CHAPTER 9 OPENER, pp. 284–285

USING THE PHOTO AND TEXT

The photograph of the hydroelectric dam offers an opportunity to discuss several aspects of electrical energy and its transmission. Have students read and discuss the information on page 284. Explain that at many hydroelectric generating stations, the water is stored behind a dam and then released through special tubes called penstocks, to turn the turbine wheels below. At Petty Harbour Generating Station, built in 1900, a tunnel was blasted 107 m through Gull Hill to allow the water to travel around the dam, and 975 m of woodstave penstock and 55 m of steel penstock were built. The electricity produced at this generating station is transmitted to St. John's to supply power for the electric tramway. Invite students to imagine the amount of potential energy stored by the large mass of water behind the dam. Visit www.discovering-science.ca for more information on hydroelectric power generation.

Hydroelectric dams like the one shown in this photograph distribute their electrical energy to many different loads at the same time. Have a discussion with your class by posing the question "How do you think the electricity gets from a dam to the light bulb in the classroom you are now in?"

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

Encourage students to read the Why It Is Important section. Have students generate a list of electric devices that they believe make their lives easier and more comfortable. Students could then be asked to rank their devices in terms of their cost to operate. Ask students, "What factors did you use when deciding their cost of operation?" Discuss the list of Skills You Will Use. Invite students to find newspaper and magazine articles associated with generating electrical energy.

USING THE FOLDABLES™ FEATURE

See the Foldables section of this resource.

9.1 SERIES AND PARALLEL CIRCUITS

BACKGROUND INFORMATION

This section of the student textbook focuses on two main concepts: series circuits and parallel circuits. The concepts of voltage, current, and resistance as they are applied to the individual circuits are analyzed. To help with the understanding of these concepts, an analogy of waterslides is used. In this analogy, the height of stairs represents the voltage applied to the circuit. The "drops" on the slide represent the potential difference (voltage drop) on each of the loads in the circuit. The children on the waterslide represent the electrons.

In a series circuit, there is only one path on which electrons can travel. Any electron in a series circuit must travel through all components of that pathway. If the circuit is open at any point, the current throughout the circuit becomes zero. Since, in a series circuit, there are no alternative routes for the electrons to take, the current throughout a series circuit is the same everywhere. Electrons on the negative terminal of the battery have a given amount of energy when compared to the positive terminal. When these electrons return to the positive terminal, they must have lost all their electrical energy. Therefore, in a series circuit, the voltage supplied by the source must be lost by all the loads in the circuit. Adding resistors in a series circuit means that each electron must now pass through that resistor, and therefore the total resistance of the circuit increases.

In a parallel circuit, there is more than one path on which electrons can travel. An analogy, such as the description of water slides used in the textbook, can help students understand how electricity flows through a parallel circuit. This concept is also similar to the checkout counters at a supermarket where shoppers have more than one choice of where to pay for groceries. If one checkout is closed, the shoppers are diverted to other cashiers. Parallel circuits represent multiple pathways on which electrons can travel in order to return to the battery. If one of the pathways becomes an open circuit, current will be diverted to other pathways and return to the battery. Since the pathways of a parallel circuit all connect at the same location, the voltage lost on each of these pathways is identical. The amount of current through each of these pathways is dependent on the resistance of the path. More current will travel through the branch of lower resistance than the branches of higher resistance. When a resistor is added in parallel to an existing circuit, the total resistance of the circuit decreases. Again, this concept is like the supermarket checkouts. If another checkout is opened, the number of shoppers that can check out per time interval increases, which means the resistance has decreased.

COMMON MISCONCEPTIONS

- If two loads are connected in parallel to a battery, students may assume that each of the loads loses its portion of the total voltage. Clarify that each load in this situation would lose the total battery voltage. This is because each electron entering the

junction point of the parallel circuit possesses the same energy. The individual electron can take only one of the pathways and then rejoins with the electrons at the junction where the branches unite. Regardless of the pathway, the electron transfers the same amount of energy. Therefore, each pathway in the circuit loses all the battery potential.
- Students may believe that when you add a large resistor in parallel, the total resistance of the circuit increases due to this large resistor. Help students realize that adding any resistance in parallel decreases the total resistance of the circuit. No matter how large the resistance is, the new branch in parallel will draw some current. Since some electrons will travel on this new pathway, the total resistance must decrease.

ADVANCE PREPARATION

- Most of the activities in this section require voltmeters, ammeters, batteries, connecting wires, light bulbs, and resistors. Book this equipment in advance if necessary.
- Low voltage power supplies could effectively replace the batteries in the activities in this section.

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

INTRODUCING THE SECTION, pp. 286–287

Using the Text

Students will be more familiar with lights connected in parallel. Many students may not be familiar with lights that are connected in series. You may wish to display a string of holiday mini lights. Ask students to state the similarities and differences between the light bulbs in a table lamp and the bulbs in the mini lights. Mini lights are not as bright as standard light bulbs. To emphasis this difference, ask students to predict what would happen if one mini light was used to replace a standard light bulb. Once students understand that mini lights operate at a lower voltage, ask, "What might be the purpose of connecting mini lights differently than standard light bulbs?" (Mini lights are connected in series so that they share the 120 V supply.)

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 3-5, Chapter 9 Key Terms, can be used to assist students.

Using the Did You Know, p. 286

Have students read the Did You Know? feature on page 286. Ask students to suggest the obstacles that Edison may have encountered in order to produce a filament. Edison performed over 3000 experiments involving more than 1600 materials to find the best filament. Some of these early filaments included cotton threads and bamboo. Students can visit www.discoveringscience.ca for more information on Edison's light bulb.

Using the Activity

Find Out Activity 9-1A

Turn Out the Lights, p. 287

Purpose

- Students investigate the flow of electrons in two different types of circuits.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 day before	Gather materials and apparatus.	For each group: – 1.5 V cell – two 2.0 V light bulbs – switch – connecting wires

Time Required

- 30 min

Safety Precautions

- Ensure that students disconnect the circuit if any wires become hot.

Science Background

Circuit 1 represents a series circuit, and circuit 2 represents a parallel circuit. In circuit 1, when one of the bulbs is removed, the other bulb will not be lit. This is because removing one bulb opens the circuit so that current cannot flow in the circuit. It does not matter which of the two bulbs in the circuit is removed.

In circuit 2, removing a bulb does not stop electrons from flowing through the other pathway, and therefore the remaining bulb stays lit. Students may notice that the brightness of the second bulb increases when the first bulb is removed. This increase is due to the terminal voltage of the battery. As less current is drawn from the battery, the amount of voltage lost inside the battery decreases, and therefore there is more voltage for the circuit outside that battery. If students ask about the increased brightness, suggest that it is due to the current passing through the battery and that this effect would not happen if a constant power supply was used. (The change in resistance that occurs inside a battery over time is due mostly to the chemical characteristics of the electrolyte and the electrodes.)

Activity Notes

- This activity works best in small groups but could be done as a demonstration.
- A low voltage power supply could be used instead of the battery. Be sure that the rating of the light bulbs equals or slightly exceeds the supply voltage.
- All light bulbs should be tested before students proceed with this activity.
- If larger voltages are used, take care that the light bulbs do not become too hot to touch.

Supporting Diverse Student Needs

- English language learners could be encouraged to label the circuit diagram with the names of the components. This is a good suggestion for any students who need the extra review and reference to earlier materials covered.
- For enrichment, groups of students could be given one extra light bulb and asked to construct a circuit such that if one bulb is removed, the second bulb goes out but the third bulb stays lit.

What Did You Find Out? Answers

1. (a) There is only one way for an electron to travel through circuit 1.
   (b) The electron must travel through two light bulbs.
2. When one bulb is removed, the other bulb is not lit. This is because the circuit is now open and there will be no current.
3. (a) There are two different paths on which the electron can travel in circuit 2.
   (b) In each of these paths, the electron travels through only one light bulb.
4. When one bulb is removed, the other bulb stays lit. This is because there is still a complete circuit containing the other bulb.

TEACHING THE SECTION, pp. 288–297

Using Reading

Pre-reading—K-W-L (Know-Want to Know-Learned)

Have students write what they already know about electrical circuits and record questions they would like to find answers to in this section. Later, students can share their questions as a class, and together the class can discuss the answers to those questions.

During Reading—GIST

Have students write short summaries of every chunk of this section. Encourage students to keep their summaries to 20 words or fewer to help them connect to the facts.

Supporting Diverse Student Needs

- To help students focus on the differences between a series circuit and a parallel circuit, provide them with BLM 3-33, Comparing Series Circuits and Parallel Circuits. They can use the comparisons made in Table 9.1, Series and Parallel Circuits (page 294), to help them complete the blackline master. Encourage students to complete BLM 3-30 on their own first. Table 9.1 can be used to help students self assess their work.

After Reading—Reflect and Evaluate

When students have completed taking notes, have them quietly review their notes and choose three interesting facts. They can share the facts in a class discussion. Students could complete any or all of BLM 3-31, Series Circuits; BLM 3-32, Parallel Circuits; BLM 3-34, Designing Circuits; BLM 3-35, Drawing Series and Parallel Circuit Diagrams; BLM 3-36, Understanding Circuit Diagrams; and BLM 3-37, Calculate Voltage and Current.

A quiz-quiz-trade activity may be useful to help students reinforce the similarities and differences between parallel and series circuits.

Using the Did You Know, p. 293

Have students read the Did You Know? feature on page 293, which introduces the idea of a compound circuit. Ask them to answer the question posed. Students should realize that if bulb 1 is removed, the circuit would be open so bulbs 2 and 3 would not light. Ask students what would happen if bulb 1 was replaced but bulb 2 was removed. (Bulbs 1 and 3 would light because there is one complete path in the circuit.) Then ask what would happen if bulbs 2 and 3 were removed. (Bulb 1 would not light because the circuit is open.) Students can obtain further practice with compound circuits using BLM 3-38, Compound Circuits.

Reading Check Answers, p. 290

1. A circuit with only one path is called a series circuit.
2. There is no current in a series circuit when the switch is opened.
3. The total voltage lost on all the loads must equal the total voltage supplied by the battery.
4. Since there is only one pathway on which the current can flow in a series circuit, the current is the same in all locations.
5. If a resistor is added in series to an existing resistor, the total resistance increases.

Reading Check Answers, p. 293

1. A circuit that contains more than one pathway is called a parallel circuit.
2. When two loads are connected in parallel, the voltage across each load will be equal.
3. When two loads are connected in parallel, the current through each load does not have to be equal.
4. A junction point is the location in a circuit where the circuit branches into more pathways or where pathways rejoin.
5. The total current entering a junction point must equal the sum of the current leaving the same junction point.
6. When you add a resistor in parallel to an existing resistor, the total resistance of the circuit decreases.

Reading Check Answers, p. 297

1. Students' answers should include three of the following differences between series and parallel circuits:
   - Electron flow: a series circuit has one path in which current can flow, while a parallel circuit has two or more paths.
   - Effect of removing a load (for example, a bulb): a series circuit is open and the current stops, but a parallel circuit still has at least one complete path so the current flows.
   - Voltage: in a series circuit, the total voltage produced by the battery is equal to the sum of the voltage lost (in the loads or resistors) in the entire circuit. In a parallel circuit, the battery's voltage is equal to the voltage lost in each branch of the circuit.
   - Current: in a series circuit, current remains the same and depends on the total resistance of the circuit. In a parallel circuit, the current must divide among the possible paths. The current in each path depends on the resistance of that path, and the total current must equal the sum of the currents through each path.
   - Resistance: When a resistor is added in series with other resistors, the total resistance of the circuit increases. When a resistor is connected in parallel to an existing resistor, the total resistance decreases.
2. Cells that are connected in series have a higher voltage and current so a bulb will be brighter; however, the batteries will not last as long. Cells that are connected in parallel have a lower voltage (the same as the voltage of a single cell) so batteries will last longer but the light will be dimmer.
3. Students' answers may vary. For example, cells in a flashlight are connected in series because a bright light is required, and having a bright light outweighs the relatively short lifespan of the batteries.
4. Students' answers may vary. For example, cells in a lighthouse light are connected in parallel because the batteries will last longer, and the circuit will still function even if one of the cells is faulty.
5. The function of a circuit breaker and a fuse is to act as a safety switch to cut off all the incoming power. A fuse has a metallic strip that melts when too much current heats it up so the fuse has to be replaced; whereas a circuit breaker has a bimetallic strip that only bends when heated up and opens the connection so it does not have to be replaced—only reset.
6. A grounding terminal is a conductor (for example, a metal wire or prong) that connects to a circuit, to allow extra current to flow into the ground so we do not get a shock.

USING THE ACTIVITIES

- Activity 9-1A, on page 287 of the student textbook, is best used as an introductory activity. Detailed information about this activity can be found in Introducing the Section.
- Activity 9-1B, on page 288 of the student textbook, is best used after students have learned the definition of a series circuit.
- Activity 9-1C, on page 291 of the student textbook, is best used after students have learned the definition of a parallel circuit.
- Activity 9-1D, on page 298 of the student textbook, could be used as a summary of, or an introduction to, how voltage and current behave in a series circuit.
- Activity 9-1E, on page 299 of the student textbook, could be used as a summary of, or an introduction to, how voltage and current behave in a parallel circuit.

- Core Lab Activity 9-1F, on pages 300 and 301 of the student textbook, is best used as a summary of the concepts learned in this section.

