuits.
2. Circuit B is an open circuit.
3. (a) The battery is the source of electric potential energy.
   (b) The light bulb converts electrical energy to other forms.

Find Out Activity 8-2C

Pushing Electrons, p. 265

Purpose

- Students investigate the action-at-a-distance force on electrons in a circuit by using magnets as a model.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 day before	Gather materials.	For each group: – 6 plastic drinking straws – 3 bar magnets

Time Required

- 15 min

Science Background

Both magnetic force and electric force are action-at-a-distance forces. By aligning the magnets such that like poles are interacting, the magnets repel each other just like electrons repel each other. When one magnet is pushed, each magnet experiences the push without contact. This process is analogous to the electrons contained in a conductor. Electrons on the negative terminal of the battery are "pushed," and this force is transmitted to all the free electrons in the circuit.

Activity Notes

- This activity could be done individually, in small groups, or even as a demonstration.
- Be sure the magnets are aligned exactly as shown in the illustration. Like poles of the magnets must be positioned as shown.
- Depending on the strength of the magnets, care must be taken to push the first magnet slowly.

Supporting Diverse Student Needs

- Students could choose to explain verbally how this model illustrates the motion of electrons rather than writing a short paragraph.
- For enrichment, consider asking students how to change this model to represent an insulator rather than a conductor. Students might respond by removing the straws so that the magnets are not free to move, which would therefore represent an insulator.

What Did You Find Out? Answers

1. Electrons in a circuit apply an action-at-a-distance force on each other just like these magnets. When one magnet is pushed, all the magnets experience the force.
2. In an electric circuit, the source of the "push" is the battery or power supply.
3. The wooden blocks would not apply an action-at-a-distance force on each other; therefore, they would not represent the forces on the electrons as well as the magnets.

Find Out Activity 8-2D

Measuring Current, p. 266

Purpose

- Students construct a circuit from a circuit diagram and use an ammeter to correctly measure current.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 day before	Gather materials and apparatus.	For each group: – 1.5 V cell – various flashlight bulbs (1.5 V, 3.0 V, 6.0 V) – 1 set of connecting wires – 1 knife switch – 1 ammeter

Time Required

- 40 min

Safety Precautions

- Remind students to make sure that the positive terminal of the ammeter is connected to the positive terminal of the battery, and the negative terminal of the ammeter is connected to the negative terminal of the battery.
- Remind students to never connect an ammeter directly across the terminals of a battery.
- Remind students that there must be a load, like a light bulb, in the circuit to limit the flow of electrons.
- If the wires get hot, ensure that students disconnect them immediately.

Science Background

When the switch is closed, the circuit becomes a complete path and current will flow through the circuit. Since the ammeter is part of this complete path, current will flow through the ammeter. By changing the flashlight bulb, a different load is being added to the circuit; therefore, the current flowing in the circuit will change.

Activity Notes

- Students should be instructed to have the switch closed only long enough to measure the current, which will extend the battery life.
- A demonstration of connecting components and how to use an ammeter would be appropriate.
- You may wish to distribute BLM 3-22, Find Out Activity 8-2D, Measuring Current, for students to use in recording their data.

Supporting Diverse Student Needs

- If students have difficulty stating a hypothesis, set up a statement like the following and have them choose the words in parentheses that they think are appropriate: The (lower/higher) the voltage in the light bulb, the (lower/higher) the current in the circuit.

- If students need additional guidance to use an ammeter properly, refer them to Science Skill 7, Using Electric Circuit Symbols and Meters, on page 492 of the student textbook.
- Some students may have difficulty converting between the different units, mA and A. Students could record the measured currents in units of A.
- For enrichment, consider asking students to suggest reasons why different light bulbs might have a different current when connected to the same battery.

What Did You Find Out? Answers

1. (a) The circuit that contains the bulb rated at the lowest voltage should produce the greatest current.
   (b) The circuit that contains the bulb rated at the largest voltage should produce the least current.
2. The positive lead of the ammeter should be connected to the positive side of the battery so that electrons travel in the right direction through the meter. If electrons pass backward through the meter, the meter could be damaged.
3. The purpose of the switch is to control the current. When the switch is open, no current flows, and when the switch is closed, current flows.
4. Always start with the meter set to a large current scale so that you do not overload the meter. As well, if the scale setting is too low, you will not be able to take a measurement.
5. Students' predictions may vary, but should state that the resulting current will be lower because the voltage rating of the light bulb is higher. For example, if the light bulb is rated at double the voltage as before, the resulting current should be half of what it was before.

