Unit 4

Unit 4 The Characteristics of Electricity

BIG IDEAS

- The production and consumption of electrical energy has social, economic, and environmental implications.
- Static and current electricity have distinct properties that determine how they are used.
- Electricity is a form of energy produced from a variety of non-renewable and renewable sources.

The Characteristics of Electricity Overall Expectations

- **E1** assess some of the costs and benefits associated with the production of electrical energy from renewable and non-renewable sources, and analyse how electrical efficiencies and savings can be achieved, through both the design of technological devices and practices in the home
- **E2** investigate, through inquiry, various aspects of electricity, including the properties of static and current electricity, and the quantitative relationships between potential difference, current, and resistance in electrical circuits
- **E3** demonstrate an understanding of the principles of static and current electricity

Materials

Please see page TR-35 for a list of the materials required for this unit and other units.

In this unit, students will learn about static electricity and current electricity. In Chapter 10, students are introduced to static electricity. Students investigate the different ways in which objects become charged and how they interact. In Chapter 11, students study the properties of current electricity. They will compare different types of batteries, and investigate the electrical properties of series and parallel circuits. In Chapter 12, students examine how electricity is generated, and assess the social, economic, and environmental impact of the different methods of energy production. This chapter aims to help students realize the importance of electricity in their everyday life, and enables them to become informed electrical energy consumers.

Using the Unit Opener (Student textbook pages 396 and 397)

- The unit opener photograph shows high-power transmission lines and towers. The inset photograph shows clothes hung out on a clothesline to dry. Students will likely be familiar with the fact that these transmission lines transmit electricity, but do they know where the electricity comes from? Use this photograph as a starting point to diagnose students' preconceptions on electricity. Consider engaging students by
  - discussing current campaigns such as David Suzuki's campaign to save energy, and the advertisements that feature tips on saving electricity. Ask students to give their opinions on the effectiveness of these campaigns, and ask them to suggest alternatives that would be more effective for their age group.
  - having students draw separate spider maps to show what they already know about the topics shown at the bottom of page 397. Refer students to Study Toolkit 4, Organizing Your Learning: Using Graphic Organizers, on page 566. They can revisit and revise these maps at the end of the unit.
- Check what students know and believe already about the characteristics of electricity using **BLM 10-1 Unit 4 Anticipation Guide.** When you have completed the unit, have them reflect on how and why their understandings and attitudes may have changed.

Assessment OF Learning for Unit 4

Activity	Evidence of Learning	Supporting Learners
Unit Inquiry Project	Students describe components in an electrical circuit and draw schematic diagrams. Students design and construct a circuit board that represents the actual wiring in a room. Students redesign a room so it becomes "greener."	Review series, parallel, and household circuits in Sections 11.3 and 11.5, and on **BLM 10-2 Designing Circuits.** As a class, brainstorm ideas on how to make any room in a home greener. As an alternative, have students conduct Internet research to discover tips on making their homes green. Start at **www.scienceontario.ca**.
Unit Issue Analysis Project	Students define the issue, describe multiple perspectives, and take a position with supporting evidence. Students conduct research, and communicate information to the intended audience.	Refer students to Science Skills Toolkit 1, Analyzing Issues–Science, Technology, Society, and the Environment, on pages 529 to 531, and Science Skills Toolkit 11, How to Do a Research-Based Project, on pages 552 and 553. See **BLM A-5 Investigating an Issue Checklist.** See **BLM G-12 Scientific Research Planner.**

Get Ready (Student textbook pages 398 and 399)

Prerequisite Learning

Students would benefit from understanding

- the different types of energy and transformation of energy. (questions 1 and 3)
- the difference between insulators and conductors. (question 2)
- the characteristics of simple circuits. (questions 1, 4, and 6)
- a static charge. (questions 1 and 5)

Prerequisite Skills

Students need to be able to

- design a test to carry out. (question 5)
- analyze diagrams. (question 6)
- interpret data from a table. (question 7)
- communicate in writing. (question 8)

Students can review some of these skills using **BLM 10-3 Skills for Unit 4.**

Answers

Concept Check

1. **a.** energy **b.** transformed **c.** Static **d.** current **e.** parallel **f.** series

2. Answers may include the following:
Insulating materials: paper placemats, paper plates, plastic cutlery, glasses, plastic chairs; wooden tables; plastic storage containers, plastic chip bag, plastic wrap, clothing and shoes, book, rubber wheel, food, water

Conducting materials: laptop, music player, chair legs, wheel spokes, earrings, belt

3. **a.** MP3 player—sound energy
b. toaster oven—heat and light energy
c. television set—light energy and sound energy
d. blender—mechanical energy and sound energy

4. **a.** a load: laptop, music player, watch
b. a power source: battery or wall socket, battery, battery
c. a switch: on-off switch on laptop and music player, no switch on watch. The circuit is completed when the battery makes contact with the metal in the watch.

Inquiry Check

5. Answers will vary, but could include rubbing the balloon on a sleeve and trying to stick it to the wall.

6. **a.** B **b.** A **c.** A **d.** B

Numeracy and Literacy Check

7. **a.** summer weekdays from 11 A.M. to 5 P.M.; winter weekdays from 7 A.M. to 11 A.M. and 5 P.M. to 8 P.M.
b. weekends and holidays (all day)

8. Answers will vary, but students might include the following ideas in their announcements: turn off lights in rooms that you are not using; turn off appliances that you are not using (for example, television, DVD player).

Assessment FOR Learning		
Tool	**Evidence of Learning**	**Supporting Learners**
Get Ready Concept Check	Students describe types of energy and list some characteristics of electricity and electrical circuits.	Bring in examples of small electrical devices or small circuits. Have students discuss what makes them work. Focus on where the energy comes from, how it travels, and what type it is.
Get Ready Inquiry Check	Students design a step-by-step plan to test an object's ability to hold a static charge. Students use inference to interpret circuit diagrams.	Have students work in pairs to deconstruct sample procedures in the textbook, identify the important parts, and tell why each part needs to be there. Ask students to write a procedure, and have a classmate edit it based on its completeness and the clarity of the instructions given. Discuss how you might complete each sentence together. Point out how helpful techniques such as elimination and comparison can be useful. Construct a word web for load, to help students infer the answer to parts b and d. See **BLM G-4 Making Observations and Inferences.**
Get Ready Numeracy and Literacy Check	Students analyze a data table to extract information. Students write a paragraph that encourages reducing the use of electrical energy, addressed to students and school staff.	Have students create a bar graph of the data to produce a visual display of the information to analyze. Use **BLM 10-3, Skills for Unit 4.** Have students listen to other PA announcements. Ask them to work in small groups of three or four to discuss what information should be included in the announcement, as well as the tone that appeals to both staff and students.

Using Making a Difference (Student textbook pages 427, 444, and 511)

Making a Difference on page 427 describes how a student designed a system that uses electricity to clean household wastewater, called grey water. Recycled grey water can be used to water lawns, which helps to conserve water. Students can be asked to research other benefits of recycling grey water. (For more information about grey water recycling, see www.scienceontario9.com.) Students can present their findings in a method of their choice. You can use **BLM A-30 Presentation Rubric,** or **BLM A-31 Communication Rubric,** to guide them.

Making a Difference on page 444 describes how two university engineering students invented the CPRGlove™ to inform the person wearing it if he or she is performing CPR incorrectly. The question at the end of the feature asks students to brainstorm ideas for new technology that could be invented to help them solve a problem that they have experienced. As a numeracy and literacy link, students could research the cost feasibility of manufacturing such an invention, and produce a brochure, radio, or television advertisement to introduce the product to potential customers.

Making a Difference on page 511 describes how two high school students investigated the efficiency of dye-sensitized solar cells (DSSCs) by conducting numerous experiments. Students are asked to find the names of organizations that help promote funding of research into sustainable energy technologies. This research can be used as a springboard to discuss the importance of sustainable energy efforts, both on the individual level as well as at the government and corporate levels.

Using Science at Work (Student textbook pages 520 and 521)

The Science at Work feature, on pages 520 and 521, introduces Ben Gulak, who invented a motorized unicycle for a high school science project. The aim was to design a vehicle that had less effect on the environment than gas powered motorcycles and scooters. As an introduction to this feature, have students examine the photograph of the Uno, and compare it to a traditional motorcycle. Ask, "How is its design eco-friendly?"

An extension to the career study is suggested in question 3 on page 521. As an alternative, students may opt to research the career opportunities specifically related to "green technology," a term used by Ben Gulak on page 520.

Preparing for the Unit Projects

Show students some brochures, posters, or websites promoting energy conservation. Ask them to list ways we can use energy more responsibly. Then have them skim the projects on pages 522 and 523. Ask students to brainstorm things they might need to learn in order to complete one of the projects. Have them skim the unit and predict where they might learn about each topic they mentioned. As you progress through the unit, draw students' attention to skills and understandings that will help them complete each project.

Using the Case Studies

The suggestions below provide opportunities for students of multiple learning styles to engage in and explore issues. The strategies chosen support bodily-kinesthetic, spatial, and interpersonal learning styles. The strategies also serve as pre-reading strategies and scaffolds for English language learners.

Chapter 10 (Student textbook pages 422 and 423)
Before reading the "E-waste" case study, have students make their own list of the electronic devices that they use at home. Ask them to place a checkmark beside those items that have been thrown out and replaced with newer models. With students' input, create a list on the chalkboard of 10 common electronic devices that have become e-waste in their homes. After reading the case study, invite students to explore websites whose focus is reducing e-waste. Have them begin their search at **www.scienceontario.ca**.