Detailed notes on doing the activities follow.

Think About It Activity 9-1B

Is the World Series a Series Circuit? p. 288

Purpose

- Students brainstorm examples in their community that represent a series circuit.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
Day of instruction	No advance preparation necessary.	None

Time Required

- 25 min

Science Background

A series circuit is defined as having only one pathway on which to travel. In an electric circuit, the pathway starts at the source of potential, such as a battery, and returns to the same source of potential. Electrons that leave the battery have only one pathway on which to return to the battery. To relate this concept to other examples, it is important that there is only one pathway for objects to travel on. It may be difficult to find examples where the objects return to their starting point. For the purpose of this activity, the main focus should be on having a single pathway, with less emphasis on there being a complete circuit.

Activity Notes

- Have students read the introduction to this activity. For each of the examples, discuss why these represent series pathways. As well, identify the object that is travelling in the circuit.
- Students must compare their lists with other groups' lists and agree on a common example.

Supporting Diverse Student Needs

- Having students sketch their examples and trace the single pathway will aid in their understanding of series circuits, especially for visual learners.
- Appoint one interpersonal learner in every group to make sure everyone in the group has a chance to contribute in a meaningful way.
- As an extension, have students discuss the energy transformations that take place in their examples.

What Did You Find Out? Answers

1. Students' answers may vary but their examples must demonstrate a series pathway.
2. (a) Students' answers may vary but the object should complete the whole circuit.
   (b) Students' answers may vary, but could include gravitational, mechanical, or electric energy.
   (c) If the circuit became broken or blocked, the motion of the objects in the circuit would stop.

Think About It Activity 9-1C

More Things Are Parallel Than Lines, p. 291

Purpose

- Students brainstorm examples in their community that represent a parallel circuit.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
Day of instruction	No advance preparation necessary.	None

Time Required

- 25 min

Science Background

A parallel circuit is defined as having more than one pathway on which to travel. In an electric circuit, electrons that are leaving the source of potential, such as a battery, have more than one way to return to the battery. To relate this concept to other examples, it is important that there is more than one pathway on which an object can travel between two locations. It may be difficult to find examples where the objects return to their starting point. For the purpose of this activity, the main focus should be on having multiple pathways between two fixed locations.

Activity Notes

- Have students read the introduction to this activity. Discuss why the example represents parallel pathways. As well, identify the object that is travelling in the circuit.
- Students should compare their lists with other groups' lists until a common example is obtained.

Supporting Diverse Student Needs

- Having students sketch their examples and trace the multiple pathways will aid in their understanding of parallel circuits, especially for visual learners.

- As an extension, have students discuss the energy transformations that take place in their examples. Encourage students to comment on the fact that the energy transformed in each of the pathways should be equal.

What Did You Find Out? Answers

1. Students' answers may vary but should demonstrate a pathway that has more than one way to travel between two locations.
2. (a) Students' answers may vary, but the object should be able to travel through only one pathway at a time.
   (b) Students' answers may vary but could include gravitational, mechanical, or electric energy.
   (c) If one pathway of the circuit became broken or blocked, the objects in the circuit would travel through the other pathways.

Find Out Activity 9-1D

A Series of Lights and Cells, p. 298

Purpose

- Students investigate voltage and current in a series circuit using voltmeters and ammeters.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 day before	Gather materials and apparatus.	For each group: – two 1.5 V cells – two 1.5 V flashlight bulbs – 2 ammeters – voltmeter – switch – connecting wires

Time Required

- 60 min

Safety Precautions

- If any wires become hot, ensure that students disconnect the circuit immediately.

Science Background

A series circuit has only one pathway on which the current can travel. Since there is no way for current to divide into different branches of the circuit, the current throughout the circuit will be the same. The voltage measured across a load is sometimes called a voltage drop because of the loss of electrical energy. Since bulb 1 and 2 represent the only loads in the series pathway, the sum of the voltages dropped across the bulbs must equal the voltage supplied by the source. However, since some voltage is lost in the connecting wires and meters, the readings on the meters will be less than the expected (theoretical) values.

To see cells that are connected end-to-end (in series), refer to the Did You Know? feature on page 289. When cells are connected in series, the total voltage increases and is equal to the sum of the voltage of the cells.

Activity Notes

- Depending on the amount of equipment available, this activity is best done in small groups, but it may also be done as a demonstration.
- A low-voltage power supply may be used instead of the two 1.5 V cells.
- If the students' set-up does not measure a current, check that the bulbs are not "burnt out" and that the ammeters are in good working condition. Some ammeters contain a fuse to protect the meter. If this fuse is damaged, then current will not flow through the ammeter.
- Ensure that batteries are connected in series: the positive terminal of one battery is connected to the negative terminal of the other battery.
- The ammeter and voltmeter readings may be less than their theoretical values due to voltage drops across the wires and meters. This is normal.

Supporting Diverse Student Needs

- Pair English language learners or students who have reading and/or organizational challenges with students who have strong language skills. Allow them to prepare their data tables together with the materials close at hand so that they may match terms with the actual materials.
- You may wish to distribute BLM 3-39, A Series of Lights and Cells, for students to use when recording their data, and to keep students organized.
- As an extension, students could be asked to predict the effect on, current through, and voltage across, each bulb if another bulb were added in series to the original circuit. Students could then experimentally test their prediction.

What Did You Find Out? Answers

Part 1

1. The current in ammeters 1 and 2 should be the same.
2. The voltage across the two bulbs should be 1.5 V, or about 0.75 V across each bulb.
3. The total voltage lost on the two bulbs should equal the battery voltage.
4. In a series circuit, the current measured in the circuit is dependent on the number of bulbs. To test the prediction that the current does change, add another bulb and measure the current in the circuit. It should change (drop).

Part 2

5. The voltage in Part 2 doubles to 3.0 V. The current also doubles because the resistance in the circuit is the same as it was in Part 1.
6. In a series circuit, $V = IR$, so an increase in voltage results in an increase in current.
7. Both the voltage and current increase as additional cells are connected in series. A useful application of series cells is using batteries to power a bright portable light so that you can read or see details in the dark.

Find Out Activity 9-1E

Parallel Lights and Cells, p. 299

Purpose

- Students investigate voltage and current in a parallel circuit using voltmeters and ammeters.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 day before	Gather materials and apparatus.	For each group: – two 1.5 V cells – three 1.5 V flashlight bulbs – 3 ammeters – voltmeter – switch – connecting wires

Time Required

- 60 min

Safety Precautions

- If any wires become hot, ensure that students disconnect the circuit immediately.

Science Background

A parallel circuit has more than one pathway on which current can travel. The current leaving the source of potential (battery) will be split at the junction point where the circuit branches. Since current is the flow of electrons, the total number of electrons entering this junction must equal the sum of the electrons travelling through the branches of the parallel circuit. The sum of the currents in each branch of the parallel circuit should equal the total current leaving the battery.

Electrons leaving the battery have potential energy. Upon returning to the battery, they must travel through either bulb 1 or bulb 2 before they all travel through bulb 3. Electrons will either travel through bulb 1 and then bulb 3, or through bulb 2 and then bulb 3. Theoretically, the sum of the voltage drops across bulb 3 and bulb 1 (or bulb 2) will be the same as the battery voltage. Since some voltage is lost in the connecting wires and meters, the readings on the meters will be less than the expected (theoretical) values.

This activity involves a simple compound circuit, where two bulbs are connected in parallel and then connected in series to another bulb. To see bulbs that are connected in this way, refer to the Did You Know? feature on student textbook page 293. In this case, the expected voltage drop across each bulb in parallel should be half of the voltage drop of the bulb connected in series. The voltage drop across the bulbs in parallel is less than if they were connected in series because not all of the electrons will travel through each of these bulbs, whereas all of the electrons will travel through bulb 3.

To see cells that are connected side-by-side (in parallel), which occurs in Part 2 of this activity, refer to the Did You Know? feature on student textbook page 292. When cells are connected in parallel, the voltage of the circuit remains the same as the voltage of the individual cells.

The advantage of using cells in parallel is that since the voltage supplied is the same as that supplied by only one cell, the circuit will be able to operate for twice as long.

Activity Notes

- Depending on the amount of equipment available, this activity is best done in small groups, but it may be done as a demonstration.
- A low-voltage power supply may be used instead of the two 1.5 V cells.
- If the students' set-up does not measure a current, check that the bulbs are not "burnt out," that the wires are connected properly, and that the ammeters are in good working condition. Some ammeters contain a fuse to protect the meter. If this fuse is damaged, then current will not flow through the ammeter.
- If you use bulbs of higher voltage, note that bulbs 1 and 2 may not light, or they may produce a very weak light.
- Ensure that batteries are connected in parallel: the positive terminal of one battery is connected to the positive terminal of the other battery; and negative is connected to negative.
- The ammeter and voltmeter readings may be less than their theoretical values due to voltage drops across the wires and meters. This is normal.

Supporting Diverse Student Needs

- Pair English language learners or students who have reading and/or organizational challenges with students who have strong language skills. Allow them to prepare their data tables together with the materials close by so that they may match terms with the actual materials.

- The circuit diagram is fairly complex. Ensure that each group includes visual-spatial learners who can help to plan the circuit.
- You may wish to distribute BLM 3-40, Parallel Lights and Cells, for students to use when recording their data, and to keep students organized.
- As an extension, students could be asked to predict the effect on, current through, and voltage across, each bulb if another bulb were added in parallel to the original circuit. Students could then experimentally test their prediction.

What Did You Find Out? Answers

Part 1

1. The voltage drop across each of the two bulbs in parallel is the same (bulbs 1 and 2). It should be about half of the voltage drop across the bulb connected in series (bulb 3).
2. The current in ammeter 1 is the same as the current in ammeter 2, but the current through ammeter 3 is double that amount and is the sum of the currents through ammeters 1 and 2.
3. The sum of the current in ammeter 1 and ammeter 2 should equal the current in ammeter 3.
4. As the number of bulbs in a parallel circuit increases, the current through each bulb decreases so that the sum of the currents in the parallel circuit is equal to the current in the rest of the circuit. To test this, add another bulb, bulb 4, in the parallel circuit. The total current will increase. If bulb 4 is parallel to bulbs 1 and 2, the current in bulb 4 will be equal to the current in each of bulbs 1 and 2 and one-third the current in bulb 3. If bulb 4 is parallel to bulb 3, the current in all of the bulbs is the same. For both cases, the sum of the currents will equal the current in ammeter 3.
5. The voltage across each load connected in parallel is the same, but is less than the voltage across the load located outside of the parallel branch of the circuit. The current through each parallel load is the same—the sum of the currents in the parallel branch equals the total current entering or leaving the branch.

Part 2

6. The voltage and the current are the same in both Part 1 and Part 2.
7. (a) When cells are connected in parallel, there is no change in the voltage or the current.
   (b) Parallel connections of cells produce more electrical energy over time so the battery will last longer. A longer-lasting battery is useful in applications where there is not a large energy draw and for batteries that are in hard-to-reach places, which are difficult to replace on a frequent basis.

Core Lab Conduct an Investigation 9-1F

Resistors in Series and Parallel, pp. 300–301

Purpose

- Students investigate the total resistance of resistors connected in series and in parallel by measuring current and voltage.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 class before 1 day before	Remind students to bring a calculator. Gather materials and apparatus.	For each group: – 6.0 V lantern battery or power supply – 3 resistors of different sizes (100 Ω–500 Ω) – ammeter – voltmeter – switch – connecting wires – calculator

Time Required

- 60 min

Safety Precautions

- If any components become hot, ensure that students open the switch immediately.
- If a power supply is being used instead of batteries, ensure that students turn off the power supply while constructing the circuit.

Science Background

A resistor slows down the flow of electrons in a circuit. If resistors are placed in series, each of the resistors adds to the resistance. Therefore, placing resistors in series increases the total resistance of the circuit. This would be analogous to cars driving over a single-lane bridge. If the road has one bridge, the bridge will create resistance and traffic will slow down. If a second bridge is placed after the first, this will further slow down traffic. The two consecutive bridges create more resistance than a single bridge.

Calculating the total resistance for an electric circuit can be done using Ohm's law. By measuring the current leaving the source of potential (battery) and also measuring the total voltage applied to the circuit by that source, resistance can be calculated ($R = \frac{V}{I}$).

In Part 1 of this activity, the total resistance of the circuit that is calculated using Ohm's law is greater than the individual resistors.

Resistors placed in parallel create another pathway on which current can travel. If resistors are placed in parallel, the total resistance of the circuit will decrease. Using the bridge analogy, a single bridge creates resistance to the flow of cars on the highway. If a second bridge is placed beside the first, in parallel, traffic is now split between two possible routes. Placing the second bridge in parallel allows more cars to pass over the river in a given time than if only one bridge were present. In Part 2 of this activity, the total resistance of the circuit, calculated using Ohm's law, is less than that of the individual resistors.

Activity Notes

- It may be advantageous to have students prepare their write-up and data tables before the day of the activity.
- Students will need a calculator for this activity.
- Using the resistor colour code is not required curriculum learning for students, so the following steps in the Procedure are optional: Part 1 step 2, and Part 2 step 9. You or interested students can refer to the colour codes on student textbook page 277 in Chapter 8, and provide the other students with the values of the resistors.
- You may wish to distribute BLM 3-41, Resistors in Series and Parallel, for students to use when recording their data.