Conduct an Investigation 8-2E

Make a Model Circuit, p. 267

Purpose

- Students investigate the concept of an electric circuit by constructing a model that involves the members of their group and simple props.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
2 days before	Divide students into groups (4 to 5 students per group). Have students read the problem and criteria. Students should complete Design and Construct steps 1 to 3.	For each group: – Students will supply their own materials.
1 day before	Have students practise their presentation. Students should check that it meets the stated criteria.	
Day of instruction	Groups present their human circuits and complete the Evaluate section of the activity.	

Time Required

- 90 min

Science Background

An electric circuit is a complete path that contains a source of electric potential energy, conducting wires, and a load. Free electrons flow through this complete pathway. Electrons that leave the battery have electric potential energy. Somewhere along the circuit, the electrons must lose this electric potential energy before returning to the battery.

When designing this model, students should form a circle or other closed shape to represent the complete circuit. An object that represents the electron is passed from person to person. Several identical objects should be used since the circuit contains many free electrons. One of the students should represent the battery and one student should represent the load. The rest of the students will represent the conducting wires. The "battery" should lift the object, representing the electron, high above his or her head.

This action now represents an electron with potential energy. Until this electron gets to the "load," it must remain at the same height since it remains at the same potential energy. The person who represents the "load" in the circuit must lower the object, since a load changes the electric potential energy into other forms. As the object is lowered by the "load," another form of energy should be produced by this person (perhaps sound energy). The height of the object after passing through the load should remain low until the object reaches the battery.

Activity Notes

- Discuss the criteria with the class before they start their planning.
- Students need to understand that, by lifting an object, that object has more potential energy. Conversely, by lowering an object, the object loses potential energy.

Supporting Diverse Student Needs

- English language learners or students with reading/organizational challenges should be placed in groups that include students with strong language skills.
- This activity provides an opportunity for interpersonal learners to work in a group situation. As much as possible, ensure that each group include at least one student with strength in this area.
- For enrichment, students could add a second load to their human circuit. When adding a second load, each load will be responsible for losing its portion of the potential energy created by the battery.

Evaluate Answers

1. Lifting an object should demonstrate an increase in potential energy, whereas lowering an object displays a decrease in potential energy.
2. Another form of energy should have been produced in the process. Perhaps sound energy was produced as the object was lowered.
3. Students' answers may vary but could include how to pass the object and what form of energy to produce as the object is lowered.
4. Students' answers may vary but could include that the objects did not flow at a steady rate, and the load gave off only one form of energy.
5. Students' answers may vary based on their model and other groups' models.

USING THE FEATURE

Science Watch: The Faraday Cage, p. 268

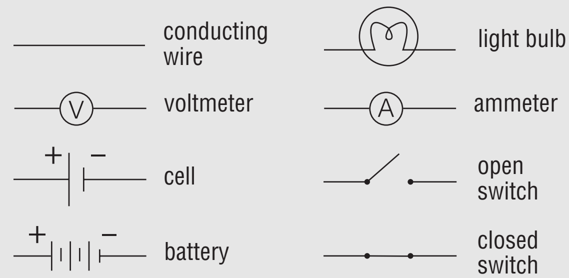
This feature provides an excellent starting point for discussion or further research on the topic of safely controlling large voltages. Have students read the feature individually or as a class. Several websites with more information on Faraday cages can be found at www.discoveringscience.ca.

SECTION 8.2 ASSESSMENT, p. 269

Check Your Understanding Answers

Checking Concepts

1. The battery in an electric circuit gives the electrons their potential energy.
2. The load in an electric circuit transforms electrical energy into other forms.
3. Students' answers may vary but could include light bulb, buzzer, heater, and motor.
4.

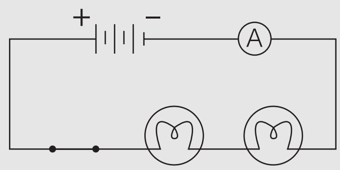


5. Current is the amount of charge passing a given point in a conductor every second.
6. Current is measured in amperes (A).
7. An ammeter is used to measure electric current.