Chapter 11 (Student textbook pages 442 and 443)
Before reading the "Electric Avenue" case study, place students in small groups to generate discussion. (If you have several English language learners with the same first language, they could form one group and discuss in their first language as well as in English.) Give each group chart paper to record their ideas.

- Have students think about and jot down the advantages and disadvantages of gasoline-burning cars and electric cars.
- Ask students to list factors (such as technological development and ease of use, financial cost of manufacturing and maintaining the vehicle, and environmental impact) which they should consider before choosing either type of car. Ask students to assign a weighting of −5, −3, −1, +1, +3, +5 for each factor, with −5 being a strong disadvantage, and +5 being a strong advantage. Ask students to compare their weightings with those of other students in their small groups. After reading the case study, ask students to return to the list of factors, and revise their weightings either upward or downward.

Chapter 12 (Student textbook page 508 to 509)
Before reading the "Off the Grid and Living Green" case study, ask students to think about the quantity of electricity that they use at home. Explain what "off the grid" means, and ask them to consider if, in their current circumstances, they could move one step closer to living off the grid. Ask them to pick a number from 1 to 10. One means it would be extremely difficult for them to move one step closer, and 10 means it would be easy for them to move one step closer. Ask students to explain their choice. After reading the case study, ask students to compare their circumstances to the circumstances of the home mentioned in the case study.

Chapter 10 Static Charges and Energy

In this chapter, students will learn about the properties of static electricity. They will investigate how different materials become charged by friction, contact, and induction, and use diagrams to model the distribution of positive and negative charges in neutral and charged objects. Students will conduct experiments to determine the interaction of charged objects (the law of electric charges), and compare the conductivity of various materials. They will explore how various technologies work, such as lightning rods, grounding wires, photocopiers, and radiation dosimeters.

Using the Chapter Opener (Student textbook pages 400 and 401)

- Use the opening paragraph and picture on page 400 to elicit responses from students about lightning, electric charges, discharge, and shocks. Ask questions to determine their prior knowledge of these concepts. For example, "What happens to objects that are struck by lightning?", "Why?", "What causes lightning?", "What do you see sometimes in your day-to-day life that is similar to lightning?". To support English language learners, print key words on the chalkboard accompanied by icons to represent the meanings of the words, or create a word map.
- Help students become aware of the effects that electric charges have in our daily lives. Ask them to begin making a list in their notebooks of all the technology that relies on electric charges to work. They will add to this list as they work through this chapter.
- Have students interpret the diagram shown in Figure 10.7 on page 408 using the Interpreting Diagrams strategy described in the Study Toolkit on page 402. By doing this task, they will learn how to interpret a type of diagram used throughout the chapter and be prepared to better understand the concepts covered. (See notes below.)
- As an alternative, use a local news story about electrical storms, or lightning strikes, to get students thinking about static electricity in our daily lives. For English language learners, ensure that these types of materials are supported by clear illustrations.

Activity 10-1 Lightning in a Glow Tube (Student textbook page 401)

Pedagogical Purpose

This activity enables students to feel and see an electric spark. Common materials are used to create a static charge that is then discharged through a glow tube. The observations will allow students to make a connection between static charges and lightning. As students analyze what is going on, they can be introduced to concepts such as static charge, discharge, charging by friction, charging by induction, insulator, and conductor. Use this activity as an opportunity to introduce students to new terminology that they will encounter in the chapter and/or to determine prior knowledge and misconceptions students may have about electrostatics.

Materials

Please see the teaching notes for each activity for a list of the materials required. Please see page TR-35 for a summary of the materials required in this chapter and other chapters.

Advance Preparation

- Activities in this chapter require materials for producing static charge, such as those listed in Table 10.1, Electrostatic Series of Some Common Materials, on page 405 of the student textbook. The most commonly used materials include wool, fur, a rubber balloon, a glass rod, and an ebonite rod. Gather these materials ahead of time.
- Activity 10-1, on page 401 of the student textbook, uses materials that can be found around the house (for example, foam plates, cups, and so on). Ask students to gather these materials, if possible, a few weeks before the activity.
- Activity10-2, on page 412 of the student textbook, and Plan Your Own Investigation 10-B, on page 430 of the student textbook, require a class set of pith ball electroscopes and metal leaf electroscopes. A few months before the first activity, order or borrow enough electroscopes so that each pair of students has one electroscope to use.
- Plan Your Own Investigation 10-A, on page 429 of the student textbook, requires a class set of conductivity testers and an assortment of various materials listed on page 429. Try to obtain enough testers so that students can work in pairs or small groups.
- Students can review the Key Terms in Chapter 10–listed on pages 403, 411, and 418 of the student textbook–using **BLM 10-4 Chapter 10 Key Terms.**

Planning		
Materials	Masking tape Aluminum pie pan Wool cloth	Foam cup Foam plate Neon glow tube
	• Begin gathering materials a few weeks before the activity. Foam cups, foam plates, and aluminum pie pans may be purchased at dollar stores, or students could be asked to bring them from home. Neon glow tubes or bulbs are available in most electronics stores.	
Time	Approximately 25 min in class 10 min to assemble a set of materials beforehand, if you wish to show students what they look like	
Safety	• If students are allergic to fur, ensure that it is not one of the materials used.	

Background

The entire apparatus for charging the aluminum pie pan is called an *electrophorus*, which is Greek for "charge carrier." Since foam is an insulator, the charged plate will hold onto its charge and can be used to charge the aluminum pie pan several times.

When the foam plate is rubbed with a wool cloth, electrons transfer from the cloth to the plate (see Table 10.1, Electrostatic Series of Some Common Materials, on page 405 of the student textbook), making the foam plate negatively charged. This process is called charging by friction.

When the aluminum pie pan is placed on top of the negative plate, the electrons on the foam plate repel some of the electrons on the aluminum pie pan, causing them to move away from the side closest to the foam. When you touch the pie pan, you act as a conductor; a small electric shock is felt as the electrons move from the pie pan through your finger. The aluminum pie pan is now positively charged. This process is called charging by induction.

If you bring the positive pie pan near any object that can be a source of electrons, a second spark will occur when electrons move from the object to the pie pan. You can also discharge the pie pan using a neon glow tube. When one metal lead is in your fingers and the other lead is touching the pie pan, an electric spark travels through the low-pressure neon gas in the tube, creating a noticeable glow.

Activity Notes and Troubleshooting

- If the foam plate is being used for the first time, it may be necessary to rub it for a minute before it becomes charged.
- You may find that rabbit fur charges the plate more effectively than wool.
- To test whether the foam plate is charged, students can slowly move it back and forth above their bare arms. They should feel a tingly sensation as the hairs on their arms respond to the electrical force created by the charged foam plate. If they feel nothing, they can try rubbing the plate again.
- Dimming the lights in the room will make it easier for the spark to be seen when the aluminum pie pan is discharged. Students may also experience small shocks—also evidence of an electric charge.

Additional Support

- ELL Students should work in pairs or groups of three. Working in groups of three allows English language learners to participate at a level suitable for their English proficiency. Completing hands-on tasks allows English language learners to demonstrate understanding without the need for verbal proficiency.) Each student can be assigned a specific task: construction of the apparatus, charging of the foam plate, and charging and discharging of the aluminum pie pan.
- For students with vision impairments, replace the glow tube with a device that makes a sound, such as a buzzer.
- DI This activity will appeal to spatial and bodily-kinesthetic learners. Students who have difficulty putting the apparatus together (for example, taping the foam cup to the aluminum pie pan) should be partnered with a classmate who can help them.
- ELL You may wish to provide English language learners with the definitions for *static charge* and *electric shock* prior to the activity. Discuss examples that they have encountered in their daily lives to help solidify their understanding of these two concepts (for example, their hair stands up when they pull off their wool hat or sweater; they feel a "zap" when they touch the door knob after shuffling across the carpet).
- ELL Support English language learners and others requiring accommodation with written instructions, by demonstrating the steps to be carried out and having students respond by listening and performing the appropriate actions.
- ELL To build English language learners' understanding of written instructions, highlight key verbs and explain them in simple language.
- Enrichment—Have students give the foam plate a positive charge. What materials can they use to rub the plate? (See Table 10.1, Electrostatic Series of Some Common Materials, on page 405 of the student textbook.) Ask students to predict, and then investigate, whether the results will be the same when the positive (instead of the negative) plate is used to charge the aluminum pie pan.

Answers

1. When your finger touched the aluminum pie pan in step 4, a small electric shock was felt because the pie pan had a static charge. Electrons moved from the pie pan and into your finger.
2. The glow tube was not glowing before it touched the pie pan. It glowed briefly in step 5 when the static charge on the aluminum pie pan discharged through the glow tube. Afterward, the glow tube did not continue to glow because the charge on the pie pan was not replaced.

Study Toolkit

Strategy	Page Reference	Additional Support
Interpreting Diagrams	Have students use the strategy described on page 402 to identify three things they can learn from Figure 10.7 on page 408 of the student textbook.	
Identifying the Main Idea and Details	Have students use the strategy described on page 402 to make notes about the three methods of charging objects found on pages 403, 412, and 415.	Prior to note taking, model this strategy by working through an example together using a graphic organizer (for example, Main idea: "Static is all around us." Details: Clothes stick together; static shock can happen when grabbing a doorknob). Draw students' attention to clue phrases (signal words–"for example, for instance") that show that a detail will follow. Then repeat in written form.
Word Families	As they work through the chapter, have students use the strategy described on page 402 to complete a glossary list of all the words with the base *electro* in this chapter.	