Supporting Diverse Student Needs

- Some students may benefit from a review of Ohm's law from Chapter 8 to ensure success in this activity.
- A variety of skills; including interpreting diagrams, building circuits, calculating resistance, and encouraging group members; are necessary to complete this investigation successfully. Ensure that each group includes students with a variety of learning styles.
- As an extension, students could be asked to find the relationship between total resistance and individual resistors when connected in either series or parallel.

Analyze Answers

Part 1

1. Students' answers may vary but should be close to the sum of the individual resistors used.
2. The total resistance is greater than each individual resistor.
3. Each resistor loses different voltage.
4. The total voltage lost on the three resistors should be equal to the battery voltage.

Part 2

5. Students' answers may vary but should be less than any of the resistors used.
6. The total resistance is less than each individual resistor.
7. The voltage across each resistor is the same.

Conclude and Apply Answers

1. In a series circuit, the total resistance is greater than the individual resistors. The total voltage supplied to the circuit is equal to the sum of the voltages across each resistor.
2. In a parallel circuit, the total resistance is less than the individual resistors. The total voltage supplied to the circuit is equal to the voltage across each resistor.

USING THE FEATURE

Science Watch: The Robotic Cockroach, p. 302

After reading the feature, students could be asked to do the following:

- Answer the questions on page 302.
- Research to find out more about the design and applications of modern robots.
- Research to find out more about the use of strain gauges in technology.

Students may start their research at www.discoveringscience.ca.

Science Watch Answers

1. Advantages may vary, but could include speed and mobility. Disadvantages may vary, but could include the difficulty in co-ordinating six legs and the number of moving parts.
2. (a) The electrical resistance of the strain gauge changes when it is deformed.
   (b) If the electrical resistance changed, then the amount of current would also change.
3. Students' answers may vary but may include airplanes and submarines.

SECTION 9.1 ASSESSMENT, p. 303

Check Your Understanding Answers

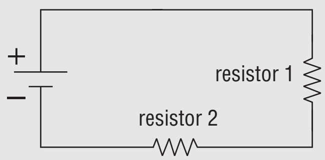
Checking Concepts

1. A parallel circuit contains more than one pathway on which electrons can travel. A series circuit has only one pathway on which electrons can travel.
2. The sum of the voltages lost on each load is equal to the voltage supplied by the battery.
3. The voltage across the two resistors must be the same as the battery voltage.

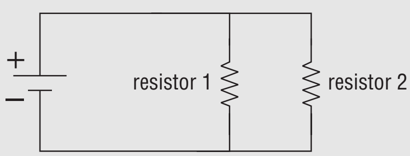
4. The current in one branch of a parallel circuit is less than the total current entering the junction point of the circuit.
5. A circuit breaker has a bimetallic strip that when heated by excess charge, bends enough to open the circuit and stop the electron flow.
6. A grounding terminal is a metal wire or prong that connects to a circuit. If any extra current is in the circuit, it will flow along the conductor into the ground so we do not get a shock.

Understanding Key Ideas

7. (a) 2.0 A
   (b) 6.0 V
8. (a) 2.0 A
   (b) 9.0 V
9. (a)



   (b) (i) The total resistance has increased.
   (ii) The current leaving the cell has decreased.
   (iii) The voltage across resistor 1 has decreased.
10. (a)



   (b) (i) The total resistance has decreased.
   (ii) The current leaving the cell has increased.
   (iii) The voltage across resistor 1 is the same.

Pause and Reflect Answer

The lights in schools are connected in parallel. We know this because if one of the lights "burns out," the others stay lit. Also, if the lights are turned off in one room, the rest of the school's lights do not go out.

Other Assessment Opportunities

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

9.2 THE POWER OF ELECTRICITY

BACKGROUND INFORMATION

This section examines electrical energy in terms of its rate of transfer as well as the cost associated with consuming electrical energy.

The unit begins with the definition of power. Power is the rate at which energy is transformed or transferred. The unit for measuring power is the watt (W). A device that can transform one form of energy into another form in a shorter period of time has more power. Electrical power, therefore, is the rate at which electrical energy is transformed. In an electric generator at a hydroelectric dam, gravitational potential energy is transformed into electrical energy. The amount of energy that is transformed per second is the power output of that generating station. The Churchill Falls Generating Station has a generating capacity of 5428 MW (megawatts) or 5428 million watts of power. This means that it transforms 5428 million joules of gravitational potential energy into electrical energy every second.

Loads that consume electrical energy are also given a power rating. A 60 W light bulb transfers 60 J of electrical energy into other forms of energy every second. Calculation of the electrical power requires knowing the voltage across the device as well as the current through the device. Power is the product of voltage and current ($P = VI$). For the power to be measured in watts, the voltage must be measured in volts and the current must be measured in amperes. Calculation of electrical power is not a curriculum outcome and material covering this concept is optional.

Since power is the rate at which energy is transformed, the amount of energy transformed can be calculated by knowing the power and the time. For example, if a device has a power rating of 4 W, it transforms 4 J of energy every second. If this device was used for five seconds, then it transforms 4 J of energy per second for each of those five seconds. Therefore, this device transforms 20 J of electrical energy. Energy, therefore, equals the product of power and time ($E = Pt$). In order for the energy to be measured in joules, the power must be measured in watts and the time, in seconds.

The joule is a relatively small amount of energy when examining the electrical energy transformations in common devices. A 60 W light bulb that is left on for one hour transforms over 200 000 J of electrical energy into other forms of energy during that hour. A larger unit for measuring energy is practical when dealing with electric devices. This larger unit of energy is the kilowatt-hour. The kilowatt-hour is still a measurement of power and time, but rather than the power being measured in watts, it is measured in thousands of watts, or kilowatts. Rather than having the short time interval of one second, one hour is used. To calculate energy in the kilowatt-hour, the power must be in the units of the kilowatt, and the time must be in hours. There are 1000 W in one kilowatt and 3600 seconds in one hour.

This section ends with the monitoring of electrical energy consumption in our homes. The electric meter that is attached to homes measures the amount of energy being consumed by that household. The turning disk indicates that energy is being consumed. If you turned off every electrical device in your home, the disk would stop moving. The needled dials record the total amount of energy in kilowatt-hours. A representative from the power company reads this meter and records the energy consumed. A month or two later, a new reading is recorded. The difference between these two measurements is the amount of electrical energy that the home has consumed in this time period. The power company charges a fixed amount of money for every kilowatt-hour of electrical energy used.

COMMON MISCONCEPTIONS

- Students may assume that power has something to do with strength. If something has more power, it does not necessarily mean it is stronger; instead, it means it has the ability to transfer energy at a faster rate.
- Students may assume that the power rating is how much energy of one form is produced. For example, students might assume that a 60 W light bulb produces 60 J of light energy every second. The 60 W rating is the amount of electrical energy it transforms every second. Most of this electrical energy does not go to light but instead ends up as thermal energy.
- Students may assume that they pay for the amount of power. The cost of electricity is based on the energy, not the power. If you use a 60 W light bulb for one hour, it would cost more than using a 100 W light bulb for 20 minutes.

ADVANCE PREPARATION

- Students will perform energy and power calculations in this section. Advise students to bring calculators to class.
- Activity 9-2A, on page 305 of the student textbook, requires three low-voltage power supplies and glass thermometers. Reserve this equipment if necessary. Useful research materials for advance preparation can be found at www.discovering-science.ca.

INTRODUCING THE SECTION, pp. 304–305

Using the Text

Have students read page 304, and discuss the difference between energy transformation and the rate at which energy is transferred. A good starting point would be to ask students to describe sports that require a lot of energy compared to sports that require the energy to be transformed quickly. Endurance sports like running marathons and playing soccer require a lot of energy. Weightlifting and sprinting require the energy to transfer quickly. To finish this discussion, have students refer to Figure 9.17, on page 304. Ask, "What is the reason that the sports car can transfer the energy faster?" Through eliciting answers, the concept of "more power" should eventually be conveyed.

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 3-5, Chapter 9 Key Terms, can be used to assist students.

Using the Did You Know, p. 304

Have students read the Did You Know? feature on page 304. Students will be surprised that drying their hair requires the amount of energy that it does. Ask students if all the energy transformed from the electricity went into drying the hair. This discussion will lead to the fact that electrical energy is often transformed into many other forms.

Using the Activity

Find Out Activity 9-2A

Energy Transformation in Resistors, p. 305

Purpose

- Students investigate the rate of energy transfer in different resistors.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 day before	Gather materials.	For demonstration: – 3 power supplies – 3 resistors of different sizes (50 W–100 W) – 3 glass thermometers – clear adhesive tape – stopwatch – connecting wires

Time Required

- 30 min

Safety Precautions

- Remind students to avoid touching the resistors while current passes through them and immediately afterward. The resistors can get hot enough to cause burns.
- Ensure that students do not use the power supply to generate voltages greater than 6.0 V.
- Remind students to be careful taping the resistor to the glass bulb of the thermometer.

Science Background

Resistors transform electrical energy into other forms of energy. In this situation, thermal energy is created from the electrical energy. Each of the resistors is a different value but is connected to the same amount of voltage. Therefore, the amount of current in each of the three resistors is different. The resistor with the smallest resistance will produce the greatest current. Since current is the amount of charge passing through the resistor per second, the resistor with the greatest current will be able to transfer the electrical energy the quickest. This result means that the smallest resistance will have the greatest power, since it has the greatest current.

Another way to analyze this result is by using the equation $P = VI$. Each of the three resistors will have the same voltage. Therefore, the resistor with the greatest current will have the most power, which means that it can transfer the electrical energy the fastest. The greatest current, and therefore the most power, will be in the resistor with the least resistance.

Activity Notes

- This activity is to be done as a demonstration. Students should be encouraged to make their own data tables and record the values you obtain.
- Most of the resistors ordered by schools have a power rating of 0.25 W. Care should be taken not to exceed this power rating, which means not applying too much voltage to the resistor. The calculation you can use to determine the amount of voltage is $V^2 = PR$.
- Be sure that the resistor is in good contact with the bulb of the thermometer. Have students use lots of tape to keep the heat from escaping.
- You may wish to distribute BLM 3-42, Energy Transformations in Resistors, for students to use when recording their data.

Supporting Diverse Student Needs

- English language learners and/or challenging needs students could be encouraged to create a labelled sketch of the apparatus.
- Interpersonal learners, students with difficulty reading, and others may benefit from answering the What Did You Find Out? questions with a partner, then comparing their answers with another pair of students.
- For enrichment, students could research how devices such as electric baseboard heaters and fish tank heaters control the amount of heat they produce.

What Did You Find Out? Answers

1. The resistors are producing thermal energy.
2. The resistors with a smaller resistance transformed the energy more quickly.
3. The resistor with the least resistance had the greatest current, since each resistor was connected to the same voltage. According to Ohm's law, the less the resistance, the greater the current.
4. The greater the current, the faster the energy is transformed by the resistor.

Using a Demonstration

Connect a variable power supply to an ammeter and light bulb in series. The ammeter will measure the current through the light bulb. Increase the voltage in the power supply until the bulb begins to glow red. Ask, "What form of energy is the electrical energy transformed into, in the light bulb?" (thermal and light energy)

Before increasing the voltage, observe the ammeter to note the amount of current passing through the light bulb. Then increase the voltage supplied by the power supply so that the light glows significantly brighter. Ask, "How does the amount of energy emitted by the light bulb compare to the previous observation?" The amount of energy in the form of both light and thermal energy will have increased.

Observe the ammeter to note the amount of current now passing through the light bulb. The amount of current will be greater than it was previously. Explain to students that if the two set-ups were left on for the same amount of time, more energy would have been converted by the larger current than the smaller current. Based on their observations, students could be asked for the relationship between the amount of current and the rate of energy transformation. The amount of current is proportional to the rate of energy transfer, since current is the flow of electrons. The electrons possess electric potential energy before they enter the light bulb. As they pass through the light bulb, they transfer their electric potential energy into thermal and light energy. A greater current means that the energy can be transferred at a faster rate.

TEACHING THE SECTION, pp. 306–310

Using Reading

Pre-reading—Key Word Concept Map

Consider discussing the Key Terms in this section with students before commencing reading. They could collaborate on a map on the chalkboard that relates all of the concepts, and relates each unit to the quantity it measures. 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—Note Taking

Encourage students to take notes as they read the assigned text material. It can be helpful to reword the topic titles as questions, and then use the questions to guide note-taking.

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 in a class or small-group discussion. Emphasize the importance of using precise language. Students could complete BLM 3-43, Calculating Power; BLM 3-44, Electrical Power and Energy; BLM 3-45, Power Problems; BLM 3-46, Calculating Energy Consumption; and BLM 3-47, The Price of Energy.

Supporting Diverse Student Needs

- Pair logical-mathematical learners with other students as they complete BLM 3-39, Calculating Power. Doing so will help students who do not have strong mathematics skills when they do similar calculations in Part 2 of Activity 9-2C, on page 311, as well as in BLM 3-44, Electrical Power and Energy, and in BLM 3-45, Power Problems.

Reading Check Answers, p. 310

1. Power is the rate of change in energy.
2. Power (P) is equal to the product of voltage (V) and current (I).
3. A power rating of 40 W means that the device consumes 40 joules of electrical energy every second.
4. $E = Pt$
5. The unit of energy commonly used for large amounts of energy is the kilowatt-hour (kW•h).