Understanding Key Ideas

8. Electron flow is the movement of electrons. Electron flow travels from negative to positive. Conventional current is defined as the flow of positive charge. Conventional current travels from positive to negative.
9. Static electricity is charge that is stationary. Current electricity is charge that is able to move.
10. The electrical energy transformed in the light bulb would increase when the voltage increases. This result is analogous to climbing more stairs on the waterslide. If you climb more stairs on the waterslide, you now have more potential energy and therefore will gain more kinetic energy.
11. Since electrons are all negatively charged, they repel each other with an action-at-a-distance force. Each electron will apply a force on the other electrons nearby, and therefore they all experience the "push."
12. Two conductors could have different currents even though their electrons travel at the same speed because it is the amount of charge passing a given point that determines current. If one conductor has a larger cross-sectional area, it will allow more electrons to flow than a thin conductor. This result is analogous to the water current in a river compared to a stream.

13.



Pause and Reflect Answer

Students' answers may vary, but should include an object or substance with energy (battery), the object or substance needing to move (charge), and another form of energy being created (load). A ski lift might be one possible answer. Skiers represent the charge. The chairlift represents the battery since it lifts skiers to a higher potential energy. The load would be the ski hill since it transfers the skiers' potential energy into kinetic energy, sound energy, and heat.

Other Assessment Opportunities

- Consult the Unit front matter for a list of applicable Assessment Blackline Masters.

8.3 RESISTANCE AND OHM'S LAW

BACKGROUND INFORMATION

Resistance is the property of any material that slows down the flow of electrons. There are three factors that affect the amount of resistance in a material. If the length of the material that the current would pass through is increased, the resistance of that material is also increased. The cross-sectional area is inversely proportional to the resistance. If you decrease the cross-sectional area of the material through which the current would pass, the resistance is increased. Finally, the resistance is dependent on the type of material through which the current passes. This property is called the material's resistivity. The resistivity of copper, for example, is different than that of gold.

The resistivity of a material can change if the temperature of the material is changed. (This is sometimes referred to as a fourth factor affecting resistance.) For example, if you measured the resistance of a light bulb without it being lit, it would have a different resistance than if it were hot and emitting light. Since all electrical resistors produce heat, in various amounts, the resistance can slightly change. To get an accurate value for resistance, the current through the resistor should be measured using several different voltages. When these data are graphed on a voltage vs. current graph, the slope of the best-fit line represents the resistance.

Ohm's law explains the relationship of voltage, current, and resistance. The amount of current that flows in a circuit is dependent on both the amount of voltage applied to the circuit and also the resistance of the circuit. By changing the resistance of the circuit, a set voltage can produce different currents.

COMMON MISCONCEPTIONS

- It is a common assumption that a greater voltage will always produce a greater current. Although this assumption is correct if the resistance is constant, a 9.0 V battery, for example, can produce different amounts of current depending on the resistance of the circuit to which it is connected.
- Students may believe that connecting wires have no resistance. All conductors have some amount of resistance, but the resistance of the connecting wires is really quite insignificant compared to the electric loads in the circuit.

ADVANCE PREPARATION

- Students will perform Ohm's law calculations in this section. You may wish to advise students to bring calculators to class.
- Activity 8-3D, on pages 278 and 279 of the student textbook, requires various resistors and many 1.5 V cells. Check that the batteries are fresh and do not need replacing. In this activity, the batteries could effectively be replaced by using variable power supplies. If students will be using power supplies, book this equipment ahead of time.

Useful research materials for advance preparation can be found at www.discoveringscience.ca.

INTRODUCING THE SECTION, pp. 270–271

Using the Text

Write the term "resistance" on the chalkboard. Before students read page 270, ask them to brainstorm definitions or ideas that pertain to the word "resistance." As a class, come to an agreement on the meaning of the word. Then have students read the text on page 270. Once they are finished reading, revisit the meaning and ask students if any adjustments need to be made to the previously agreed-to meaning. If so, make the adjustments by encouraging students to suggest changes and to explain why those changes should be made.

Using the Key Terms and Section Summary

At the beginning of each section in the student textbook are the Key Terms and section summary. Both can be used as a pre-reading strategy and a review tool. Before reading the text in the section, students should be able to define the Key Terms by scanning the text and using the Glossary. The Key Terms include terms from the curriculum outcomes and additional terms that are important for students to know and understand.

The section summary provides an overview of the key concepts being covered in the section. Students may not know all the concepts and terms described in the summary, but they can use this information to help guide them through their reading.