Section 10.1 Exploring and Explaining Static Charges

(Student textbook pages 403 to 410)

Specific Expectations

- **E2.1** use appropriate terminology related to electricity
- **E2.2** conduct investigations into the transfer of static electric charges by friction, and produce labelled diagrams to explain the results
- **E2.3** predict the ability of different materials to hold or transfer electric charges
- **E2.4** plan and carry out inquiries to determine and compare the conductivity of various materials
- **E3.2** explain the characteristics of conductors and insulators and how materials allow static charge to build up or be discharged

In this section, students will learn how objects can be charged by friction. They will apply their understanding of the atom to explain the behaviour of static charges, and use diagrams to show the differences between neutral and charged objects. Students will carry out an investigation to determine the conductivity of different materials. They will compare the characteristics of insulators and conductors, and explain how grounding works.

Common Misconceptions

- **Students may think that static electricity is a physical substance that is created.** However, no new matter is made when a static charge "builds up" on an object. A static charge is produced when there is an imbalance of positive and negative charges in the object due to the transfer of electrons from one object to another. Overall, the net charge is still zero; no new charges have been created or destroyed, just moved around. Remind students of addition with integers. $0 + 0$ is the same as $(-2) + (+2)$.
- **Some students may think that when two objects are rubbed together, the protons move from one object to the other, while the electrons move in the opposite direction (that is, positively charged objects contain only protons and negatively charged objects contain only electrons).** Have students review their understanding of the Bohr-Rutherford model of the atom. The positive protons and neutral neutrons are located in the nucleus, while the negative electrons orbit the nucleus in specific energy levels (similar to the way the planets revolve around the Sun in specific orbital paths). Due to their mobility, small mass, and distance from the nucleus, the outermost electrons can easily transfer between atoms during rubbing or contact. The number and location of the protons in an object do not change during rubbing.
- **Some students may conclude that insulators cannot be charged no matter how much you rub them, since an insulator is a material in which electrons cannot move easily from one atom to another.** This idea is not true. Have students charge a rubber balloon and a foil balloon separately, then hold them against the wall and let go. The charged rubber balloon will stick to the wall much more easily than the charged foil balloon. Being an insulator means it is harder for the charge to dissipate or flow elsewhere. In fact, producing static electricity requires the use of electrically insulating materials.

Background Knowledge

Static electricity occurs under the following conditions:

1. Two objects made of different materials are rubbed together.
2. Both objects are electrical insulators.
3. Humidity is relatively low.

When two objects made of different materials are rubbed together, electrons transfer from one object to another, producing two objects of opposite charge. Whether an object becomes positively charged or negatively charged depends on the type of materials involved. For example, a rubber balloon becomes negative when rubbed with a piece of wool, but the same balloon becomes positive when rubbed with a piece of foam. An electrostatic series shows a list of materials arranged in order of their ability to hold on to their electrons (for example, Table 10.1, Electrostatic Series of Some Common Materials, on page 405 of the student textbook; or **BLM 10-5 Electrostatic Series**). This list can be used to predict whether an object will acquire a positive or negative charge when rubbed with a different material.

“Static cling” occurs when oppositely charged materials attract to one another and stick together. For example, when plastic wrap is pulled from its roll, the friction as it brushes the side of the box or even your fingers causes electrons to be transferred from one area to another. The surface that loses electrons has a positive charge while the area that gains electrons has a negative charge. As a result, the plastic wrap clings to any neutral or oppositely charged object by electrical attraction, such as a sandwich, a plate, or even another part of the plastic wrap.

Another example of static cling occurs when drying clothes in a dryer. In the rotating drum of a dryer, static charges build up on the different materials as they rub against one another in the warm, dry air, causing oppositely charged clothing items to attract and stick together. One way to avoid this static cling is to wash loads of clothes that are made of the same fabric (that is, do one load of items made from cotton only, another load of items made from wool, and so on). Another way to eliminate static cling is with anti-static sheets. These sheets work by giving the clothes a chemical coating that prevents their actual surfaces from touching one another.

Materials can be classified according to their electrical conductivity. Materials in which electrons can move easily between atoms are called *conductors*, and those that do not allow electrons to flow through easily are called *insulators*. Because different materials have different degrees of conductivity, there is a range between strong insulators and strong conductors. Typically, metals are good conductors while non-metals are good insulators. However, there are some non-metals that conduct fairly well; they are called semiconductors (for example, silicon).

Air and water can behave as insulators or conductors depending on the conditions. For example, dry air is a good insulator while humid air is a fair conductor. Pure water is a good insulator, while water containing dissolved minerals is a good conductor. When minerals are dissolved in water, they break up into electrically charged atoms called ions, which can move freely through the water. Different ions can carry varying amounts of electric current depending on their size and amount of electrical charge. Smaller, highly charged ions are the most efficient transporters of electric current. Also, higher concentration of ions in the water results in greater conductivity of the water. Salt water is a good conductor of electricity.

Grounding is the process in which a static charge is eliminated by adding or taking away electrons from the charged object to make it neutral. This procedure involves connecting the charged object to a conductor that is attached to Earth. Earth is so massive that it can absorb any electric charge. Depending on the situation, static electricity can be removed in different ways:

- Static charges tend to build up when the air is dry, so increasing the humidity of the air in a room will prevent static charges from occurring.
- When working with electrical components or materials that cause sparks, you can ground work surfaces by using a wire connected to the ground, or wear static control wristbands that are wired to grounding points.

To eliminate or reduce the shock felt from small electric discharge, you can do the following:

- Touch an insulating material that will slowly take away the static charge.
- Touch a metal object with the palm of your hand, rather than the tip of your finger, so the charge will spread over a larger area, reducing the sensation felt from the discharge.
- Try rubbing an anti-static sheet. The sheet contains chemicals that are electrically conductive, which helps to dissipate the static charge.

Literacy Support

Using the Text

- ELL Use several pre-reading strategies to engage English language learners. Use a simple scavenger hunt to help students locate various text features. At the same time, students will be exposed to words that describe the text features, like *figure*, *table*, *bolded*, *diagram*, and *subtitle*. For example,
  Which picture or figure shows an example of static charge? Find three materials in the Electrostatic Series table on page 405 of your textbook. List the bolded words on page 406. Why are they bolded? Find the definition of insulator. *Find a symbol for* grounded. *Which diagram shows a negative charge? Find a subtitle that explains how to keep fuel trucks safe."*

  Debrief this activity with students. Ensure English language learners understand the idiom *Grounding for Good.*

Before Reading

- Have students preview the text features in this section. Use each heading as a topic title for discussion. Ask students to read the titles and look at the diagrams to write a prediction about what each section will be about. Upon reading the student textbook, ask students to compare their predictions with, or verify their predictions against, what they learned. Refer students to Study Toolkit 1, Preparing for Reading: Previewing Text Features, on page 563 of the student textbook.
- ELL As you discuss each heading, ensure that English language learners understand the Key Terms in that subsection. Provide examples and non-examples of each term, for example, lightning is electricity, but energy from burning wood is not electricity.

During Reading

- ELL English language learners need support to manage the density of text. Consider "chunking it." Provide students with a limited section to read and give them a purpose for reading. Model skimming the text by posing a question and then skimming the text to locate a chunk of text to answer this question. For example, select the subsection Charging by Friction, on page 403; ask, "How can I charge something by friction?"; and skim to find the sentence that begins, "Rubbing a piece of wool cloth… ." Explain why and how this sentence was selected. (because it includes the phrase "examples of charging by friction") To practise this skill, have students work with a partner to locate information in the student textbook to answer the questions you pose.
- Students can write questions based on the headings to which they will find the answers as they read the section. For example, "How do objects become charged when they are rubbed together?" "What are the properties of the subatomic particles in an atom?" "Why is grounding important in certain work conditions?"
- Refer students to the Word Families strategy in the Study Toolkit on page 402 of the student textbook.
- ELL Note taking is an important skill for all students, including English language learners. Provide the following structure for English language learners: Create a table with the headings Term, Definition, Drawing/Example, and My Language. Ask students to fill in this table using the bolded terms as a guide.
- ELL English language learners benefit from returning to the textbook for multiple purposes. Consider partnering English language learners with students who have strong first-language skills, and assigning a chunk of the textbook. Have students discuss and record the main ideas and supporting details. Have the groups share orally while you clarify the main ideas, missed details, and misconceptions.

After Reading

- Use graphic organizers. Have students draw a concept map to connect the different concepts that they have learned about related to static electricity. They can use **BLM G-34 Concept Map.** Invite students to share their ideas with the rest of the class in a short oral presentation.