USING THE ACTIVITIES

- Activity 9-2A, on page 305 of the student textbook, is best used as an introductory activity. Detailed information about this activity can be found in Introducing the Section.
- Activity 9-2B, on page 310 of the student textbook, is best used once students are familiar with calculating energy consumption on page 308 and have covered the material on page 309.
- Activity 9-2C, on page 311 of the student textbook, is best used after students have learned about watts on page 306. To calculate power, they can refer to the equation $P = VI$ introduced at the top of page 304. This activity could also be used as a summary for this section.

Detailed notes on doing the activities follow.

Think About It Activity 9-2B

The Cost of Electricity, p. 310

Purpose

- Students relate the concepts of power and time to calculate energy consumption and the cost of operating electrical devices.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 class before	Remind students to bring a calculator for the next class. Make copies of BLM 3-48, Think About It Activity 9-2B, The Cost of Electricity.	For each student: – calculator

Time Required

- 20 min

Science Background

Electric power is the rate at which electrical energy is transformed. To calculate the amount of energy consumed, use the equation $E = Pt$. For the energy to be measured in kilowatt-hours, the power must be in kilowatts and the time, in hours. To calculate the amount of cost associated with the energy consumed, multiply the energy by the cost per kilowatt-hour. Appliances in homes that have the greatest daily cost would have a large power rating and be used for long periods of time, such as electric stoves, dryers, and water heaters.

Activity Notes

- Review with students the equation $E = Pt$.
- You may wish to distribute BLM 3-48, Think About It Activity 9-2B, The Cost of Electricity, for students to use when recording their data.

Supporting Diverse Student Needs

- Some students may have difficulty changing the power from watts to kilowatts. Dividing the power measured in watts by 1000 gives the power in kilowatts.
- Challenge students to come up with different energy problems for each other to solve.
- Encourage students to use their research skills to determine the current cost of electricity in Newfoundland and Labrador.

What To Do Answers

1.–3.

Appliance	Power (W)	Time of Use Each Day (h)	Energy (kW•h)	Cost (cents)	Cost (dollars)
Television	200	2.0	0.4	4	0.04
Stereo	80	1.5	0.12	1	0.01
Kitchen stove	12 000	2.0	24	230	2.30
Microwave	1 400	0.5	0.7	7	0.07
Bedroom light	100	4.0	0.4	4	0.04

What Did You Find Out? Answers

1. The kitchen stove had the greatest daily cost.
2. Students' answers may vary but should include appliances that have a high power rating and are used for long periods of time.

Conduct an Investigation 9-2C

A Current View of Power, p. 311

Purpose

- Students investigate the relationship between resistance, current, and power.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 class before	Remind students to bring a calculator for the next class.	For each group: – 3 resistors of different sizes (100 Ω–1000 Ω) – 1.5 V cell – ammeter – voltmeter – switch – connecting wires
I day before	Gather materials and apparatus.	

Time Required

- 50 min

Safety Precautions

- If any of the resistors or wires become hot, ensure that students disconnect the circuit immediately.

Science Background

The power rating of a resistor can be calculated by using the equation $P = VI$. A resistor is connected to a battery, and the voltage across the resistor and current through the resistor can be measured using a voltmeter and an ammeter, respectively. The resistor with the least resistance will draw the highest current when connected to a constant voltage. Since more electrons travel through this low-resistance resistor per second, the electrical energy is transformed at a faster rate. Therefore, the low-resistance resistor has the greatest power rating. This means that a 100 W light bulb would have a lower resistance than a 60 W light bulb.

Activity Notes

- This activity is best done in small groups but could also be done as a demonstration with students recording the results.
- In order for the power to be calculated in watts, the current must be in amperes. If students are measuring the current in milliamperes, be sure that a conversion is made.
- A low-voltage power supply could be used instead of the battery.
- Note that reading resistor colour codes is not required curriculum learning for students, so Procedure step 2 should be considered optional.

Supporting Diverse Student Needs

- For students who have trouble organizing their observations on paper, you may wish to distribute BLM 3-49, A Current View of Power, for students to use when recording their data.
- Partner English language learners or students with reading, mathematical and/or organizational challenges with students who have stronger language skills.

- This is a good hands-on activity for body-kinesthetic and visual-spatial learners. Students with good mathematics abilities should readily conceptualize the relationship among current, power, and resistance. As much as possible, ensure that both types of learner are represented in each group.

Analyze Answers

1. The voltage across each of the three resistors is the same.
2. The current through each resistor is different.
3. The resistor with the least resistance had the greatest power.
4. The resistor that has the most power has the least resistance. As the amount of current through a resistor increases, the power also increases.

Conclude and Apply Answers

1. A 60 W light bulb would have more resistance than a 100 W light bulb. When both bulbs are connected to the same voltage, the 60 W bulb transforms less energy per second than the 100 W bulb. This result is because the 60 W bulb has more resistance and allows less current to flow through it.

USING THE FEATURE

Career Connect: Industrial Electrician, p. 312

This material can be used as extension material to challenge students in several ways. After reading the Career Connect page, students could be asked to do the following:

- Answer the questions on page 312.
- Research the prerequisites for a career as an electrician. Students could be encouraged to prepare a plan for the courses that they would take in secondary school to prepare themselves for this career (or other careers that interest them).
- Visit www.discoveringscience.ca for more information on careers involving electricity and electronics.

Career Connect Answers

1. Industrial electricians work in industrial environments like factories, mines, or utility companies, whereas residential electricians work mostly in people's homes. Both types are involved in installing new electrical equipment, but industrial electricians are also responsible for checking, troubleshooting, and repairing the equipment afterward.
2. An industrial electrician keeps other workers safe by making sure that there is no voltage on equipment that could cause an electric shock.
3. To become an electrician, you need to take a nine-month pre-employment course in order to be registered as an electrical apprentice. You then need to complete an eight-week block of training after every year of working, and after three years, you can write the inter-provincial journeyman exam to become a qualified journeyman electrician.

SECTION 9.2 ASSESSMENT, p. 313

Check Your Understanding Answers

Checking Concepts

1. Electrical energy is energy released into an electrical load by moving electrons.
2. The rate of change in energy, the rate at which work is done, or the rate that energy is transformed is called power.
3. Possible units for energy are joule and kilowatt-hour. Power is measured in watts or kilowatts.
4. A joule per second is called a watt.
5. Large amounts of energy are measured in kilowatt-hours.
6. 1 kW•h is equal to 3.6×10^6 J = 3600 kJ or 3.6 MJ.
7. Three factors that determine electrical energy consumption are voltage of the device, current, and time that a device is operated.

Understanding Key Ideas

8. If one of the circuits has less resistance, then the battery will supply more current and therefore more power to that circuit.
9. 36 000 J
10. (a) 0.40 kW•h
    (b) 3.84 cents, which would be rounded to 4 cents
11. The second load produces 15 J of heat energy. The loads in the circuit can lose only as much energy as the source provides.

Pause and Reflect Answer

These sites are called power stations because they transform other forms of energy into electrical energy. The rate at which energy is transformed is called power, and therefore these energy-transforming locations can be called power stations.

Other Assessment Opportunities

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

9.3 ELECTRICAL ENERGY IN THE HOME

BACKGROUND INFORMATION

Conservation of energy is a basic understanding in physics. Energy exists in a variety of forms and can be converted to a variety of forms. When energy is used, the total energy going into a system is equal to the energy stored internally plus the energy that comes back out of the system, which is often in other forms. This section deals with electrical devices that are designed to convert electrical energy into other forms of energy, such as thermal energy, light energy, sound energy, and mechanical energy. The efficiency of the energy conversion can be calculated by dividing the useful energy output by the energy input, and is usually multiplied by 100 to express the value as a percent. Using a percent allows for easy comparison of all types of electrical devices. In Canada it is now required by federal law that special efficiency information be shown on EnerGuide labels attached to appliances. This label states the amount of electrical energy per year that the appliance uses, and is used to aid consumers in making "smart" purchases (for example, comparing refrigerators of the same capacity and buying the most efficient model). Understanding the efficiency of electrical devices is important in order to avoid wasting energy and paying high costs for energy consumption. (In some countries, such as Japan, the cost of electrical energy is much higher than it is in Canada.) New technologies are being designed to increase energy efficiency of devices that are important for us to use. Ultimately our use of energy has an impact on our environment and our way of life.

COMMON MISCONCEPTIONS

- Students may think that brightness of a light is directly related to the power rating of a light bulb; that is, the higher the power rating, the brighter the light. This concept does apply when you are comparing similar light bulb technology (for example, incandescent bulbs that are 40 W, 60 W, and 100 W). However, this relationship does not apply when comparing incandescent and CFL bulbs—the brightness is about the same for a 60 W incandescent bulb as for a 13 W CFL bulb.
- Students may believe that operating electrical devices will cost the same if the devices both use the same voltage and operate for the same amount of time. However, the amount of current needs to be considered. To clarify this concept, explain that operating a toaster will cost more than operating a radio for equal amounts of time even though they both use the same voltage (110 V). This is because the current to the toaster is much higher than that to the radio.
- Students may think that all the electrical energy that is used to make a stove element hot is transferred directly to the water in a cooking pot. Explain that some of the electrical energy is converted to heat energy, and some is converted to other forms such as light energy (the element glows) and sound energy (the cracking sound of the element and the pot as they expand when heated).
- Students may think that electrical devices that have Canadian Standards Association (CSA) approval on their labels are energy efficient. Clarify that CSA approval means that the device has been tested and is certified safe from producing electrical shock. All electrically operated equipment must meet rigorous safety standards in order to be legally sold in Canada. Consumers should always ensure that a device has the required CSA approval before buying it.

ADVANCE PREPARATION

- Activity 9-3A, on page 315 of the student textbook, requires two desktop lamps and two thermometers, as well as incandescent and compact fluorescent (CFL) light bulbs that are roughly equivalent in the amount of light they produce. Try to obtain identical desktop lamps and thermometers so that the only variable is the type of light bulb being used.
- Students will perform calculations with the efficiency equation in this section. Advise students to bring calculators to class.
- For Activity 9-3B, on page 322 of the student textbook, you might want to assign the research as homework a few days ahead of time, or book library/computer time for students to research during class.

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

INTRODUCING THE SECTION, pp. 314–315

Using the Text

Students have already seen that energy can be converted from one form to another, when they used a battery to power a circuit. The chemical energy produced in the dry cell is directly converted into electrical energy, which may then be converted into light energy and heat energy inside a light bulb. Ask students to identify other electrical devices in the home that convert electrical energy into different forms of energy. For example, a hair dryer produces thermal energy but also sound energy that is undesirable; a toaster produces mostly thermal energy but also some light energy and sound energy that are lost to the surroundings. Lead students to realize that if an electrical device can convert most of the energy into the desired form, then less energy would be wasted. Students should be familiar with the issue of not wasting electrical energy at home because the cost of electricity is increasing. They will likely realize that conservation of energy is very prevalent in the media.

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 3-5, Chapter 9 Key Terms, can be used to assist students.

Using the Did You Know, p. 314

Have students read the Did You Know? feature on page 314. Some students may want to use the equation $E = Pt$ to calculate the amount of energy that a 100 W light bulb uses in 24 h (8.64×10^6 J or 8640 kJ). Students may be interested in knowing that daily energy requirements (at normal activity levels) vary for different ages (for example, a toddler uses about 6000 kJ per day; a teenage boy, about 12 000 kJ per day; an adult heavy labourer, about 15 000 kJ per day). Energy values of foods are listed on package labels and are given in calories instead of Joules. Jogging is an activity that burns about 650 calories per hour.

Using the Activity

Find Out Activity 9-3A

Putting Energy Conversions to Good Use, p. 315

Purpose

- Students investigate electrical energy conversions to determine which conversions are "useful."

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 day before	Gather materials and apparatus.	For demonstration: – incandescent light bulb (60 W) – compact fluorescent light bulb (13 W) – 2 desktop lamps – 2 thermometers – ruler

Time Required

- 20 min

Safety Precautions]

- Ensure that students avoid touching the light bulbs, as they will become hot.

Science Background

A brief comparison between an incandescent light bulb and a compact fluorescent light (CFL) bulb was previously made in the Did You Know? feature on student textbook page 306. Students will know from page 308 that the amount of electrical energy consumed is calculated using the equation $E = Pt$; therefore, the amount of energy consumed by the 60 W light bulb in 10 minutes is equivalent to 36 000 J. Experimentation has shown that for incandescent light bulbs, about 95 percent of the input energy is released in the form of thermal energy, or heat. By calculating 95 percent of 36 000 J, the amount of energy produced as heat during 10 minutes should be about 34 200 J. This result is a measure of thermal energy, which is related to the change in temperature shown on the thermometer. Consequently, the amount of energy produced in useful form (that is, light energy) during 10 minutes should be about 1800 J. The efficiency of an incandescent light bulb for producing light energy is only about 5 percent. A 13 W compact fluorescent light bulb produces about the same amount of light as a 60 W incandescent light bulb and so it is about four times as efficient.

Activity Notes

- If possible, the two desktop lamps should be similar so that the differences between them are negligible and the only difference in the two set-ups is the type of light bulb used. (The packaging says that the light produced by a 13 W CFL bulb is roughly

equivalent to the light produced by a 60 W incandescent bulb.)
- This activity is to be done as a demonstration. Students should be encouraged to make their own data tables and record the values you obtain.
- You may wish to distribute BLM 3-50, Putting Energy Conversions to Good Use, for students to use when recording their data.