After reading the section, students can go back to the Key Terms and section summary to consolidate their understanding and identify areas that require clarification. At the end of the chapter or unit, students can use the Key Terms and section summary for review. BLM 3-2, Unit 3 Key Terms, and BLM 3-4, Chapter 8 Key Terms, can be used to assist students.

Using the Did You Know, p. 270

Have students read the Did You Know? feature on page 270. Ask students to contribute their ideas about electrical safety around water. Students' responses may include the following: dry your hands before unplugging an electric cord, never have an electric appliance near your bathtub (excluding battery-powered devices), and do not stand in puddles if an electrical cord is on the ground. The discussion could then lead to why wet skin has less resistance. Skin is not a good conductor of electricity. Since the outside layer of skin is dead and contains little moisture, it has a high resistance. Water is a good conductor of electricity. If your hands are wet, then current can pass through the outer layers of skin and into your body.

Using the Activity

Find Out Activity 8-3A

Resist Your Thirst, p. 271

Purpose

- Students relate the concept of current to resistance by investigating the flow of fluid through different straws.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 day before	Gather materials.	For each group: – 100 mL water for each trial – 1 plastic disposable cup – 4 drinking straws – 1 stopwatch – 2 pieces of clear adhesive tape

Time Required

- 30 min

Safety Precautions

- Ensure that students do not share straws, cups, or water.

Science Background

The amount of time required to drink the 100 mL of water is proportional to the resistance. The longer time means that the water was flowing through the straw at a slower rate; therefore, the current of water was small. Since resistance slows down current, the longer time corresponds to a greater resistance. Decreasing the cross-sectional area (step 3) or increasing the length (step 5) increases the resistance. This result occurs for an electrical conductor as well.

Activity Notes

- This activity is best done in groups of two. To be sure of fair testing, have the same student drink each time. Students should drink the water as quickly as possible each time.
- To insert the three straws end-to-end (step 5), slightly fold the end of one straw so that it easily slides into the other straw. Be sure to tape the joints so that no air or water leaks through the joints.
- You may wish to distribute BLM 3-23, Resist Your Thirst, for students to use when recording their data.

Supporting Diverse Student Needs

- For enrichment, ask students to describe another change to the straw(s) that would affect the resistance. Students could then test their prediction.

What Did You Find Out? Answers

1. Students' answers may vary but will most likely be the following: three straws side-by-side, single straw, three straws end-to-end, and single straw with a fold.
2. The greater the resistance, the more time is required to drink the fluid.
3. Students' answers may vary but could include cross-sectional area of straws and length of straws.

Using a Demonstration

- One simple demonstration is to have a group of 10 to 15 students walk together as a group in an open area of your classroom. Make sure that the group members stay close to each other but do not touch. These students represent the electrons travelling through a conductor. Now ask the students to leave the room through an open door. They still must stay together as a group but not touch each other. After the last student has left the room, bring your class together and discuss what they observed in terms of resistance and current. The

door represents a resistance for the students, and therefore the students' motion was slowed down. It can be pointed out that all the students in the group were equally slowed down by the door's resistance.
- Another demonstration could involve using a variable resistor. These variable resistors are sometimes called rheostats or potentiometers. Connect a power supply, variable resistor, and light bulb in series. By adjusting the electrical resistance, the current flowing through the light bulb will also change. The change in current can be seen by the brightness of the light bulb. You could then ask students where they have seen a similar variable resistor. Students' answers may include volume controls, dimmer switches, and thermostats.

TEACHING THE SECTION, pp. 272–277

You may decide that it is not necessary for students to consider the details on student textbook page 277, Resistor Colour Code. This information is not required curriculum learning, so it is optional.

Using Reading

Pre-reading—Predict-Read-Verify

Break up the section into manageable chunks:
- Resistance and Current
- Ohm's Law
- Determining the Resistance
- The Resistor
- Resistance Is a Big Loser

Ask students what they think each title means and to make a prediction about what they will learn. They can then read the sections and compare their predictions with what they learned.

During Reading—Note Taking

Encourage students to take notes as they read each of the chunks. They can reword the topic titles as questions and use the questions to guide their note taking.

After Reading—Reflect and Evaluate

When students have completed taking notes, they can quietly review their notes and choose three pieces of information they have learned that they find most interesting. These interesting pieces of information can be shared in class discussion. Students could complete any or all of BLM 3-24, Ohm's Law; BLM 3-25, Resistor Colour Code; BLM 3-26 Practising Calculating Resistance; and BLM 3-27, Electricity Crossword Puzzle.