Using the Images

- Use Figure 10.1, on page 403, to explore the idea of static charge. Ask students how the image shows the presence of static charge. (There are socks sticking to the shirts; the cat's fur is standing on end.) Probe students' understanding further by asking them why the socks are sticking together, and why the cat's fur is standing on end.
- Have students cover the caption for Figure 10.3, on page 404, with their hand and then examine the diagram. The diagram shows an example of charging by friction. Ask students what the "plus" signs and "minus" signs represent. Ask students to observe the + and – signs on the hair and comb, both before and after combing. Ask, "What does this information indicate about the movement of charges between objects when they rub against one another?" (Before and after combing, the number of "plus signs" on the hair and comb remain the same. After combing, the number of "minus signs" on the hair decreased, while the number of "minus signs" on the comb increased by the same amount. This result suggests that during the process of charging by friction, positive charges do not move, while negative charges do move. When hair is combed, it becomes positively charged while the plastic comb becomes negatively charged. The total number of positive and negative charges remains the same, indicating that no new matter is produced when static charge occurs.)
- Have students look at Figure 10.7, on page 408, as they read the caption. Ask, "How does the diagram indicate the overall charge of the hand, doorknob, and doorframe?" (The overall charge is indicated by the number of "plus signs" and "minus signs" on each object.) Ask, "If arrows are used to show the flow of electrons from one object to another, how can they be used to represent a transfer of many electrons versus a transfer of a few electrons?" (Draw more arrows when there is a large number of electrons being transferred, and draw fewer arrows to indicate a transfer of few electrons.)
- ELL To check for understanding, have English language learners make a quick sketch to represent a concept, such as the transfer of electrons, while you walk around providing feedback.
- Have those students who need more practice predicting charges with friction complete **BLM 10-6 Predicting Charges;** or **BLM 10-7 Predicting Charges (Alternative Version).**

Assessment FOR Learning		
Tool	**Evidence of Student Understanding**	**Supporting Learners**
Discussion; **BLM 10-6 Predicting Charges;** or **BLM 10-7 Predicting Charges (Alternative Version)**	Students use an electrostatic series to predict and explain the behaviour of materials that are rubbed together.	Have students draw diagrams to show the movement of electrons when two items are rubbed together, and then describe the resulting charges. Provide students with the actual materials to test as they complete the blackline master.
Learning Check questions, page 407	Students accurately list and describe behaviours of insulators and conductors.	Encourage students to use a conductivity tester to develop or verify their responses. This could be done in a small group or as a class.
Plan Your Own Investigation 10-A, Comparing Conductivity, page 429	Students devise a plan that will allow them to classify materials according to their conductivity.	Have students test only good conductors and insulators at first. Once they have categorized those, have them test a semiconductor and describe how its conductivity compares to the conductivity of the other materials. Students who have trouble planning an investigation can use **BLM G-7 Design Your Own Investigation,** to help them.
Section 10.1 Review questions, page 410	Students draw and interpret diagrams of charge transfer and accurately describe conductors and insulators.	Have students explain orally each step of charging by friction, including what the electrons and protons do. For English language learners, consider having students play a game in which each group draws symbols to represent a review point, and then another group guesses which point is represented by the symbols drawn.

Instructional Strategies

- You may decide to use **BLM 10-8 Static Electricity in Your Home,** at the beginning or end of the section to determine the amount of prior knowledge students have about, or their understanding of, static electricity.
- **ELL** Many items referred to in the student textbook will be new to English language learners. Whenever possible, bring in concrete objects (realia) such as plastic wrap, anti-static sheets, different types of fabrics (nylon, wool, silk, cotton), and so on, to build background knowledge that may be missing. Use photographs when real objects are not possible.
- As a class, have students take turns reading aloud the information in the textbook, one section at a time. Choose students who are comfortable reading aloud. As an alternative to reading aloud or individually, provide English language learners and others who require this accommodation, with the section in a recorded format.
- Follow the strategies described in Using the Text and Using the Images. Use **BLM 10-9 Charging by Friction,** to make an overhead transparency to show students how electrons move when objects become charged by friction.
- You can include quick demonstrations throughout (or allow students to carry out the demonstrations) to provide concrete examples that help students relate to the information in the student textbook. English language learners benefit from observing or experiencing a concept before they read about it. For quick activity ideas, see **BLM 10-10 Dancing Rice;** and **BLM 10-11 Magic Light Bulb.**
- As a quick and fun review of the concepts, using visuals, make an overhead transparency of **BLM 10-12 Electrifying Cartoons,** and have students discuss and analyze what the cartoons depict.
- Have students carry out Plan Your Own Investigation 10-A, on page 429 of the student textbook, after they have read Insulators and Conductors, Using a Conductivity Tester, and Water: Insulator and Conductor, on pages 406 and 407 of the student textbook.

Learning Check Answers (Student textbook page 406)

1. According to the electrostatic series on page 405 in the student textbook, a plastic comb holds on to its electrons tighter than hair, becoming negatively charged.
2. Both your hair and the comb become more charged because you have increased the amount of contact between your hair and the comb, and so more electrons move from the hair to the comb.
3. The polyester holds on to electrons more strongly than leather. So you would place leather above polyester in an electrostatic series.
4. Since hair is listed above wool on the electrostatic series, hair is weaker at holding onto its electrons. So the hair would have a positive charge.

Learning Check Answers (Student textbook page 407)

5. Non-metals are good insulators for example, rubber, plastics, and so on. Metals and some solutions are good conductors for example, copper, water from a faucet.
6. A conductivity tester is used to distinguish between an insulator and a conductor. It is made up of a battery that is connected to a light and two contact points. When the contact points touch a material that conducts electricity, the light goes on.
7. The friend is correct. A good insulator does not allow electrons to flow through it; thus, it is a poor conductor.
8. A steady stream of water could conduct electricity and electrocute the firefighter who was holding the hose. The mist that firefighters spray is safer because the air between water droplets acts as an insulator.

Section 10.1 Review Answers (Student textbook page 410)

Please see also **BLM 10-13 Section 10.1 Review (Alternative Format).**

1. According to the Bohr-Rutherford model of the atom, each type of material contains atoms, but holds on to its electrons with a different strength. In a conductor, electrons are able to move easily from one atom to another. In an insulator, electrons cannot move easily from one atom to another.
2. **a.** Negative balloon: show an excess of "minus signs."
   b. Positive balloon: show a deficit of "minus signs."
3. Use an aluminum comb (conductor) instead of a plastic comb to avoid generating an electric charge on your hair.
4. Since nylon is above silk on the electrostatic series (Table 10.1, Electrostatic Series of Some Common Materials, student textbook page 405), the nylon socks will be positive and the silk blouse will be negative.
5. conductors: any metal; uses: copper or aluminum wires, mercury switches
   insulators: non-metals such as wood, rubber, and plastics; uses: covering for wires, wall socket protectors, wire connectors, screwdriver handles
6. **a.** All three objects are neutral since each contains the same number of positive and negative charges.
   b. Solid X is positive and cloth Y is negative. Cloth Y has the greater hold on electrons.
   c. Z, Y, X
7. The rainwater does not form a continuous stream between the transmission line and a person beneath it. Air between raindrops acts as an insulator.
8. A conducting floor prevents charge build-up, which might otherwise damage electronic equipment or cause sparks that could ignite gas used for anesthetic. Wax is an insulator, so it should not be used.

Section 10.2 Charging by Contact and by Induction

(Student textbook pages 411 to 417)

Specific Expectations

- **E2.1** use appropriate terminology related to electricity
- **E2.2** conduct investigations into the transfer of static electric charges by friction, contact, and induction, and produce labelled diagrams to explain the results
- **E2.3** predict the ability of different materials to hold or transfer electric charges, and test their predictions through inquiry

In this section, students will learn how objects can be charged by contact and by induction, and compare and contrast these methods. Using a pith ball electroscope and a metal leaf electroscope, students will conduct investigations to detect the presence of electric charges. Students will apply the laws of electric charges to explain the behaviour of charged materials, and draw diagrams to show the movement of electrons during charging by induction.

Common Misconceptions

- **Some students may confuse *charging by friction* with *charging by contact*, since both methods involve two objects touching each other.** Have students use diagrams to visually represent both methods, showing the movement of electrons in each situation and the end products. Charging by friction involves rubbing two different and neutral materials together to produce oppositely charged objects, while charging by contact involves touching a charged object to a neutral object, resulting in both objects having the same type of charge. You can also refer students to Figure 10.3, on page 404, and have them look carefully at the charges on each object before and after.
- **Some students believe that neutral objects do not respond in the presence of a charged object.** Demonstrate the attractive forces between these objects by using a plastic comb, a piece of wool, and small pieces of paper. Charge the comb and wool by rubbing them together. They will become oppositely charged by friction. When each is held over the neutral pieces of paper, the paper will "jump up" to stick to both types of charged objects.

Background Knowledge

An electroscope is an instrument used to detect the presence of an electric charge. The first electroscope was invented around 1600 by English scientist and physician William Gilbert. The device consisted of a metal needle that was allowed to pivot freely on a pedestal (similar to a compass needle). The needle would move in response to a charged object brought near it. Later versions of the electroscope included the pith ball electroscope, invented by British weaver's apprentice John Canton in 1754, and the gold leaf electroscope developed by British physicist Abraham Bennet in 1787. The pith ball electroscope includes a ball made of lightweight material that is suspended on a thread. The neutral ball swings toward any charged object brought close to it. Some models involve two pith balls hanging side-by-side, similar to the parallel strips of metal leaves found in a metal leaf electroscope. In this case, each of the pith balls (or leaves) repels each other and moves apart when an object with an electric charge is brought near.

Charging by contact, also known as charging by conduction, involves touching a neutral object with a charged object. Suppose you take a negatively charged object and touch it to a neutral object. Some of the excess electrons in the charged object (which are repelling each other) will try to spread apart by moving onto the neutral object. Now, the charged object will not be as negative as before. The neutral object always acquires the same type of charge as the charged object.

Charging by induction involves bringing a charged object near a neutral object, but not touching it. No negative charges actually transfer between the objects. Instead, the negative charges in the neutral object respond to the charged object by either moving toward or away from the charged object. With the electroscope, the metal sphere always acquires a charge opposite to that of the charged object.

Literacy Support

Using the Text

Before Reading

- Help students make connections to prior knowledge. Demonstrate charging a plastic comb and picking up small pieces of paper or wool, as described at the top of student textbook page 411. Ask students to use what they learned in Section 10.1 to explain why this process occurs. Ask them how this process is different from charging by friction, as shown in Figure 10.3. Refer to this demonstration as students read the section, to help them visualize what is happening.