Supporting Diverse Student Needs

- As an extension, students could compare the information given on different light bulb packaging. For example, the packaging for a CFL bulb might provide information such as energy used: 13 W; light output: 900 lumens; life: 10 000 hours (nine years with average use, based on three hours average use per day); comparisons: the 13 W CFL bulb produces as much light as a 60 W incandescent light bulb; the CFL bulb lasts about 13 times longer, and provides up to 78 percent in energy savings (based on 12 cents per kilowatt hour).
- For enrichment, students could predict which setting of a tri-light incandescent light bulb (for example, 30 W/70 W/100 W) would generate the most heat, and thus reduce the life of the bulb. They could discuss situations when the related brightness (for example, 300 lumens/ 945 lumens/ 1245 lumens) would be required (for example, mood lighting/general lighting/task lighting).
- Students could use what they learn in this activity to develop a poster or other campaign to encourage the use of energy efficient bulbs.

What Did You Find Out? Answers

1. In an incandescent light bulb, electrical energy is converted into some light energy but mostly thermal energy (when the electron flow causes the filament wire to heat up). In a CFL light bulb, electrical energy is converted into some thermal energy but mostly light energy (when electron flow collides with mercury atoms in the bulb, which emit their excess energy in the form of ultraviolet light and then cause the phosphor lining of the bulb to emit visible light).
2. (a) The CFL light bulb uses less energy per second.
   (b) Students should observe that both bulbs produce about the same amount of light.
   (c) The incandescent light bulb produces much more heat than the CFL light bulb.
3. The total input energy used should be equal to the sum of the light energy produced and the heat energy produced. Energy cannot be destroyed, so all the input energy is converted into forms of output energy.

TEACHING THE SECTION, pp. 316–321

Using Reading

Pre-reading—Predict-Read-Verify

Break the section into chunks, such as the following:
- Energy Conversions
- Calculating Efficiency
- Making Energy-Conscious Choices
- Doing Your Part

Use the chunks as topics for discussion. Ask students what they think the heading means, and have them make a prediction about what they will learn in each chunk. They can then read the section and compare their predictions to what they learned.

During Reading—Think, Pair, Share

Ask students to read each chunk independently, record their thoughts, and then pair up with another student to discuss their thoughts. Students should work through the sample questions on pages 318 and 319, and try to do the Practice Problems on their own, using a calculator. Students can then check their partner's solutions, and make sure they agree with the answers.

Supporting Diverse Student Needs

- Students who do not have strong mathematics skills can work with students who are logical-mathematical learners.
- Remind students that they can use the Reading Check questions on pages 318 and 321 to help them decide if they have missed any important information in their reading. Have them read each question and share their answer with a classmate. For any question that their partner thinks they have not answered fully, both students should look up the information in the textbook that they need to develop a full answer.
- This section and the next should strongly appeal to students who are interested in environmental protection. Encourage students to use the information presented to discuss environmental concerns with others.

After Reading—Reflect and Evaluate

Have students review their notes and choose three facts that they think represent interesting new ideas. They can then write a statement about why they found these facts to be interesting or how they could apply them in their daily life, and share these statements in a class or small group discussion. Students could complete BLM 3-51, Calculating Energy Efficiency, and BLM 3-52, Calculating Energy Input or Output.

Reading Check Answers, p. 318

1. Students' answers should include three of the following: thermal energy (heat energy), light energy, sound energy, mechanical energy.
2. Efficiency is a comparison between the amount of useful energy produced (output energy) and the original amount of energy used (input energy). It is usually expressed as a percent.
3. Useful energy is the desirable energy that an electrical device is designed to produce so that it can perform a function. Waste energy is the undesirable energy that is also produced by the device, which is lost to the surroundings.
4. Four types of light bulb technologies are incandescent, fluorescent (CFL), light emitting diodes (LED), and halogen. The most energy efficient is LED. The most common is incandescent, though CFL is becoming more common each year as energy conservation becomes more widespread in the country.

Reading Check Answers, p. 321

1. $\text{Efficiency} = \dfrac{\text{useful energy output}}{\text{total energy input}} \times 100\%$
2. You could look at the EnerGuide label that is attached to the appliance, to see how much energy it uses in a typical year of use.
3. Three sources of heat loss in a home are through windows, doors, and air ducts and vents.
4. Students' answers may vary, but they should realize that if clothes are sorted into heavy, medium, and lightweight items, the lightweight items will dry faster and will not need to be dried as long. Also, if clothes are sorted by the amount of soiling, the least soiled clothes could be washed in cooler water or by using the washer's economy cycle, which is faster.

USING THE ACTIVITIES

- Activity 9-3A, on page 315 of the student textbook, is best used as an introductory activity. Detailed information about this activity can be found in Introducing the Section.
- Activity 9-3B, on page 322 of the student textbook, is best used after students have learned about making energy-conscious choices on page 320. Detailed notes on doing the activity follow.

Think About It Activity 9-3B

Conserving Energy, p. 322

Purpose

- Students research to determine different ways of conserving energy at home

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 or 2 days before	For homework, have students research different ways of conserving energy at home.	For each student: – Students will supply any materials that they require for research.

Time Required

- 15–20 min for class discussion

Science Background

Generally, people agree that we need to conserve energy in as many ways as possible. To reduce the amount of electrical energy we use, there are three possible approaches: turning off devices when they are not in use, changing the way things are done to use less electrical energy, and choosing more energy efficient devices. Considering the equation $E = Pt$, energy consumption will be reduced if the power rating of a device is lower and the time that it operates is reduced.

Activity Notes

- Procedure step 1 can be assigned as homework, where students individually determine possible ways of conserving energy, or you might wish to reserve library time at school for students to do some of their research. Encourage them to gather related information by looking through pamphlets and local power company newsletters, and talking to family members. Then ask students to bring their individual lists to class on the prearranged day in order to complete step 2.
- Students can work in large groups to combine their lists for all five of the suggested categories in What to Do step 1. Alternatively, small groups might focus their work on one of the categories and prepare a presentation to share with the rest of the class.
- A small group might focus on a different subtopic, such as electrical devices that are in standby mode when they are not in use (for example, microwave oven, computer, answering machine, TV sets, electric toothbrushes), and share their research with the class.
- As described in the Extension section of the activity, students might do further research on the topic of conserving energy, starting at www.discoveringscience.ca.

Supporting Diverse Student Needs

- To help students who are struggling think of strategies for reducing electrical energy consumption, ask them to focus on how they could reduce the amount of time that an electrical device is used.
- To help students think about alternative approaches to using electrical energy, they could consider what people use when they go camping and do not use electricity.
- This is a collaborative activity. If students work in groups, ensure that each group includes interpersonal learners.
- Students who are visual-spatial learners might enjoy making posters or compiling a computer slide show presentation to convey their ideas to the class.
- As an extension, students could examine power company statements to determine how much energy is consumed at home during different time periods, and give reasons why the amounts vary during the seasons.

What Did You Find Out? Answers

1. Students' answers will vary but could include the following examples for each category: (a) cooking: use appliances that are energy-efficient (for example, toaster, kettle, stove); use the most efficient appliance to cook foods (for example, a microwave instead of a stove to heat up small portions; a kettle instead of a stove to boil water); cook many foods at the same time in the oven whenever possible; use the economy cycle on a dishwasher and do only full loads; (b) laundry: use a washer and dryer that have Energy Star® ratings; wash clothes in cold water whenever possible; air dry clothes whenever possible on a drying rack or clothesline; sort clothes to wash like clothing at the same time; avoid washing or drying partial loads; empty the dryer's lint filter before each load; dry consecutive loads; (c) refrigerator or freezer: use a refrigerator or freezer that has an Energy Star® rating; thaw or partially thaw frozen foods in the refrigerator before cooking; do not open the door unnecessarily; use the large freezer to freeze fresh foods; use the refrigerator's freezer to store food already frozen; (d) water heater: turn off when going away on an extended vacation; increase insulation around the tank and copper pipes to minimize heat loss; (e) crafts and recreation: use energy-efficient light bulbs; turn off lights and computer devices when not being used; spend less leisure time with electrical devices (for example, read a book instead of watching TV); reduce the need for air conditioning by opening windows at night and closing them in the morning, and drawing drapes to block out sunlight.
2. Students' answers will vary, and might include possible ideas such as changing bad energy-use habits that occur many times every day, or buying a high-efficiency refrigerator since it is constantly in use and requires a lot of energy to operate.

SECTION 9.3 ASSESSMENT, p. 323

Check Your Understanding Answers

Checking Concepts

1. As electrons flow through the thin filament in an incandescent light bulb, the electrical energy is converted mostly to thermal energy but also some is converted to light energy.
2. Efficiency is a measure of the percent of energy converted in useful form compared to the total amount of energy consumed in an electrical device. It is calculated by dividing the useful energy output by the total energy input and then multiplying by 100 to express the value as a percent.
3. An EnerGuide label tells how much energy an appliance uses in a typical year of use.
4. Having an Energy Star® logo means that the electrical device uses 10 to 50 percent less energy compared with a standard product in the same category.
5. Incandescent light bulbs involve heating a wire filament hot enough to make it glow.
6. CFL bulbs contain mercury vapour, which is a toxic substance, so the bulbs must be disposed of properly.

Understanding Key Ideas

7. A clothes dryer converts electrical energy into useful heat energy and mechanical energy, so that the clothes tumble and dry evenly. Some sound energy is also produced, which is considered waste energy.
8. Students' answer may vary. For example, a toaster converts electrical energy into thermal energy. A radio converts electrical energy into sound energy. A lamp converts electrical energy into light energy. An electric toothbrush converts electrical energy into mechanical energy and sound energy.

9. Incandescent light bulbs are relatively inexpensive, but they consume a lot of energy and do not last very long. They are also only about 5 percent efficient. Halogen lights glow brightly, but they still use a lot of energy and are only about 15 percent efficient. They are also a fire hazard. CFL light bulbs are relatively expensive and must be disposed of properly because they contain mercury, but they use little energy and last a long time. They are also three to four times more efficient at generating light than incandescent bulbs. LED lights are very energy efficient but they have limited usage at present.
10. The hair dryer is 46.3 percent efficient.
11. The 100 W incandescent light bulb is 2.3 percent efficient.
12. In a typical year of use, the electric stove will consume about 504 kW•h of electrical energy. Because the arrow on the EnerGuide scale is at the halfway mark, its energy efficiency is about mid-range compared to other stoves. Some will have higher efficiency and some will have lower efficiency.
13. Students' answers will vary and may include the following examples. (a) You could use a high-efficiency washer and dryer. To save energy consumption, you could let washed clothes air dry whenever possible and eliminate the need for a dryer. (b) You could put insulation around the hot water tank and pipes so that less heat is lost. Instead of taking a bath, you could shower for a short period of time and use less hot water. (c) You could replace your incandescent light bulbs with high-efficiency CFL bulbs. You could turn off all lights that are not essential for use in your home. (d) You could unplug computers and the television when not in use so that standby energy is not being consumed. You could spend less leisure time using electrical devices.

Pause and Reflect Answer

Students' ideas could involve making posters to educate the community about tips for conserving energy, or finding ways to improve collection and disposal of hazardous CFL bulbs and outdated electrical devices, such as computers and televisions. Some ideas for how a school could save energy and save money would be to use high-efficiency light bulbs; use timers to regulate the time that the lights and heating system are on; and turn off the power supply for computers at the end of a school day.

Other Assessment Opportunities

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

9.4 ELECTRICITY AND THE ENVIRONMENT

BACKGROUND INFORMATION

There are many sources of electrical energy. Students are already familiar with using batteries that convert chemical energy into electrical energy. Other examples of electrical energy sources were introduced to students in Chapter 8 on student textbook page 254. Friction, piezoelectric crystals, and generators involve mechanical energy; photo-electrochemical cells involve radiant energy; thermocouples involve thermal energy. There are five basic forms of energy that can be directly converted to electrical energy: mechanical energy, thermal energy, sound energy, radiant energy (light, radio, microwave, solar), and chemical energy. Other forms of energy, like nuclear energy and using the fossil-fuel form of chemical energy, can be indirectly converted but require several energy transformations to produce large amounts of electrical energy.

Electrical energy is our premier form of energy because it has many benefits. For example, it is clean and safe to use if the proper precautions are taken; it can be transmitted across large distances and can travel through conductors practically anywhere—underground and under water; and most importantly, it can be produced from all other forms of energy and then be converted back into these forms except for nuclear energy and the fossil-fuel form of chemical energy.

Most of Canada's electrical energy comes from the conversion of mechanical energy—the form of energy that involves some type of system with moving parts. The electrical energy that is used by homes and industry originates in electric generators in which a revolving magnet generates the electrical energy. At this level, students need to be aware only that electricity and magnetism are related forms of energy. Students are expected to be able to trace the path of energy conversions and transfer from source to use. For example, consider the energy produced at a nuclear power station: nuclear energy is transformed to heat energy (in the water), to mechanical energy (in the turbine), to magnetic energy (in the generator), to electrical energy (carried through utility lines), to light energy and heat energy (in a streetlight).

As described on student textbook page 328, transformers generally do one of two functions: step up (increase) the voltage, or step down (decrease) the voltage. You might provide examples of transformers, such as power adapters for various electrical devices (for example, electronic games, electronic keyboard). It is important to use the correct adaptor for a specific device, since the wrong adapter may not step down the voltage by the correct amount and the device will be damaged. There is a third type of transformer (called an isolation transformer) but this does not need to be addressed.