Supporting Diverse Student Needs

Help students understand the marble analogy shown on page 272, and compare it to the other analogies shown earlier: water flowing in a hose (p. 263) and vehicles travelling on a highway (p. 270). The marbles or vehicles convey the idea of discrete units flowing. The water represents a steady flow, whereas the marbles will quickly run out of the tube. This may cause problems with students fully being able to appreciate the analogy, especially if students and/or teachers set the analogy up as a demonstration. The more road lanes there are, the less traffic build-up there will be, so the faster the traffic flows and the faster a vehicle travels. Students could reflect upon the many analogies given and discuss with each other which are good and less so at illustrating the concepts. Reasons should be given. All analogies have weaknesses but they can be very useful for making abstract scientific concepts such as electron flow more concrete, hence their extensive use throughout this section.

Reading Check Answers, p. 277

1. Current is inversely proportional to the resistance. If the resistance is increased, the current decreases. If the resistance is decreased, the current increases.
2. If the voltage applied to the circuit is increased, the current in the circuit will increase.
3. Voltage (*V*) = current (*I*) *x* resistance (*R*)
4. Electrical resistance is measured in ohms (Ω).
5. When current flows through a resistor, the electrical energy is transformed into other forms, usually heat.
6. Energy "lost" in a resistor means that the electrical energy has been transformed into another form of energy that is not easily changed back into electrical energy.
7. (optional) Manufacturers indicate the value of resistance by coloured bands.

USING THE ACTIVITIES

- Activity 8-3A, on page 271 of the student textbook, is best used as an introductory activity. Detailed information about this activity can be found in Introducing the Section.
- Activity 8-3B, on page 275 of the student textbook, is best used after students have learned how to determine resistance using Ohm's law.
- Activity 8-3C, on page 276 of the student textbook, is best used after students have learned the circuit symbol for a resistor.
- Core Lab Activity 8-3D, on pages 278 and 279 of the student textbook, is best used as a summary activity for this section.

Detailed notes on doing the activities follow.

Think About It Activity 8-3B

Calculating Resistance, p. 275

Purpose

- Students calculate resistance using voltage and current data.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
Day of instruction	No advance preparation necessary.	For each student: – 1 calculator

Time Required

- 20 min

Science Background

When a load is connected to different voltage supplies, the current through the load will change. Using Ohm's law ($V = IR$), the resistance can be calculated for each voltage-current value. Due to experimental error and the fact that resistance can slightly change due to the heating of the load, the values of resistance obtained for each set of data are slightly different.

Activity Notes

- Encourage students to show their calculations, with appropriate units, rather than just writing down the answer.
- You may wish to distribute BLM 3-28, Calculating Resistance, for students to use when recording their data.

Supporting Diverse Student Needs

- You could set up the circuit (or have a student do it) to help students visualize it. If you set up the circuit, you may want to change the values to reflect your demonstration. This approach would be a good lead up to the Core Lab Activity 8-3D.
- Pair students who do not have strong mathematical skills with students who can support them in calculating resistance.
- As enrichment, students could plot the data on a voltage vs. current graph. The slope of the best-fit line is the resistance of this load.

What Did You Find Out? Answers

1. The resistances were very close to each other.
2. Students' answers may vary but could include inaccuracy in the meters or inaccuracy in reading the meters, and the resistance of the load slightly changing due to heat.

Think About It Activity 8-3C

Circuit Diagrams with Resistors, p. 276

Purpose

- Students draw circuit diagrams for circuits that contain resistors.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
Day of instruction	No advance preparation necessary.	For each student: – 1 ruler

Time Required

- 10 min

Science Background

Circuit diagrams use internationally accepted symbols for electronic components. The symbol for a resistor is the sawtooth. Circuit diagrams represent a simplified model of the circuit.

Activity Notes

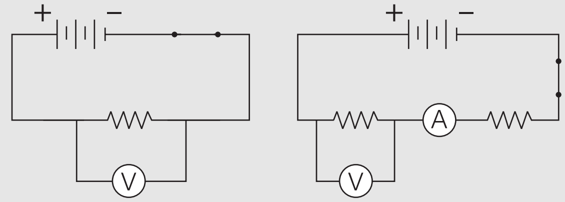
- All circuits should be drawn using a ruler. All turns in the circuit should be drawn at 90° angles.
- Not all students' circuit diagrams will be identical. The size and spacing of the components is not important, but the components should be in the same order as the initial illustration.
- The battery in this circuit may be symbolized as either a battery or a cell. Modern convention is to use the cell symbol to represent both cells and batteries.