During Reading

- For each part of the section, have students analyze the content and summarize the key ideas. They must reduce the passage to just 20 words that capture the gist of the text, and include diagrams where appropriate (for example, an electroscope with its parts labelled).
- ELL English language learners can complete a graphic organizer as a method of summary. The organizer could have the headings Section, Summary, and Page Number, and these subheadings for each section: Main Idea, Details, and Example/ Sketch. Look at Study Toolkit 4, Organizing Your Learning: Using Graphic Organizers, on page 566 of the student textbook, with students to help them see the advantages of each type of organizer.

After Reading

- Have students compare and contrast charging by friction, contact, and induction using a Venn diagram. They can use **BLM G-39 Venn Diagram.**

Using the Images

- Have students examine the photograph of the different electroscopes in Figure 10.10, on page 411. Discuss the similarities and differences in their characteristics. Ask, "How might these similarities and differences affect how each one works?"
- Have students review the diagrams in Figure 10.11, on page 413. Ask, "How are charged objects and neutral objects portrayed?" (with a corresponding number of plus and "minus signs"; an imbalance of one type over the other represents a charged object.) "What is used to indicate the direction of electron transfer?" (arrows)
- Have students copy Figure 10.12, on page 413, into their notes. Ask them why there is only one "plus" or "minus" sign in each diagram of the atom. (The sign is used to indicate the overall charge on the atom. A neutral atom is left unmarked. It does not mean that the atom has only one charged particle on it.)
- After looking at Figure 10.14, on page 415, and reading the caption, have students draw a set of diagrams to show the induced charge separation on the pith ball when a positively charged rod is used instead. (The diagrams should look the same as those in Figure 10.14, except the rod should contain more "plus signs" than "minus signs," and in the pith ball, the negative charges should have moved to the side of the pith ball closest to the positive rod.)

Assessment FOR Learning		
Tool	**Evidence of Student Understanding**	**Supporting Learners**
Learning Check questions, page 415	Students apply the laws of electric charges to explain the behaviour of interacting objects.	Reinforce the concepts with **BLM 10-14 Behaviour of Electric Charges.**
Section 10.2 Review questions, page 417	Students understand the difference between charging by friction, contact, and induction.	Have students review the information presented in the section summary and elaborate on each point, either orally or with pictures. Refer to **BLM 10-15 Charging by Contact and by Induction.**
Activity 10-3, Drawing Charges You Cannot See, page 416	Students draw diagrams, showing the movement of electrons, to explain induced charges.	Review the behaviour of electric charges (attraction and repulsion) and examine Figure 10.14, on page 415. Have students explain in words what is happening in each part of the diagram.
Plan Your Own Investigation 10-B, Be a Charge Detective, page 430	Students devise a plan that will allow them to correctly place new materials in an electrostatic series.	Give students only two materials in significantly different positions on an electrostatic series, and have students compare their conductivity. Once they have done that, give them a third material and have them decide how it compares to the first two. Add a couple of other materials one at a time.

Instructional Strategies

- Start by demonstrating how a charged comb will cause small pieces of paper to move, as described at the top of student textbook page 411. Use the questions in the introductory paragraph of this section (on page 411 in the student textbook) to determine students' prior knowledge and/or misconceptions about the attractive forces between interacting objects (charged and neutral).
- Distribute and discuss **BLM 10-15 Charging by Contact and by Induction,** to help students understand the behaviour of electrons when objects are charged in these ways.
- Have students read about the two types of electroscopes (pith ball and metal leaf), and make notes to compare them.
  - ELL English language learners and spatial learners can draw and label the electroscopes instead of writing notes.
- At this point, you may choose to carry out Activity 10-2, Detecting Static Charge Using an Electroscope, on page 412 of the student textbook, as the activity provides a good introduction to the differences observed between objects that are charged by contact versus charged by induction. Afterward, have students return to the textual information in the student textbook to explain why they observed what they did.
- ELL English language learners and other students requiring reading accommodation would benefit from being paired with students who have strong reading skills, to help them with the section.

- As students read through pages 412 to 415, make sure they also examine the diagrams to supplement their reading. Have them make notes in a table format to compare the different methods of charging objects, according to the starting materials, what happens, and the end products. Below is an example of the type of table students may set up and complete:

Charging Method	Starting Materials	What Happens	End Products
By friction	Two neutral objects made of different materials	Upon rubbing, electrons transfer from one object to the other.	Two oppositely charged objects
By contact	One charged object and one neutral object	When the two objects touch, electrons will move from one object to the other.	Two objects of the same type of charge as the initial charged object
By induction	one charged object and one neutral object	Electrons in the neutral object are redistributed (but not transferred) when the charged object is brought near it, without making contact.	The induced charge on the neutral object is opposite to the original charged object.

- You may wish to compile a class table, based on a discussion of the tables students created. This table can be posted in the classroom for students to refer to.
- Use Activity 10-3, on page 416 of the student textbook, to reinforce the concepts that students have read about under the heading Charging by Induction.
- DI Bodily-kinesthetic learners may benefit from modelling each charging situation using small paper plates (for each object), pennies (for protons), and paperclips (for electrons), moving paperclips from one plate to another to model what is happening before they draw diagrams.
- Have students carry out the Plan Your Own Investigation 10-B, on page 430 of the student textbook, any time after they have read about Detecting Charges and Charging by Contact on pages 411 and 412 of the student textbook.
- ELL To ensure that English language learners fully understand, and are successful with, the activities, explain and model the learning processes. Show them what is expected, let them participate with an English-speaking peer, and then have them try out activities on their own. For example, in Section 10.2, use the charged comb activity to ensure that students understand the words *predict*, *observe*, and *record*. Complete the activity with students, using the key terms and these process words, and model what they would record. Explain that they will be using a pith ball electroscope and a metal leaf electroscope with different materials to predict and observe the presence of static charges.
- Have students compare and contrast contact and induction using a graphic organizer such as **BLM G-39 Venn Diagram,** as they read and complete the activities.

Activity 10-2 Detecting Static Charge Using an Electroscope

(Student textbook page 412)

Pedagogical Purpose

The purpose of this activity is to allow students the opportunity to use two kinds of electroscopes (pith ball and metal leaf) to observe the behaviour of a charged object and a neutral object. Although the terminology is not discussed, the activity gives students a visual distinction between charging by contact and charging by induction.

Planning	
Materials	Different materials listed in the electrostatic series in Table 10.1 on page 405 of the student textbook Metal leaf electroscope Pith ball electroscope • If possible, order enough electroscopes for students to work in pairs or small groups. Ensure that different materials listed in Table 10.1 are available for students to use. **BLM G-23 Data Table** (optional)
Time	Approximately 45 min in class
Safety	• Remind any students who are allergic to fur not to handle it. Tell students who use a glass rod to handle it carefully and make sure that it cannot roll off their table.

Background

An electrostatic series is a list of different materials placed in order according to their ability to hold on to their electrons. It can be used to help predict the type of charge on materials that are rubbed together. Whenever two materials are rubbed together, the result is two oppositely charged objects due to the transfer of electrons from one to the other.

In a metal leaf electroscope, the pair of leaves separate in response to the presence of a charge. Electrons in the electroscope will either move into or out of the leaves, depending on the type of charge on the charged object. If they move in, the leaves will both become negative and repel from each other. If the electrons move out, the leaves will both become positive and repel each other. This process is called charging by induction. When contact is made, electrons transfer to or from the electroscope, making it acquire a charge that is the same as the charged object. In both cases, the leaves will remain open even after the charged object is removed. This process is called charging by contact.

In a pith ball electroscope, the neutral pith ball will always be attracted to the charged object and swing toward it. When contact is made, the pith ball will acquire the same charge as the charged object, and respond by repelling and swinging in the opposite direction.

Activity Notes and Troubleshooting

- As there are a limited number of roles, this activity works best if students work in pairs or small groups. Otherwise, you may perform it as a demonstration.
- As with any static electricity activity, results are best if the humidity in the room is low.
- Review an electrostatic series (Section 10.1) and how it can be used to predict the charge on an object when two materials on the list are rubbed together.
- Have students choose two pairs of materials on the electrostatic series: one pair to use with the metal leaf electroscope, and the other pair for the pith ball electroscope. Advise students to select materials that are not too close together on the list.
- Tell students not to handle the objects more than necessary once they have been charged. Humans are fair conductors and could neutralize the static build-up. If the electroscopes do not respond, students should recharge their objects and try again.

Additional Answer

- ELL For English language learners and those students who need reading accommodation, complete this activity as a demonstration, and have students record their observations. Or, depending on the level of English language proficiency, have these students record observations in picture form rather than in word form.
- Enrichment—Have students design and build their own electroscope to test out.

Answers

1. The leaves of a metal leaf electroscope show the presence of charge by spreading apart. The pith ball moves toward the charge when a charge is nearby.
2. The leaves spread apart and remained apart. The effect was the same, regardless of the type of charge.
3. The leaves returned to the undeflected position. Your finger acts as a ground, which discharges the electroscope.

Activity 10-3 Drawing Charges You Cannot See (Student textbook page 416)

Pedagogical Purpose

The purpose of this activity is to encourage students to use diagrams as a means of visualizing and explaining the behaviour of electric charges and how charges are induced.

Planning	
Materials	Paper Coloured pencils
Time	Approximately 30 min in class

Background

During induction, no electrons are transferred between objects, so the net charge remains the same. Instead, a temporary charge is induced on the neutral object due to the changed distribution of its electrons.

In a pith ball electroscope, the neutral pith ball will always swing toward the charged object. If the charged object is positive, the attractive forces would cause electrons in the pith ball to move closer to the side near the charged object. This side of the pith ball becomes negatively charged (and is attracted to the oppositely charged object) until the electrons redistribute themselves when the charged object is taken away. Something similar occurs when the charged object is negative, as shown in Figure 10.14, on page 415 of the student textbook.