COMMON MISCONCEPTIONS

- Students may think that the delivered voltage to a house can be either 120 V or 240 V. Explain that each line delivers about 120 V, but there are two lines, as well as a third neutral line that is connected to the ground for safety. Some high-powered electrical devices in a home require 240 V to operate, such as a hot water heater and a stove, so the two lines are combined. Most electrical devices require 120 V to operate, and that is the voltage supplied to normal wall outlets and lights in a house. Point out that the voltage in a line may not always be exactly 120 V—it can be about 115 V or a bit less. These lines are also called live wires. There is no voltage in the neutral wire.
- Students may think that efficiency applies only to how well appliances transform electrical energy into other forms of useful energy. Explain that efficiency also applies to how well a form of energy is transformed into electrical energy. The waste energy usually ends up as thermal energy. The basic equation is the same as it was in section 9.3:

  $$\text{Percent efficiency} = \frac{\text{useful energy output}}{\text{total energy input}} \times 100\%.$$

  Students might be interested to know that wind generators are about 30 percent efficient at producing electrical energy; hydroelectric generators are about 20 percent efficient; solar cells vary from about 7 percent to 30 percent depending on the type; burning coal as fuel in thermal generating stations is about 22 percent; and nuclear power plants are about 20 percent efficient. For practice, have students complete BLM 3-50, The Efficiency of Producing and Transmitting Electrical Energy.

ADVANCE PREPARATION

- For Activity 9-4A, on page 325, you will need to obtain the necessary materials for each group of students: copper wire, a cardboard tube, a galvanometer or an ammeter, and a bar magnet.
- If possible, obtain an example of a generator so that students can identify the components and observe how they interact. The generator can involve the moving parts of a bicycle, or a crank that can be turned. If you build your own, you will need materials including a coil of wire wound around cardboard, magnets, a 1.5 V light bulb, and a nail for the spinning shaft. Visit www.discoveringscience.ca for details.
- If you wish to demonstrate that an energy conversion occurs from radiant energy into electrical energy, you will need to obtain a photoelectric cell (photocell or solar cell), a switch, a bulb, connecting wires, as well as a light source.

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

INTRODUCING THE SECTION, pp. 324–325

Using the Text

Have students read page 324 of the student textbook. If possible, give students the opportunity to examine a generator to observe the main components—a coil of wire and magnets, and how they interact. Generators are designed so that either the coil of wire or magnets move in relation to each other.

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 3-5, Chapter 9 Key Terms, can be used to assist students.

USING THE ACTIVITY

Find Out Activity 9-4A

Generating an Electric Current, p. 325

Purpose

- Students will build a simple generator and investigate factors that affect the current produced.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 day before	Gather materials and apparatus. Obtain wire strippers.	For each group: – 5 m insulated copper wire (about 26 gauge) – cardboard tube – galvanometer or ammeter – powerful bar magnet

Time Required

- 20 min

Science Background

Moving a magnet generates electron flow, and conversely, moving electric charges generates a magnetic field. Therefore, we say that magnetism and electricity are directly related—an increase in one causes an increase in the other. Electricity and magnetism are related forms of energy.

Recall that at the start of Unit 3, students built a simple electric motor in the activity on student textbook page 225. In that activity, students investigated how electricity and magnetism can be used to produce an electric motor. In this activity, students investigate how a simple generator uses magnetism to produce electricity.

To help students remember that magnetic materials produce energy when the movement is perpendicular to the circuit, describe the following situation. The movement of magnetic particles that occurs when a debit card is swiped through a card reader machine produces a tiny amount of electrical energy. Swiping the card works only when it is positioned perpendicular to the circuit.

Activity Notes

- Students can work together in small groups if desired.
- When students move the bar magnet inside the coil of wire at varying speeds, encourage them to first try it using the north pole of the magnet. Then ask students to predict what they think will happen if they repeat the activity using the south pole of the magnet.

Supporting Diverse Student Needs

- You may wish to distribute BLM 3-53, Generating an Electric Current, to help students organize their results as they record data.
- Encourage visual learners and English language learners to draw a sketch of the apparatus with labels for the materials.
- For enrichment, students could research the design of simple generators. As well, many inexpensive kits are available to build small generators.

What Did You Find Out? Answers

1. A moving magnet causes electron flow. Magnetism directly affects electricity.
2. The faster the magnet is moved, the faster the electrons flow so the greater the current is. When the magnet and the wire are stationary, current does not flow.
3. When the magnet and wire are moved parallel to each other, current does not flow.
4. The largest current is produced when the magnet and the wire are perpendicular to each other, and when the speed that either the magnet or the wire is being moved is the greatest.

Using a Demonstration

To demonstrate that an energy conversion occurs from radiant energy into electrical energy, you will need to obtain a photoelectric cell (photocell or solar cell). In the demonstration, students need to identify only electron flow, so you will also need a switch, a bulb, and connecting wires, as well as a light source. Ask students to predict what they think will happen when you shine the light source on the photoelectric cell and close the switch. They should realize that the bulb will glow because electrical energy is flowing in the circuit. Then ask students to predict what they think will happen if you vary the distance of the light source from the photoelectric cell. They should realize that the bulb will glow dimmer the farther away the light source is from the photocell, until you reach a distance where the light is not strong enough and the bulb does not glow.

Invite students to explain the energy conversion: when light strikes the surface of certain materials in a photoelectric cell (for example, silicon), electrons are released and produce an electric current. Then ask students to think of some common devices that use photoelectric cells to produce electrical energy. Some possible answers include the following: solar calculators, bar code readers at supermarket checkout counters, automatic switches that turn on streetlights at dusk, solar panels on a roof that provide some power for household needs, and flat surfaces covered with solar cells that power satellite equipment in space.

TEACHING THE SECTION, pp. 325–334

Using Reading

Pre-reading—Key Word Concept Map

Discuss the Key Terms in this section with students before commencing reading. Have students work in pairs to create a graphic organizer showing the relationships between the terms. This will clarify terms before students begin reading, allowing them to better link the terms to the concepts that they are studying. Refer students to Science Skill 8, Organizing Your Learning: Using Graphic Organizers, on page 495 of the student textbook.

During Reading—Note Taking

Encourage students to take notes as they read the assigned text material. It can be helpful to reword the topic titles as questions and then use the questions to guide note taking.

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 in a class or small group discussion. Emphasize the importance of using precise language. Students could complete BLM 3-54, The Efficiency of Producing and Transmitting Electrical Energy.

Supporting Diverse Student Needs

- Visual-spatial learners may wish to organize their notes in a graphic organizer such as a concept map. This will help them keep track of the energy sources and the conversion of different forms of energy used in the different types of generating stations.
- Body-kinesthetic and visual-spatial learners may benefit from acting out a flowchart that describes the transfer and conversion of energy from a generating station to the home; for example, wind energy → windmill generator → utility lines → porch light.
- As indicated in a note in the previous section, this section and the previous one should strongly appeal to students who are interested in environmental protection. Encourage students to use the information presented to discuss environmental concerns with others.

Reading Check Answers, p. 328

1. Electricity and magnetism are directly related; an increase in one causes an increase in the other.
2. A generator converts mechanical energy to electrical energy. A rotating turbine causes the wire conductor to rotate within the magnet of the generator or vice versa, creating an electric current.
3. Three types of electrical generating stations are hydroelectric, thermal, and nuclear.
4. A transformer is an electrical device that changes voltage. It can be found at a generating station, where it increases the voltage, or at local substations and pole or box transformers where the voltage is decreased enough for household use.
5. Electrical energy is transmitted at high voltage and low current because the power loss due to resistance in the wires is decreased.

Reading Check Answers, p. 334

1. Hydroelectric power generation is common in Newfoundland and Labrador because fast-flowing water is an abundant and a renewable resource; and hydroelectric generating stations are cost effective in meeting the electrical needs of the province. In Alberta, the costs for developing hydroelectric power are much higher, and the abundance of fossil fuels makes thermal generating stations a cheaper way to produce electrical energy.
2. Renewable energy sources differ from non-renewable sources in that renewable sources are not used up in the production of electrical energy, and generally they do not harm the environment. In Newfoundland and Labrador, flowing water involves a renewable energy source, and burning heavy fuel oil involves a non-renewable energy source.
3. Three examples of alternative sources of electrical energy are wind, solar, and fuel cells.
4. Three limitations in developing alternative sources of electrical energy are cost, dependability, and environmental impact.

USING THE ACTIVITIES

- Activity 9-4A, on page 325 of the student textbook, is best used as an introductory activity. Detailed information about this activity can be found in Introducing the Section.
- Activity 9-4B, on page 330 of the student textbook, is best used after students have read the information on student textbook page 329. Detailed notes on doing the activity follow.

Think About It Activity 9-4B

Seek the Source, p. 330

Purpose

- Through examining given data, students will contrast the most common sources of electrical energy in Canada.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 day before	Remind students to bring a calculator to the next class. If you wish, students can use a computer to make the five bar graphs. Ensure that a computer with graphing software is available.	For each student: – calculator – computer with graphing software (optional) or grid paper

Time Required

- 30 min (or longer if the bar graphs are drawn on grid paper by hand)

Science Background

Bar graphs are useful for visually comparing data quickly. For details on making bar graphs and interpreting them, students can refer to Science Skill 4, Using Graphs in Science, on pages 486 and 487 of the student textbook. It does not matter if the bar graphs are horizontal or vertical.

Activity Notes

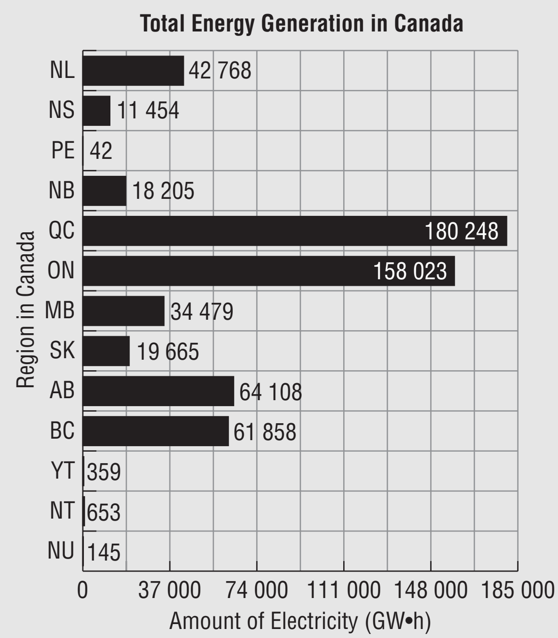
- Students can work in small groups to make the five bar graphs, either by using a computer with graphing software or drawing by hand on grid paper. Or, you might assign the What To Do step as a homework assignment, so that students can work on the What Did You Find Out? questions during the following day in class.
- If students have Internet access at home, they can make their bar graphs by simply searching key words like "Make a bar graph," and then entering the appropriate data found on student textbook page 329.
- For What Did You Find Out? question 1, students can use either the total energy given under the large pie graph (592 008 GW•h) on page 329, or they can use a calculator to find the sum of the total energy for all of the 13 regions. Note: In the first printing of the student textbook, the total for Manitoba is incorrect. It should be 34 479 GW•h. The difference in the total listed under the pie chart (592 008 GW•h) and the total correct additive number (592 007 GW•h) is due to rounding.

Supporting Diverse Student Needs

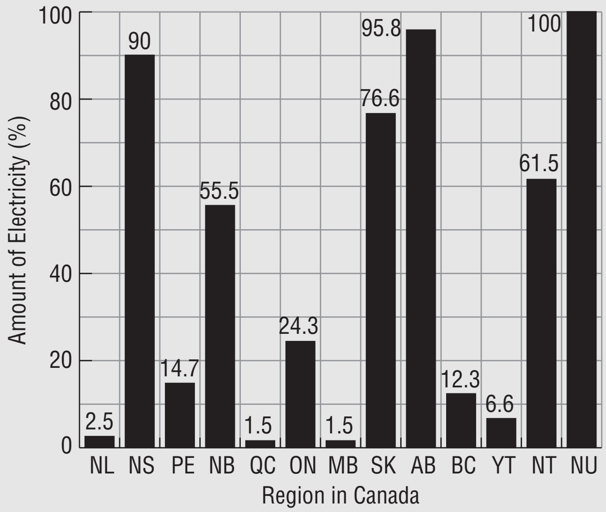
- This is a good activity for visual-spatial and logical-mathematical learners. Arrange groups so that these students can provide support to others.
- Remind students with weaker mathematics skills that percent is calculated by dividing a particular amount by the total amount and then multiplying by 100.
- For an extension, students could apply question 4 to other regions in Canada. For example, Nova Scotia thermal energy production is high, and is related to the coal industry that has been developed there. Québec and British Columbia hydro production are high, and are related to the geographic location of these relatively large regions, which are rugged with many rivers and an ocean coastline. Prince Edward Island hydro is low because geographically, the region is small and relatively flat.
- For enrichment, challenge students to calculate the amount of energy used in Newfoundland and Labrador in 2006. Hint: They will need to use the information in the Did You Know? feature on page 309 (Newfoundland and Labrador exports about 75 percent of the electricity that it produces). (Answer: 25% of 42 768 = 10 692 GW•h)

What To Do Answers

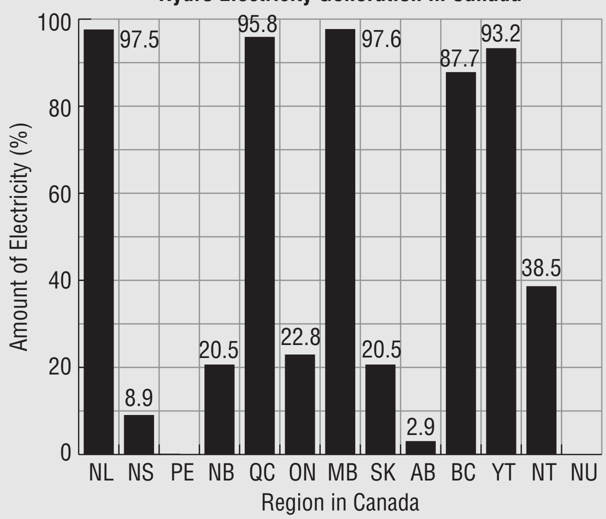
1.