Supporting Diverse Student Needs

- English language learners could be encouraged to copy and label the illustrations of the circuits before they draw their circuit diagrams.
- If students diagrams differ significantly from their classmates', two students can work together to determine what is correct and what is incorrect.
- For enrichment, challenge students to design other circuits for one another to draw.

What to Do Answer

1.



What Did You Find Out? Answers

1. All of the students' circuit diagrams should be very similar. Differences might be in the scale of the diagram or the length of the conductors.
2. A circuit diagram is more organized than an illustration. Depending on the artistic ability of the person drawing, an illustration could be hard to interpret. Different brands of components (for example, voltmeters) look different but would have the same circuit symbol.

Core Lab Conduct an Investigation 8-3D

Resistors and Ohm's Law, pp. 278–279

Purpose

- Students investigate Ohm's law by constructing a circuit and measuring the voltage and current.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 day before	Gather materials and apparatus.	For each group: – 2 different resistors (100–300 Ω) – 1 ammeter – 1 voltmeter – 1 set of conducting wires – four 1.5 V cells – 1 switch

Time Required

- 60 min

Safety Precautions

- If any of the wires or resistors become hot, ensure that students open the switch immediately.
- Remind students to make sure that the positive terminal of the meter is connected to the positive terminal of the battery, and that the negative terminal of the meter is connected to the negative terminal of the battery.
- Remind students to never connect an ammeter directly across the terminals of a battery.
- Remind students that there must be a load (in this case, the resistor) in the circuit to limit the flow of electrons.

Science Background

Applying various voltages to a given resistor will produce different currents. The various voltages are provided by connecting different numbers of 1.5 V batteries in a series configuration. By using Ohm's law ($V = IR$), the resistance of the given resistor can be calculated. To allow for experimental error and the fact that a resistor's resistance slightly changes as it heats up, an average resistance is calculated for each resistor. Depending on the resistor's accuracy (fourth band of colour), the experimental value obtained should be within this tolerance. (Note that resistor colour codes are not required curriculum learning for students, but students should find it interesting to know that the colours on a resistor have a purpose.)

Activity Notes

- Procedure step 2 is optional because students are not required to use the resistor colour codes. Also, Conclude and Apply questions 1 and 2 are optional. However, provide students with the accepted resistance so that they can make comparisons.
- This activity could be done using a variable power supply instead of multiple batteries. If students will be using power supplies, book these ahead of time.
- Students should have the switch closed only long enough to record the measured values.
- You may wish to distribute BLM 3-29, Resistors and Ohm's Law, for students to use when recording their data.

Supporting Diverse Student Needs

- Pair students who require support following written instructions with students who have strong language skills.
- This activity requires logical-mathematical, body-kinesthetic, and visual-spatial learning. Ensure that students with skills in these areas are represented in as many groups as possible.
- As enrichment, students could plot the two sets of data on a voltage vs. current graph. The slope of each best-fit line is the resistance of this resistor. Provide graphing software with regression analysis capabilities, if available.

Analyze Answers

1. Students' answers will vary but should be close to the theoretical resistance indicated by the first resistor's colour code. The correct unit for their value is Ω.
2. Students' answers will vary but should be close to the theoretical resistance indicated by the second resistor's colour code. The correct unit for their value is Ω.

Conclude and Apply Answers

1. (optional) The average value of the resistance obtained from the data should be close to but not exactly the same as the colour-code value.
2. (optional) Depending on the accuracy (fourth band of colour), there is variance in the value indicated on the resistor. As well, students may comment on the accuracy of their data.

3. As the current through an individual resistor is increased, the voltage across that same resistor also increases.

USING THE FEATURE

Science Math Connect: Using a Line Graph to Analyze Voltage and Current Data, p. 280

This feature is an excellent opportunity for students to expand their understanding of how to interpret data. The concept of a best-fit line sets up discussion on the concept of experimental accuracy. This graphical analysis of data will be used in science courses that students may take in the future. The graph of voltage vs. current can be used in conjunction with Activities 8-3B (on page 275) and 8-3D (on pages 278 and 279) to interpret the data.