In a metal leaf electroscope, the leaves move apart regardless of the charge on the object brought near it. When a negatively charged object is brought near the sphere of the electroscope, the electrons in the sphere repel by moving down into the leaves. This action causes both leaves to become negatively charged, which leads them to repel and swing away from each other. When a positively charged object is brought near the sphere, the attractive forces cause the electrons from the leaves to move up into the sphere. This action makes both leaves positive, which also causes them to repel and move apart.

Activity Notes and Troubleshooting

- Before assigning the activity, review the facts that only electrons are able to move, same charges repel, and opposite charges attract. Also, have students examine Figure 10.14, on page 415 of the student textbook, and explain to you or a classmate what is happening and why. Students will be more successful with this activity if they already understand the movement of charges.
- Before beginning the activity, demonstrate charge by induction by charging a balloon (friction) and sticking it to a wall (induction). You can also review this concept using **BLM 10-15 Charging by Contact and by Induction.**

Additional Support

- DI This activity will appeal to spatial learners and logical-mathematical thinkers. Try to arrange groups so that students with both learning styles are present in each group.

Answers

Part 1

3. a. They must be the same in number, and in the same positions.
   b. negative; opposite
   c. The pith ball is neutral because there has been no transfer of electrons.

Part 2

4. The rod is negative.
5. The sphere of the metal leaf electroscope should be positive, and the leaves should be negative. Positive charges must remain in the same position, and there must be the same number of negative charges as there are positive charges on the metal leaf electroscope.

Questions

1. The electrons in the electroscope are drawn to both leaves. The electroscope leaves both end up with negative charges, and like charges repel.
2. The rod's electric field will become too weak to influence the electroscope. The excess electrons on the leaves will return to the ball, while all the positive charges will remain fixed in position. Both the ball and the leaves will once again be neutral.
3. Positive charges never move; electrons move away from a negatively charged object, and toward an object with a positive charge; and provided there is no contact between objects, an object with an induced charge remains neutral overall.

Learning Check Answers (Student textbook page 415)

1. The pith ball has a small mass so that the electric force between the charged object and the pith ball is strong enough for the pith ball to move.
2. Charging by contact occurs when a neutral object (for example, a pith ball) and a charged object (for example, a negatively charged object) make contact. Electrons flow from the negatively charged object into the pith ball. The negatively charged object will have a reduced charge, and the pith ball will be negatively charged.
3. Similar: gravitational force and the electric force between objects of opposite charge are attractions; gravitational force increases with increased mass, and electric force increases with increased charge; both forces decrease with increased separation. Different: electric force can be a repulsion if charges are the same type.
4. a flat aluminum pie plate, a glass or plastic bottle, a rubber or cork stopper, a piece of wire (maybe from a coat hanger or a large paperclip), and aluminum foil for the leaves

Section 10.2 Review Answers (Student textbook page 417)

Please see also **BLM 10-16 Section 10.2 Review (Alternative Format).**

1. Charging by contact generates the same type of charge on the neutral object as the charged object, and charging by friction generates opposite charges on the materials rubbed together. A charge can induce a changed distribution of electrons on another object, but the object's overall charge remains unchanged.

2. A positively charged rod will draw electrons toward the sphere. Since this process increases the distance between the leaves, the electroscope must be positively charged. The diagram(s) should show a metal leaf electroscope with a positive charge. Electrons are drawn toward the sphere when the positively charged rod is near the sphere. This process removes negative charges from the leaves.

3. The strength of an object's electric field decreases with increased distance between itself and another object.

4. An insulator would not allow electrons to move, so the leaves would never become charged.

5. **a.** The wall is charged by induction. The wall and balloon are insulators so no electrons are transferred. The balloon induces an opposite charge on the surface of the wall, and sticks there because opposite charges attract. By contrast, if the wall had been charged by contact, it would have the same charge as the balloon, and then the balloon would not stick to the wall.

   b. The balloon eventually falls from the wall because although the balloon and the wall are insulators, they are not perfect insulators. Some electrons will eventually move from the balloon to the wall and the difference in charges will disappear.

6. The pith ball could be positively charged or neutral, since both would be attracted to the negative rod.

7. Rub the two objects together and place each object next to a negatively charged pith ball. The material that repels the pith ball has negative charge, which shows that it holds on to electrons more strongly than the other material does.

8. **a.** positive

   b. The rod is unchanged. Some of the electrons on the sphere that is closer to the rod would have moved toward the rod, but there should be no change in the total number of negative charges on both spheres. Because the spheres are touching, some electrons in the sphere farthest from the charged rod will move into the sphere that is closer to the rod. There should be no change in the number or position of positive charges.

   c. The rod is unchanged. The sphere that was moved away will have a deficit of electrons (that is, a positive charge). The sphere that is closer to the rod will have an excess of electrons, with a greater number of negative charges close to the rod. The total number of negative charges is unchanged. There should be no change in the number or position of the positive charges.

   d. The sphere that was moved away will have a deficit of electrons. The sphere that was closer to the rod will have an excess of electrons, redistributed evenly throughout the sphere. The total number of negative charges is unchanged. There should be no change in the number or position of the positive charges.

Section 10.3 Charges at Work (Student textbook pages 418 to 428)

Specific Expectations

- **E1.1** analyse the design of a technological device that improves its electrical efficiency or protects other devices by using or controlling static electricity
- **E2.1** use appropriate terminology related to electricity

In this section, students will learn how different technologies rely on static electricity to work, including a lightning rod, an electrostatic precipitator, a Van de Graaff generator, a photocopier, and a radiation dosimeter. They will also carry out an activity that uses electrostatic charges to separate different particles with different masses.

Common Misconceptions

- **Some students may think that lightning only moves from the sky to the ground.** Show some pictures of lightning, from the Internet. Not only does lightning go from cloud to ground, but also from cloud to cloud, or within one cloud. Furthermore, lightning may appear in many forms: a jagged line, a forked line, or even a ball.
- **Students may be confused by the explanation of lightning, where it says positive charges move up out of the ground to meet negative ones.** Students learned in Section 10.1 that protons do not move; only electrons do. The positive charges referred to here, however, are positive ions, not protons. The positive ions are atoms that have lost at least one electron. These positively-charged atoms move toward the opposite charge similar to how oppositely-charged objects would attract each other.

Background Knowledge

Lightning is an electrostatic discharge that occurs between a negatively charged cloud and any object that has become relatively positive. There are three types of lightning: cloud-to-ground, cloud-to-cloud, and in-cloud. A single lightning bolt can have up to 100 million volts of electrical energy. When lightning passes through the air, it heats up the air to around 30 000°C. The rapidly expanding air produces the sound of thunder.

Electrostatic precipitators remove unwanted solid particles and liquid droplets from a gas. By using principles of static electricity, electrostatic precipitators attract particles in much the same way that clothing picks up dust and lint. Some applications for electrostatic precipitators include reducing pollutants emitted from smokestacks; and removing dust and pollen by using an air purifier.

Literacy Support

Using the Text

Before Reading

- ELL To ensure that students have the cultural knowledge to understand this section, talk about some of the assumed knowledge required. (People: Benjamin Franklin, Frederick Cottrell; objects: atom smashers, lightning rods, electrostatic/electronics/precipitators; references: forest fires, Environment Canada/e-waste/policy)
- Before reading, ask students to record their answers to the questions, "What do I know about lightning and lightning rods?" and "What kinds of technology use some principal of static electricity in order to work?" Then, ask students to review their answers and record questions they have about lightning and about technologies that use static electricity. After they have read the various parts of this section, students can share their questions as a class and discuss the answers.
  - ELL Pair English language learners with other students who have stronger language skills, to help them with this exercise.

During Reading

- Have students monitor their comprehension. Ask students to read a subsection of the textbook independently, record their thoughts, and then pair up with another student. Each student can ask his or her partner two or three questions, to ensure comprehension. If they do not agree, they can develop a correct answer together by rereading the subsection.

After Reading

- Have students make study notes, review their notes, and choose the facts that will help them answer each of the questions they asked before they read the section.

Using the Images

- Have students examine Figure 10.17 and Figure 10.18, on pages 419 and 420, in pairs. While one student reads the caption for each part of a diagram, the other student can point out the relevant components on the diagram.
- Figure 10.20, on page 422, and Figure 10.24, on page 425, show the parts of an electrostatic precipitator and a photocopier, respectively. The caption and labelling describe how each device works. Ask students to read the flowchart beneath Figure 10.24 and identify where the principles of electrostatics are applied.

Assessment FOR Learning

Tool	Evidence of Student Understanding	Supporting Learners
Discussion/Learning Check questions, page 421	Students describe how lightning forms and how a lightning rod works. Students identify some technologies that use principles of electrostatics.	Have students complete **BLM 10-17 Lightning.** Place students into small groups to research a particular technology that functions using electrostatics.
Activity 10-4, A Static Spice Separator, page 426	Students apply principles of static charge to separate different types of particles.	Allow students to explain their results orally or by drawing diagrams.
Learning Check questions, page 426; Section 10.3 Review questions, page 428	Students apply principles of electrostatics to explain how some technologies work.	Have students draw diagrams of various technologies and add the positive and negative charges to show where electrostatics plays a role.