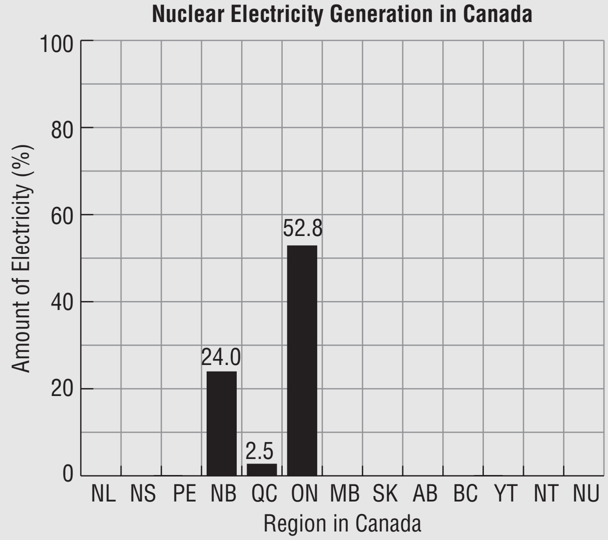
Thermal Electricity Generation in Canada



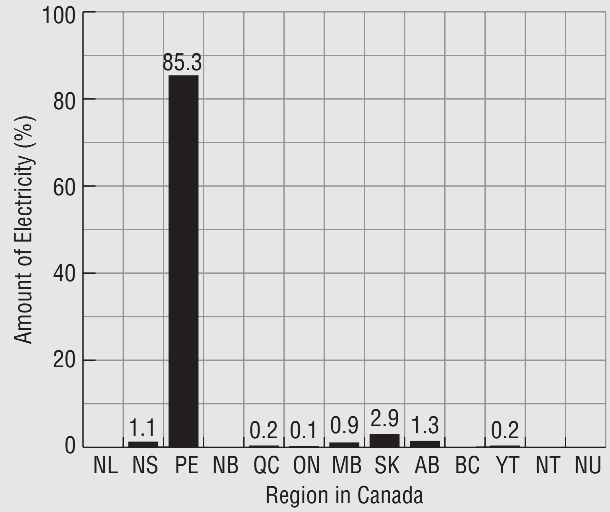
Hydro Electricity Generation in Canada



Nuclear Electricity Generation in Canada



Wind and Tidal Electricity Generation in Canada



What Did You Find Out? Answers

1. The total electrical energy production in Newfoundland and Labrador is ranked fifth highest compared to the other provinces. The percent of Canada's total energy that was produced in Newfoundland and Labrador in 2006 is 42 768 ÷ 592 008 × 100%, which is about 7.2%. The percent of Canada's population that lives in Newfoundland and Labrador (from the 2006 Statistics Canada census) is 505 000 ÷ 31 613 000 × 100%, which is about 1.6%. The discrepancy of producing more electricity than is needed in the region allows Newfoundland and Labrador to export (sell) over 75 percent of the electrical energy it produces to regions that do not produce enough energy to meet their needs. This helps Newfoundland and Labrador earn money to pay for other things that are often more expensive because of its geographic location.
2. Most of the electrical energy produced in Newfoundland and Labrador in 2006 was hydroelectric (97.5%). This percentage of hydroelectric production ranks second highest of all the regions in Canada—only Manitoba had a higher percentage of hydroelectricity production. Five regions in Canada have high values (MB, NL, QC, YT, BC) because they have developed their hydro energy source more than any of the other energy sources (thermal, nuclear, and wind and tidal).
3. The sources of electricity in Canada, from most widely used to least widely used, are hydro, thermal, nuclear, and wind and tidal.

4. Students' answers will vary, but should be based on the natural resources found in each region, and the amount of money that each region has used to develop that source. For example, Alberta has vast resources of fossil fuels and has invested a lot of money in developing thermal energy that involves burning fossil fuels; Newfoundland and Labrador has invested most of its money in utilizing the abundant flowing water that is available to be harnessed; Ontario has invested a lot of money in nuclear energy because it needs to provide a lot of energy in the highly populated areas around the Great Lakes, rather than rely on transporting large amounts of hydro energy from a distance.

SECTION 9.4 ASSESSMENT, p. 335

Check Your Understanding Answers

Checking Concepts

1. At a thermal generating station, some type of fuel (for example, coal, heavy oil, natural gas) is burned to heat water so that the resulting steam turns a turbine. The turbine is connected to a generator, which creates electric current by rotating a wire coil within a magnet.
2. The energy source varies for producing the mechanical energy used to operate the generator in the four types of generating stations: hydroelectric uses the mechanical energy of falling or flowing water; wind uses the mechanical energy of blowing air; thermal and nuclear both use the mechanical energy of steam, except that the water is heated by burning some type of fossil fuel or by creating a nuclear reaction.
3. The essential components in a generator are a coil of wire that rotates inside a stationary field magnet.
4. A transformer is used to change the voltage of electricity.
5. Electrical energy for household use is 120 V in each wire.
6. Thermal generating stations are the second highest producer of electrical energy in Newfoundland and Labrador (2.5%).
7. Two renewable energy sources are hydroelectricity and wind (also solar, biomass, geothermal).
8. Two non-renewable energy sources are burning fossil fuels and creating nuclear reactions.
9. Solar cells are less than 30 percent efficient.
10. (a) The diagram shows a thermal generating station.
    (b) The fuel for a thermal generating station can be any fossil fuel such as heavy fuel oil, natural gas, or coal.
    (c) Advantage: Fossil fuels are readily available in some areas, so are relatively inexpensive to use for generating electricity. (Also, fossil fuels are abundant in Canada so their delivery is relatively dependable in the immediate future, and many people are employed in the business related to fossil fuels so it is good for the economy.) Disadvantage: Burning fossil fuels produces greenhouse gas emissions, which pollute the environment. (Also, fossil fuels are a non-renewable energy source, so the cost will eventually increase.)

Understanding Key Ideas

11. Students' answers may vary, depending on the type of generating station they choose to describe (hydroelectric, thermal, or nuclear). They all result in mechanical energy being converted to electrical energy in a generator, which passes through a step-up transformer, through power lines, to a sub-station, to a distribution station, and finally to the step-down transformer and a power line into a home.
12. A generator produces an electric current by either rotating a coil of wire inside a magnet or by rotating magnets inside a coil of wire.
13. Electrical energy is transmitted at high voltage and low current over large distances so that the power lost due to the resistance of the wire is minimized.
14. Students' answers may vary. They might say that wind energy would be most appropriate because it is usually windy on the coast and a single large-scale wind turbine would be the only cost; however, the wind turbine cannot be used on windless days or when wind speeds reach 90 km/h or more, so some type of backup energy system might be required. Solar energy is a good secondary source but would be of limited use on foggy or cloud covered days, as well as night. Hydroelectric power may not be appropriate because the cost of transmission lines would be prohibitive.

Pause and Reflect Answer

Students' answers will vary. Some might say that people would be prepared to pay more for electrical energy if the technology lessens a harmful impact on the environment, becomes more convenient and safer to use, or becomes more dependable, and will decrease other costs.

Other Assessment Opportunities

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

CHAPTER 9 ASSESSMENT, pp. 336–337

PREPARE YOUR OWN SUMMARY

Students' summaries should incorporate the following main ideas:

1. Series and Parallel Circuits
   - In a series circuit, there is only one path for current to travel. In a parallel circuit, there is more than one path for current to travel.
   - When any part of a series circuit is opened (removed), the current stops throughout the circuit. When one branch of a parallel circuit is opened (removed), the current still travels through the other branches of the circuit.
   - The current is the same throughout a series circuit. The current entering a parallel circuit must divide among the possible paths, so must equal the sum of the currents through each branch of the circuit. The current in each path depends on the resistance of that path.
   - The voltage on each load of the series circuit does not have to be equal. The sum of all the voltages across the loads in series must equal the voltage supplied to the circuit. The voltage across each load connected in parallel is the same.
   - When a resistor is added in series with other resistors, the total resistance of the circuit increases. When a resistor is connected in parallel to an existing resistor, the total resistance decreases.
2. Power
   - Electrical power is the rate at which electrical energy is being transformed into other forms (for example, heat, light, sound, mechanical).
   - One joule of electrical energy transformed in one second is one watt (W).
   - Electrical power can be calculated using the equation $P = VI$.
   - The power rating of an appliance is the amount of electrical energy it consumes every second.
   - The larger the power rating, the greater the current through the device. In order to have a large current, the resistance of the device must be low.
   - The amount of electrical energy consumed by an appliance can be calculated by using the equation $E = Pt$, where P is in joules and t is in seconds.
   - The cost of using an appliance is calculated by multiplying the amount of energy consumed in kilowatt-hours by the cost per kW•h, which is set by the power company.
3. Energy Efficiency
   - The percent of energy efficiency can be calculated as (the amount of useful energy output (in joules) ÷ total amount of energy input (in joules) × 100%).
   - Appliances have EnerGuide labels. The higher the energy efficiency of an electrical device, the better the device uses the energy it consumes, and less energy is wasted.
   - Incandescent light bulbs produce mostly heat, and only 5 percent is useful light energy. Newer technologies of light bulbs are more efficient: halogen (contain better filaments), compact fluorescent (contain mercury vapour, although mercury is toxic), and light emitting diodes (semiconductor chips instead of a glass bulb).
   - Energy can be conserved by using more efficient electrical devices, reducing the time that an electrical device is used, or by changing behaviour and materials.
4. Producing Electrical Energy
   - Large quantities of electrical energy are produced in three types of generating stations: hydroelectric, thermal, and nuclear.
   - Mechanical energy is converted to electrical energy in a generator, where a coil of wire rotates inside a magnet or vice versa.
   - Electrical energy passes through a step-up transformer so that it can be transmitted at high voltage and low current over transmission wires. It is converted to household voltages through several other transformers.
   - The availability of energy resources in a region usually determines the type of energy used in that region.
   - Common sources of electrical energy are hydro, thermal, and nuclear. Alternative sources include wind generators, solar panels, and fuel cells.
   - For each source of electrical energy, we need to consider safety, efficiency, cost of production, degree of environmental impact, and dependability.

CHAPTER REVIEW ANSWERS

Checking Concepts

1. A series circuit contains only one pathway, whereas a parallel circuit contains more than one pathway.
2. The current through the second resistor is the same as the current through the first resistor.
3. The total voltage lost on the three resistors would be 6.0 V.
4. (a) Increases
   (b) Decreases
5. The voltage is the same on both of the resistors.
6. (a) The total current entering the junction point must equal the sum of the current leaving the junction point.
   (b) The current in the two pathways will be different.
7. (a) Power is the rate at which energy is transformed.
   (b) Power is measured in watts (W).
8. To calculate the electrical energy consumed by a device, you need to know the power rating of the device (in watts) and the amount of time (in seconds) that the device was used.
9. (a) Electrical energy is measured in joules (J) and kilowatt-hours (kW•h).
   (b) The kilowatt-hour is a larger unit.
10. Energy is the product of power and time: $E = Pt$.
11. Useful energy is the wanted output energy that an electrical device was designed to produce. Waste energy is the unwanted output energy that also is produced by the device. The total energy consumed equals the sum of the output energies.
12. Renewable energy sources are those that can renew or replace themselves when they are used to produce electrical energy. Non-renewable energy resources are used up in the production of electrical energy and cannot be replaced within a human lifetime.