Science Math Connect Answers

1. The green line represents the best-fit line for the plotted data points.
2. If the load were connected to 5.0 V, 2.0 mA of current would flow through the load.
3. Load #2 has a higher resistance. This result is shown by the line having a greater slope.

SECTION 8.3 ASSESSMENT, p. 281

Check Your Understanding Answers

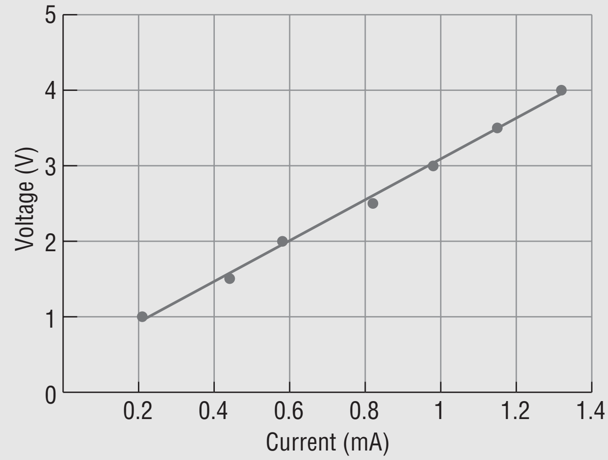
Checking Concepts

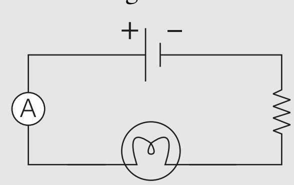
1. Resistance is the property of a material that slows down current and converts electrical energy into other forms.
2. The resistance in a wire is affected by its diameter, length, the material used for the wire, and the temperature.
3. Voltage equals the product of current and resistance.
4. To calculate resistance, you need to know voltage and current.
5. (a) Ohm is the unit of resistance.
   (b) The symbol for resistance is the Greek letter omega, Ω.
6. A resistor is used to control current or potential difference in a circuit.
7. Coloured bands are used by manufacturers to indicate the value of resistance.
8. 

Understanding Key Ideas

9. 300 V
10. 0.10 A
11. 4500 Ω or 4.5 k Ω
12. 4300 Ω or 4.3 k Ω with an accuracy of 10%
13. (a)

The Effect on Changing Voltage on the Current in an Electrical Circuit



   (b) Answers may vary slightly, depending on the placement of the line of best fit. The slope of the line should be about 2.8 (V/mA) or 2800 Ω.
   (c) The slope of the graph represents the resistance of the load.
14. When the resistor is added to the circuit, it will transfer some of the electrical energy into other forms. This will leave less electrical energy for the light bulb; therefore, it will be less bright.
15. 

Pause and Reflect Answer

Connect the resistor to one of the batteries, and measure the current through the resistor and the voltage across the resistor. Using Ohm's law, you can calculate the resistance of the resistor. To improve accuracy, repeat the above method for the remaining batteries and average your values of resistance.

Other Assessment Opportunities

- Consult the Unit front matter for a list of applicable Assessment Blackline Masters.

CHAPTER 8 ASSESSMENT, pp. 282–283

PREPARE YOUR OWN SUMMARY

Students' summaries should incorporate the following main ideas:

1. Electrical Energy
   - When electrons are separated from the positive nucleus, they gain electric potential energy.
   - Electrochemical cells, or batteries, are common sources of electrical energy.
   - The amount of electrical energy depends on the amount of charge separated and the voltage.
   - Electrical energy can be produced by many other forms of energy.
   - Any device that converts electrical energy to other forms is called a load.
2. Current
   - Electric current is defined as the amount of charge that passes a given point per second.
   - Electric current is measured in amperes (A).
   - An ammeter is a device used to measure electric current.
   - Conventional current is defined as a flow of charge from positive to negative. Conventional current would leave the positive terminal and return to the negative terminal. Electric current refers to electron flow, which would leave the negative terminal and return to the positive terminal.
3. Voltage
   - Voltage is a common name for electric potential difference.
   - Voltage is measured in volts (V).
   - A voltmeter is used to measure voltage.
   - An electrochemical cell uses two dissimilar metals and an electrolyte to separate charge and produce voltage.
4. Resistance and Ohm's Law
   - Resistance slows down the flow of electrons and transforms electrical energy into other forms.
   - Resistance is measured in ohms (Ω).
   - Resistors are electrical components used in circuits to decrease current and transform electrical energy into other forms.
   - To measure the resistance of a resistor, a current must travel through the resistor and the voltage across the resistor is measured. The resistance of this resistor can be calculated using Ohm's law.
   - Ohm's law states that the relationship of voltage, current, and resistance is given by $V = IR$.
   - Manufacturers display the value of the resistance of a resistor by using a colour code.
5. Circuits
   - A complete pathway that allows electrons to flow is called a circuit.
   - Circuit diagrams are drawn to represent electric circuits.
   - In a complete circuit, the total electrical energy supplied by the source must be changed to other forms of energy by the loads in that circuit.