Instructional Strategies

- Begin by asking students where electric charges can be used. They will almost certainly mention electric current for lights and so on, but will probably not be aware of all of the applications in this section. Ask how electric currents might have been used to help create several common school fixtures, for example, a painted metal desk or chair.
- Have students who are confident reading take turns reading aloud.
    - ELL Be sensitive to those who require reading accommodations, including English language learners. Have these students listen to an audio recording of the section. Or, partner English language learners with two other confident readers, allowing English language learners to listen as others read.
- The Case Study, on pages 422 and 423, encourages students to begin to think about the wider implications of their use of electronic devices.
- Enrichment—You may decide to challenge students to build an electrostatic precipitator by following the instructions on **BLM 10-18 Building an Electrostatic Precipitator.**

Activity 10-4 A Static Spice Separator (Student textbook page 426)

Pedagogical Purpose

In this activity, students apply their understanding of static charges to separate two kinds of solid particles. The ensuing discussion of possible uses for electrostatic separators will enable students to realize that electrostatics plays an important role in the technological world.

Planning		
Materials	2 mL salt 2 mL pepper Wool cloth	Plastic spoon or ruler Paper
Time	Approximately 15 min in class	
Safety	Remind students not to taste any of the materials in the science classroom, and to be careful when shaking out the pepper.	

Background

An electrostatic separator is a device that uses an electrostatic charge to separate different particles that have different masses. Particles with smaller masses will move toward the charged object. Some applications for electrostatic separators include mineral processing, plastics recycling, and recycling of metals and non-metals from e-waste.

Activity Notes and Troubleshooting

- Materials for this activity are easy to find and inexpensive. Try to have enough on hand so that every student has a chance to separate the spices.
- Tell students to spread the same amount of salt and pepper in a thin layer.
- Remind students that the charged plastic is not to touch the mixture.

Additional Support

- Enrichment—As a challenge, have students build a household tool or appliance that is used to separate particles (or small pieces) using electrostatics.

Answers

1. pepper
2. Each is attracted to the charged plastic as a result of induced charges. Pepper particles have a smaller mass than salt crystals, and thus, the force of attraction can overcome gravity and pick up pepper more easily than salt.
3. yes, if a larger static charge were used and/or the shells were broken into small pieces
4. A broad range of answers may be correct. One of the more common examples that some students may think of is separating different kinds of lightweight materials at recycling centres.

Learning Check Answers (Student textbook page 421)

1. Lightning usually strikes the grounded object that is the shortest distance from the lightning.
2. It may prevent a lightning strike. If a lightning bolt does strike, a lightning rod will conduct the charge safely to the ground.
3. Ions are charged particles, formed when an atom or molecule gains or loses one or more electrons. Ions, including positive ions, can be carried by currents in the air.
4. In Canada, lightning causes about one third of all forest fires. Buildings can catch fire. People and animals that are hit by lightning may die.

Learning Check Answers (Student textbook page 426)

5. During electrostatic spray painting, the paint is given a charge as it leaves the nozzle of the sprayer. The object to be coated is either grounded or given an opposite charge so the paint particles would be attracted to it.
6. In the dark, selenium is a fair conductor. However, when exposed to light, selenium becomes a very good conductor.
7. Van de Graaff generators can accelerate particles to very high speeds, and when the particles are focussed to crash into each other, they can break apart and even form new subatomic particles.
8. An electrostatic precipitator uses the laws of electric charges to remove dust particles and liquid droplets from polluted gas.

Section 10.3 Review Answers (Student textbook page 428)

Please see also **BLM 10-19 Section 10.3 Review (Alternative Format).**

1. Lightning follows a jagged path between a cloud and the ground or a tall structure because air currents and turbulence produce regions of differing conductivity for the lightning discharge to follow.
2.

Parts of a Lightning Rod	Function
Metal sphere or point	This metal part becomes positively charged by induction.
Copper wire or cable	This insulated cable conducts the charge safely to the ground without it touching the building.
Metal plate or metal cable in the ground	This conductor grounds the charge.

3. In their brochures, students should mention how the dust and pollen particles are charged, and then attracted to an oppositely charged or grounded plate. When the particles collide with the collection plate, they are neutralized, collected, and removed.
4. The abrasive material can be sprayed on glue-coated backing, in much the same way as any coating. The particles are given a charge and sprayed on to grounded or oppositely charged backing.
5. A Van de Graaff generator is a machine used to generate very large static charges. Uses: demonstration purposes; research to accelerate particles to probe the properties of matter, tests of the electronic circuits used in space technology.
6. In a photocopier, the negatively charged toner, attracted to the positive parts of the drum, is spread to the paper because the sheet of paper is given a larger positive charge than the drum.
7. A gas becomes a good conductor when ionized by absorbing energy from another source, such as high-energy radiation.
8. **a.** The movable fibre should be shown with fewer negative charges than positive. The gas molecule must have the same number of positive and negative charges.

   b. Radiation ionizes the gas molecule by causing it to lose an electron. The electron is attracted to the positively charged fibre, reducing its charge. As the charge on the fibre decreases, its deflection becomes smaller.

Plan Your Own Investigation 10-A Comparing Conductivity

(Student textbook page 429)

Pedagogical Purpose

The purpose of this activity is for students to be able to classify objects according to their conductivity. They will make predictions and then test them using a conductivity tester.

Planning		
Materials	Conductivity tester Coated wire Small block of wood Metal comb Beaker Tap water Stir stick **BLM 10-20 Plan Your Own Investigation 10-A Comparing Conductivity** (optional) **BLM G-23 Data Table** (optional) • Order and begin to gather the materials a few weeks before the activity.	Aluminum (strip or wire) Copper wire Graphite Nylon comb Distilled water Salt
Time	Approximately 45 min in class	
Safety	• Students should handle the pieces of wire with care so as to avoid being poked by the ends of the wire and also to not break the wire.	

Background

Because different materials have different degrees of conductivity, there is a range between strong insulators and strong conductors. Typically, metals are good conductors while non-metals are good insulators. Air and water can behave as insulators or conductors depending on the conditions. For example, dry air is a good insulator and humid air is a fair conductor. Pure water is a good insulator, while water containing dissolved minerals is a good conductor.

Activity Notes and Troubleshooting

- Prior to the activity, review the concepts of insulators and conductors, and demonstrate how a conductivity tester is properly connected.
- Have students work in groups of three or four.
- Some students may wish to test other materials, as well. You might want to have an assortment of other somewhat conductive materials on hand.

Additional Support

- DI This activity will appeal to spatial and bodily-kinesthetic learners. Ensure each group includes students who are capable of careful observation and organized recording.
- If students have trouble designing a test to answer three scientific questions, have them pose one or two.

Answers

Analyze and Interpret

1. conductors: aluminum, copper wire, metal comb, salt solution; insulators: coated wire, wood, nylon comb, distilled water; semiconductors: graphite (may be classified as a conductor), tap water (may be classified as an insulator)

Conclude and Communicate

2. Distilled water is a non-conductor, although tap water may conduct enough to cause the conductivity tester to glow slightly. Water that contains a little dissolved salt is a good conductor.

Extend Your Inquiry and Research Skills

3. Paragraphs should include information similar to the following: Plasma resembles gas except that it is composed of high-energy, electrically charged particles—*ionized gas*. The different states found on Earth are solid, liquid, and gas. Plasma, in its natural state, exists in the stars and the "empty" space between them. Since plasma consists of electrons and ions (atoms that have lost electrons), it can be created by using energy to strip electrons from atoms. This energy could be thermal, electrical, or ultraviolet, but without sufficient sustaining power, plasmas will recombine to form neutral gas.

Plan Your Own Investigation 10-B Be a Charge Detective

(Student textbook page 430)

Pedagogical Purpose

In this activity, students devise and implement a plan that will allow them to test different materials for their charge, and to place them in an electrostatic series. To devise such a plan, students must apply their understanding of the laws of electric charges and electrostatic series. To carry out their plan, they must apply their skills in charging objects by friction and using a pith ball electroscope.

Planning	
Materials	Pith ball electroscope Some materials from Table 10.1, Electrostatic Series of Some Common Materials, in Section 10.1 on student textbook page 405 Some materials that are not in Table 10.1 (for example wood, paper, plastic wrap, a plastic compact disc case) • If available, have enough pith ball electroscopes so students can work in pairs or small groups. **BLM 10-21 Plan Your Own Investigation 10-B Be a Charge Detective** (optional) **BLM G-23 Data Table** (optional) **BLM A-27 Plan Your Own Investigation Rubri**c (optional) • Order and gather materials a few weeks before the activity.
Time	Approximately 50 min in class (5 min for planning, 25 min for carrying out the activity, and 20 min for discussion)
Safety	• Safety precautions: If using a glass rod, ensure students handle it carefully and make sure it cannot roll off the table. If students are allergic to animal fur, they should not use the material.

Sample electrostatic series (in order from weak hold on electrons to strong hold on electrons):

- Rabbit's fur
- Glass
- Human hair
- Nylon
- Rayon
- Wool
- Cat's fur
- Silk
- Aluminum
- Paper
- Cotton
- Wood
- Rubber balloon
- Copper
- Brass
- Polyester
- Foam
- Plastic wrap
- Ebonite (hard rubber)

Background

By testing a variety of materials, students should be able to develop an electrostatic series similar to this one. Materials that easily develop a positive charge have a weak hold on their electrons.

Activity Notes and Troubleshooting

- Have students work in pairs or small groups. Instruct each group to begin by reading the instructions aloud and making sure they understand each step.
- You can guide and assess students' investigations using **BLM A-27 Plan Your Own Investigation Rubric.**
- Before students begin their planning, they should review the electrostatic series and the laws of electric charges. Check their plans before allowing them to continue. Look for the use of a known charge to create a charge on the electroscope, effective use of friction to generate charges in different materials, and effective use of the electroscope to infer placement on an electrostatic series. Students may find this last part of the plan challenging.
- Encourage students to predict the placement of each new material before they test it. Reassure them that there is sometimes not a clear answer.