Understanding Key Ideas

13. (a) The second bulb goes out.
    (b) The result would be different if the bulbs were connected in parallel. Even if one bulb "burns out," there is still a pathway for current through the second bulb and therefore it would stay lit.
14. (a) Students' answers may vary but could include a car racetrack or a single-lane bridge.
    (b) Students' answers may vary but could include shoppers using multiple checkouts at the supermarket or people entering a bus by two different doors.
15. (a) The resistors are connected in parallel. Electrons leaving the battery have two pathways on which to return to the battery.
    (b) The resistors are connected in series. Electrons leaving the battery must travel through both resistors in order to return to the battery.
16. V_1 = 5.0 V, A_1 = 2.0 A
17. (a) The current would decrease because adding another resistor in series increases the total resistance of the circuit.
    (b) The current would increase because adding another resistor in parallel decreases the total resistance of the circuit.
18. V_1 = 6.0 V, A_1 = 2.0 A
19. Light bulb, hair dryer, microwave oven
20. (a) 96 cents
    (b) 15 cents
21. The useful energy output of the computer are the processing activities. Heat and sound energy are wasted by the computer.
22. Students' answers may vary.
    (a) LED lights for the keypad numbers on a cellphone
    (b) a halogen headlight on a schoolbus
    (c) fluorescent lights in a school hallway
    (d) compact fluorescent light bulb in a bedroom lamp
23. The efficiency of the microwave is 13.3 percent.
24. Transformers are necessary to increase the voltage of large amounts of energy before it is transmitted (so power loss is minimized), and also to decrease the voltage of energy so that it can be delivered to households, which have electrical devices that use 120 V and 240 V.
25. Fuel cells made from renewable energy sources could be used to power a car. A wind turbine used to power the car would not be practical because the car needs to be travelling at a reasonable speed for an extended period of time in order to produce energy. Solar energy alone would not be practical because there is not enough light on cloudy days or at night.
26. Students' answers may include two possibilities. Solar cells and wind generators have the least negative impact on the environment because they use a renewable resource and are clean so they do not pollute the environment.

Also, they do not cause significant disruption of habitat for creatures living in the area. However, solar energy and wind energy require a large amount of materials and need to be distributed over a large area.

Pause and Reflect Answer

When the two resistors are connected in parallel, the total resistance of the circuit decreases. The decrease in resistance causes more current to leave the battery. Since the voltage of the battery is the same, the increased current means more energy is leaving the battery per second and therefore the battery provides more power.

UNIT 3 ASSESSMENT

PROJECT

Finding the Best Battery, p. 340

Purpose

- By measuring voltage, current, and time, students apply the power and energy concepts that they have learned throughout the unit to determine which brand of battery supplies the most electrical energy.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 week before	Divide students into groups. Have students decide what size of battery that they are going to test. Students will need to bring 3 different brands of the battery size on the day of the testing.	For each group: – 3 brands of one battery type, such as C, D, AA, or AAA – identical light bulbs – voltmeters – ammeters – stopwatches – connecting wires – switches
1 class before	Assign and have groups complete Procedure steps 1–3.	
1 day before	Gather materials and apparatus.	

Time Required

- 90 min

Safety Precautions

- If any wires become hot, ensure that students disconnect the circuit immediately.

Science Background

C, D, AA, and AAA cells all have a potential difference of 1.5 V, yet they are different in the amount of electrical energy that they can transform. Even among the same sized cells, such as AA, there is a difference in the amount of energy produced by different brands. This project is designed to determine experimentally which brand produces the most electrical energy.

By connecting the battery to a load, the current leaving the battery and the voltage across the battery can be measured. The product of this voltage and current is the amount of power ($P = VI$) that the battery is providing at a given time. If this battery is left connected to the load, the amount of voltage across the battery and the current leaving the battery will decrease. Therefore, the amount of power that the battery provides will be less as time is increased.

The decrease in power supplied by the battery is due to the internal resistance of the battery increasing. This means that there is more energy lost inside the battery than when the battery is "fresh." A battery becomes "dead" when the internal resistance is so high that the voltage lost inside the battery's internal resistance is the same as the initial voltage of the battery.

A graph of power vs. time will show decreasing power as time increases. The graph line should have a negative slope. Since energy is the product of power and time ($E = Pt$), the area under the graph line, measured to the time axis, is the total energy output during that time interval. By graphing all three batteries on the same set of axes, students can recognize which area is the greatest. The greatest area therefore represents the brand of battery that produced the most electrical energy in that time.

Activity Notes

- Three bulbs connected in parallel will have less resistance than two bulbs connected in parallel; therefore, the amount of current leaving the battery will increase. This will allow students to get faster results.
- The bulbs will stop being lit before the current and voltage become zero. If time remains, students can keep recording data until the current and voltage become zero.
- Students do not need to wait for the bulbs to stop being lit. Students can measure their values for a fixed amount of time regardless of whether the bulbs are still lit or not. If students are measuring for a fixed amount of time, then be sure that each of their three bulbs is measured for the same amount of time.

- If enough equipment is not available for the whole class to perform this activity at once, then one brand of cell could be tested each class for three consecutive classes.

Supporting Diverse Student Needs

- Pair English language learners or learners with reading and/or organizational challenges with students who have strong language skills. Encourage these students to make a sketch and label the equipment used in this activity.
- As much as possible, ensure that each group includes logical-mathematical learners, as they will be able to support others in understanding the relationship between the variables involved.
- For enrichment, ask students to predict how their graph would change if
  (a) their circuit had one less bulb connected in parallel;
  (b) their circuit had one more bulb connected in parallel.
- Consumer-conscious students may wish to extent the activity by determining if the increased energy supplied by a battery is justified by the increased cost of the battery. Students should be as analytical as possible.

Other Assessment Opportunities

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

INTEGRATED RESEARCH INVESTIGATION

Generating Electrical Energy, p. 341

Purpose

- Students develop research skills as they broaden their understanding of converting different forms of energy into electricity.

Activity Notes

- The Internet has many resources on the seven energy sources listed. Students can begin their research by visiting www.discoveringscience.ca.

Supporting Diverse Student Needs

- Be flexible in report format to accommodate students' strengths. Other report formats should be allowed, such as oral reports, models, computer slide show presentations, poems, and songs.
- For enrichment, adjust the depth of analysis expected. The debate portion of this activity will provide certain students with specific skill sets an opportunity to demonstrate their strengths.

Other Assessment Opportunities

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

UNIT 3 REVIEW ANSWERS, pp. 342–345

Visualizing Key Ideas

1. Note: You may wish to distribute BLM 3-53, Unit 3 Review Concept Map, for students to record their answers.
   In the atom: positive, proton; negative, electron; neutral, neutron.
   On objects: loses electrons, positive; gains electrons, negative.
   Electric force: neutral + charged attract; opposite charges attract; same charges repel.
   Energy units: joule (J), or kilowatt-hour (kW•h).
   Energy = power × time
   Power unit: watt (W)
   Power = energy × 1/time
   Parallel circuits: current increases, voltage stays the same, resistance decreases.
   Series circuits: current stays the same, voltage decreases, resistance increases.
   Ohm's law: voltage (V) = current (A) × resistance (Ω).

Using Key Terms

2. (a) False. If an object is neutral, it has an equal number of positive and negative charges.
   (b) True
   (c) True
   (d) True
   (e) True
   (f) False. In a *parallel* circuit, the potential difference of the source is equal to the potential difference across each load.
   (g) True
   (h) False. No real device is a perfectly efficient energy convertor.
   (i) True

Checking Concepts

3. (a) An electroscope is used to detect static charge.
   (b) An electroscope indicates the presence of a static charge by the separation of the metal leaves.
4. "Positive" and "negative" are the names given to oppositely charged objects.
5. (a) The proton and the electron are the parts of the atom that have a charge.
   (b) The proton has a positive charge, whereas the electron has a negative charge.

6. An object that is grounded becomes neutral.
7. All charging is done by the transfer of electrons.
8. (a) Any metals are electrical conductors (for example, copper, aluminum, and gold).
   (b) Most non-metals are electrical insulators (for example, plastic, wood, and glass).
9. Like charges repel. Opposite charges attract. Neutral objects are attracted to charged objects.
10. Voltage is the amount of electric potential energy per one coulomb of charge.
11. Kinetic energy is energy due to motion, whereas potential energy is stored energy.
12. (a) Voltage, or potential difference
    (b) Current
    (d) Resistance
13. Static electricity is charge that remains in one location, whereas current electricity is charge that is moving.
14. Conventional current is defined as the flow of positive charge and flows from the positive terminal of a battery to the negative terminal. Electron flow is the movement of negative charge and flows from the negative terminal of a battery to the positive terminal.
15. When a charge passes through a resistor, the electrical energy is transformed into other forms of energy.
16. Voltage is the product of current and resistance, or resistance is the ratio of the voltage to the current.
17. The coloured bands on a resistor indicate the value of the resistance.
18. A series circuit has only one path on which electrons can travel. A parallel circuit has more than one path on which electrons can travel.
19.

	SERIES	PARALLEL
Current in every part of the circuit	Same	Different
Voltage across different size resistors in the circuit	Different	Same
Total resistance when a resistor is added	Increases	Decreases

20. In any complete series circuit, the voltage supplied by the battery is equal to the sum of the voltages lost on each resistor.
21. 4.0 A
22. The cost of electricity is affected by the amount of electrical energy consumed (in kW•h), which depends on the specific time period, and the cost rate for each kilowatt-hour.
23. The 100 W light bulb consumes more energy during the same time interval.
24. An EnerGuide label tells how much energy an appliance uses in a typical year and compares its energy consumption with other appliances in the same category.
25. A transformer is an electrical device that changes voltage.

Understanding Key Ideas

26. Lightning is created when charge is separated in the clouds. When the bottom of the cloud accumulates enough negative charge, the charge moves to the neutral Earth. This negative charge is attracted to Earth's surface because a positive charge has been induced on the surface. The charge moving between the bottom of the cloud and Earth is what we see as lightning.
27. The charged balloon induces a charge on the surface of the wall. This charge induced on the surface of the wall is opposite to the charge on the balloon; therefore, the balloon is attracted to the wall's surface. Since both objects are insulators, charge will not transfer between the objects.
28. Place the object against the dome of a neutral electroscope, then touch the other end of the object with the charged rod. If the charge transfers through the object and makes the leaves of the electroscope repel, it is a conductor.
29. Bring the negatively charged acetate strip near the charged plastic. If the charged plastic repels the acetate rod, then the charged plastic is negatively charged. If the charged plastic attracts the acetate rod, then the charged plastic is positively charged.
30. You could increase the electric force between these two objects by moving them closer together or increasing the charge on either or both of the objects.
31. When something is charged by conduction, the electrons transfer from one object to the other. When something is charged by induction, the electrons relocate within the object but do not transfer between objects.
32. Current in a circuit could be increased by increasing the voltage supplied to the circuit or by decreasing the resistance of the circuit.
33. Electrons throughout the circuit apply an action-at-a-distance force on each other. As soon as one electron is pushed, all the electrons throughout the circuit are pushed.
34. 8.0 A

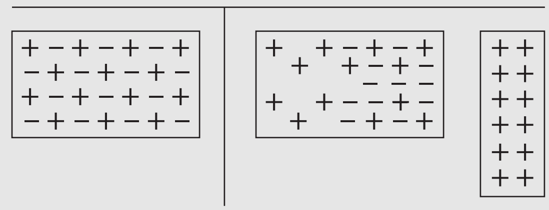
35. In a household circuit, people want the ability to turn on and off separate devices without affecting the rest of the house.
36. A generator produces electrical energy by rotating a coil of wire inside a magnet, or by rotating magnets inside a coil of wire.
37. Students' answers will vary. Energy can be conserved at home by turning off the lights when not required; using energy-efficient light bulbs, improving insulation in homes heated by electricity, and air-drying clothes when possible.
38. (a) The second bulb will not be lit.
    (b) If the bulbs were connected in parallel, the second bulb's brightness would not be affected since there is still a path on which current can travel through the bulb. Since that path still has the same source voltage, the brightness will not change.
39. 10 V

Thinking Critically

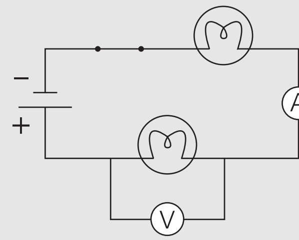
40. The puffed rice is initially neutral. When a charged object comes near, the electrons in the puffed rice move so that the cereal is attracted to the object. When the cereal comes in contact with the charged object, it may gain some charge. Now the puffed rice will be the same charge as the charged object and will be repelled.
41. Neither idea is a good idea. Golf clubs are made of metal and therefore are good conductors. Therefore, you should not be holding golf clubs when lightning is present. Lightning will tend to strike the tallest object. If you stand under a tree, lightning may hit the tree. A wet tree is a conductor, and therefore the electricity will travel down the tree and into the ground on which you are standing.
42. The wire with the low resistance will produce heat energy at a faster rate because the low-resistance wire will draw a larger current than the high resistance wire. Because of the higher current, electrical energy can be transferred at a faster rate.
43. Students' answers may vary. Fossil fuels are coal, oil, and natural gas, and they are made from the remains of plants that lived long ago. The plants originally obtained their energy from the Sun.

Developing Skills

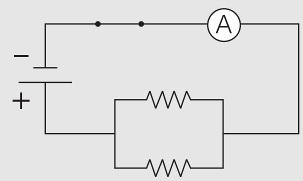
44.



45. A



B



46. 440 V
47. 20 Ω
48. 6.7 mA
49. R_2 has the largest resistance. The slope on a voltage-current graph is resistance. R_2 has a larger slope than R_1.
50. Circuit 1: $V_1 = 7.0$ V, $A_1 = 3.0$ A
    Circuit 2: $V_1 = 9.0$ V, $A_1 = 3.0$ A
51. The efficiency of the CD player is 62.5 percent efficient. The assumption is that the remaining amount of energy, 50 kJ, is all useful energy.
52. (a) (i) 2.52×10^6 J
        (ii) 0.70 kW•h
    (b) 7 cents

Pause and Reflect Answer

Students' answers will vary but could include that electrical energy is transformed into other forms of energy by an electric load, that all charging is done by electron transfer, and that energy, including electrical energy, is a valuable resource that we should conserve.