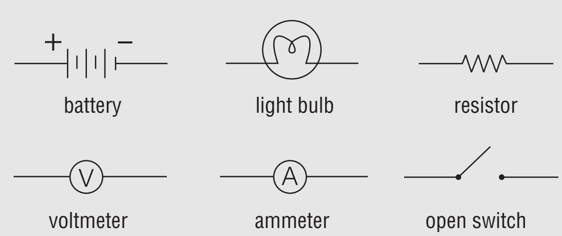
CHAPTER REVIEW ANSWERS

Checking Concepts

1. The battery is the source of electric potential energy in a circuit.
2. In a battery, chemical energy is transformed into electric potential energy.
3. The amount of electric potential energy is dependent on both the amount of charge separated and the voltage.
4. The battery provides the electrical potential in a circuit.
5. When electrical potential is used, the voltage decreases to zero.
6. Two dissimilar metals and an electrolyte are needed to produce an electrochemical cell.
7. Five methods of producing electrical energy are friction, piezoelectric crystals, photo-electrochemical cells, thermocouples, and generators. Other answers may be acceptable.
8. Voltage is measured in volts.
9. A voltmeter is used to measure voltage.
10. An ammeter is used to measure current.
11.

	SYMBOL	UNIT	UNIT SYMBOL
Voltage	V	volts	V
Current	I	amperes	A
Resistance	R	ohms	Ω

12.

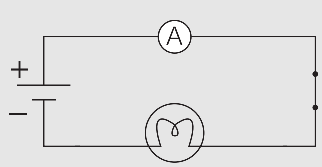


13. 1000 mA = 1 A
14. The four basic components of an electric circuit are: source, conductor, load, and switch.
15. Resistance is the property of any material that slows down electrons and converts electrical energy into other forms. A resistor is an electrical component that has resistance.

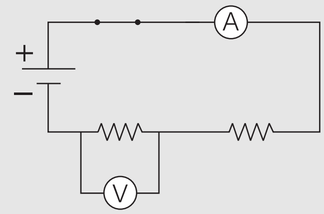
16. Voltage equals the product of current and resistance.
17. (a) The longer the wire, the greater the resistance.
    (b) The smaller the diameter, the greater the resistance.
18. When an electron passes through a resistor, its electrical energy is transformed into other forms of energy.
19. An ohmmeter is a device used to measure resistance.
20. The four coloured bands on a resistor represent the first digit, second digit, multiplier, and accuracy, respectively.

Understanding Key Ideas

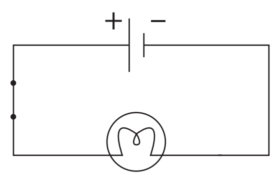
21. Skiers at the top of a hill have gained potential energy. This potential energy can now change into other forms as they ski down the mountain. Electrons on the negative terminal of the battery also have potential energy and can transform this energy into other forms of energy as they pass through the circuit.
22. The reading on the voltmeter would now be zero, because both leads are at the same terminal, which means there is no potential difference (voltage) between them.
23. Electric potential energy is due to both the voltage and the amount of charge separated. Even though the two batteries have the same voltage, one of the batteries could have more stored energy (for example, if it has not been used before).
24. Static electricity is charge that does not move. Current electricity describes charge that is able to move.
25. A complete path means the circuit is not "broken." Any electron leaving the negative terminal of the battery has a pathway to return to the positive side of the battery.
26. All the electrons "push" each other at the same time, which is due to the action-at-a-distance force between electrons.
27.



28. (a) 0.4 A
    (b) 18 000 Ω
    (c) 12 000 000 V
29. 240 V
30. 160 Ω
31. 4.0 Ω
32. 10 000 Ω
33.



Pause and Reflect Answer



It does not matter where the switch is located. When you open the switch, electrons throughout the circuit will stop moving.