Additional Support

- DI This activity will appeal to logical-mathematical thinkers, as well as spatial and bodily-kinesthetic learners. To ensure plans are solid and are carried out effectively, place some of each type of learner in each group.
- If students have trouble developing a plan on their own, you may wish to set up a sample data table as a class to help focus their thinking.

Answers

Analyze and Interpret

1. Identify the material that needs to be placed in the correct order, and agree on another material to use in generating a charge by friction. Agree on a plan to identify the charge on the material needing to be placed in the electrostatic series, and carry out the plan.
2. Materials that are close together in the series do not generate large charges when rubbed together.

Conclude and Communicate

3. Two materials that form a static charge when rubbed together will occupy significantly different positions in an electrostatic series. One will hold its electrons better than the other.

Extend Your Inquiry and Research Skills

4. Students may predict that warmer water would bend more because warm water is capable of including more dissolved particles or because warmer water is less dense.

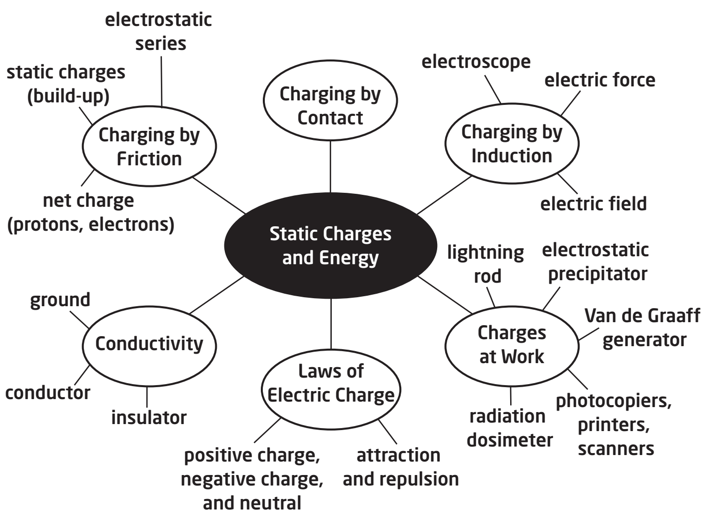
Chapter Review Answers (Student textbook pages 432 and 433)

Please see also **BLM 10-22 Chapter 10 Review (Alternative Format).**

ELL Consider asking English language learners to group the review questions. Have the students pick the questions that they feel they can answer independently. Then have them select the questions for which they are not sure of what they are being asked. Clarify these questions by restating them. Let students select the questions for which they may need some language support, and finally, those questions for which they need peer support or reteaching.

Make Your Own Summary

Below is a sample concept map, with the title for Chapter 10 in the centre.



Reviewing Key Terms

1. electrostatic series
2. conductors; insulators (or non-conductors)
3. electroscope
4. laws of electric charges; electric field
5. induced charge separation; tall building (or tall tree)
6. particles; liquid droplets

Knowledge and Understanding

7. The interaction results from the electric field between the two charges.
8. Polyethylene has a stronger hold on its electrons than silk does. When the materials were rubbed together, electrons were transferred from the silk to the polyethylene.
9. Electrons flow from the ground into a positively charged object until it is neutral. Electrons flow from a negatively charged object into the ground until the object is neutral.
10. In an insulator, electrons cannot move from one atom to another. In a conductor, some electrons can move between different atoms.
11. In solids, only electrons can move.
12. There is a new distribution of charge on the neutral object, so electrons move toward or away from the side of the neutral object that is closer to the charged object.
13. Most homes are close enough to a taller building, which will be more likely to be struck by a lightning bolt.
14. Opposite charges attract.
15. They can accelerate particles to a very high speed.

Thinking and Investigation

16. The order is as follows: acetate, lead, copper. When two materials are rubbed together, the material that becomes positively charged holds on to its electrons less strongly than the other material does. Thus, acetate has a weaker hold on electrons compared with wool, and wool holds on to electrons less than lead does. The first two experiments give the order acetate, wool, lead. Silk has a weaker hold on electrons compared with copper, and lead less than silk. Thus, the order from these experiments is lead, silk, copper. Putting both summaries together gives the order acetate, wool, lead, silk, copper.
17. X and Z are definitely charged, because they repel each other. Y is either possibly charged (opposite compared with X), or possibly neutral.
18. The student gave the ebonite rod a negative charge. Bringing the charged rod near the sphere of the electroscope forced electrons toward the leaves that then collapsed. So initially, the charge on the leaves must have been positive. When the charged rod was brought closer to the sphere of the electroscope, more electrons were forced into the leaves that then became negative and therefore diverged.

Communication

19. When objects become charged, one material has a stronger attraction to electrons than another material. Electrons already exist, but they can be moved from a material with a weak hold on them to a material with a stronger hold on them. When that happens, more electrons are present on one material, giving it a negative charge, but fewer electrons are present on the other material, giving it a positive charge. The combined charge of the two materials is still 0, as it was before the electrons moved. In this way, the movement of electrons creates both a negative and a positive charge.

20. Pamphlets should include these ideas: Static discharge could result in dangerous sparks. Carpets that resist static electricity should be used. Insulating materials should not be used, such as rubber or wool. Any electrical equipment should be grounded. Humidity in the home should be kept high.

21. Diagrams should include these elements: a wire with a strong positive charge, particles that have been positively charged and induce a negative charge on collection plates, and large hoppers to collect the neutralized particles.

22. Students' answers may include the Manufacturing Technician/Techniques—Wood Products program at Canadore College; the Bachelor of Applied Technology in Advanced Manufacturing Technologies—Wood and Composite Products program at Conestoga College of Applied Arts and Technology; Wood Products Manufacturing at the British Columbia Institute of Technology; and Pulp and Paper Operations at Malaspina University-College.

Application

23. Wiping the screen with a wool cloth charges the screen by friction. Dust is then attracted to the charged screen.

24. Students' answers will vary. They may mention the Saskpower company in Saskatchewan, which uses electrostatic precipitators at their Boundary Dam Power Station. The electrostatic precipitators capture fly ash emissions, and the cost of this project was $70 million.

25. **a.** The child's hair is standing on end; friction between the plastic slide and the child's clothing generated the charge.
    b. The child with hair on end is sliding on a plastic slide, while the uncharged child is on a metal slide.
    c. The explanation should state that static electricity can damage the electronic circuits in a cochlear implant. Large charges can build up when a child slides on plastic, and the pamphlet should advise the family to be aware of this hazard.

Chapter 11 Electric Circuits

In this chapter, students will learn about cells and electrical circuits. They will discover how a voltaic cell produces energy, and compare the properties and applications of different types of cells and batteries. Students will draw circuit diagrams, construct various circuits, and measure their electrical properties. They will investigate the relationships between current, potential difference, and resistance in series and parallel circuits, and solve problems using mathematical formulae.

Using the Chapter Opener (Student textbook pages 434 and 435)

- As a class, look at the illustration on pages 434 and 435. Ask where students have seen something like this before. They may mention that circuit boards are in computers and other appliances. Discuss what the paths and nodes are for.
- Ask students what else this photograph reminds them of. Circuit boards have a visual and functional similarity to roads and road maps, insect trails, and other pathways.
- Read the introductory paragraph on page 434 with students.
- As an alternative, have students picture the following scenario: A window display in a department store catches your attention. There is a string of colourful lights that decorates the window, and the street lamp casts an interesting glow onto the display. Suddenly, one of the light bulbs in the window begins to flicker and burn out, and the entire chain of lights goes dark. Strangely, the street lamp also burns out, but the rest of the street lamps continue to cast their light onto the sidewalk.
    - Ask students why it is that when one of the lights went out in the window, all of them went out, and why the same situation did not occur with the street lights. If they do not know, tell them that there are two types of electric connections, and in this chapter, they will learn what these connections are and how the same electrical principles cause electricity to flow through these circuits.

Activity 11-1 Shed Light On It (Student textbook page 435)

Pedagogical Purpose

This activity allows students to explore how a simple circuit is connected to control the operation of a flashlight. Different scenarios are presented so that students can investigate what factors affect the flow of current in a circuit. Students are introduced to vocabulary that they will use throughout the chapter.

Planning		
Materials	D cell in cell holder Switch Strip of aluminum foil • Gather the materials a few days before the activity.	Flashlight bulb in a holder 3 connecting wires
Time	Approximately 15–20 min in class	
Safety	• Tell students that if any wire in the circuit becomes hot, they must disconnect the wire immediately and inform you.	

Background

A simple circuit can be created by connecting loads with wires to form a single path that allows electrons to travel from the negative terminal of the battery to the positive terminal. If there is a break in any part of the path, then the flashlight bulb will stop working.

Materials

Please see the teaching notes for each activity for a list of the materials required. Please see page TR-35 for a summary of the materials required in this chapter and other chapters.

Advance Preparation

- In this chapter students will construct circuits and use ammeters and voltmeters to measure current and potential difference. Ensure that the batteries are of good charge and that there are enough meters for students to use when they are working in small groups.
- The following activities and investigations require circuit components: Activity 11-1 (page 435), Activity 11-4 (page 459), Investigation 11-A (pages 472 and 473), Investigation 11-B (pages 474 and 475), Investigation 11-C (pages 476 and 477), and Investigation 11-D (page 478). You may consider putting each set of required materials into plastic bags to distribute to the groups.
- Activity 11-2, on page 441, involves research at the library or on the Internet.
- Activity 11-3, on page 449, requires a variety of electrostatics apparatus and materials, along with some marbles and tubing.
- Investigation 11-A, on pages 472 and 473 requires a variety of metal strips, steel wool, and vinegar or sulfuric acid. Store the sulfuric acid according to the instructions on the warning label.
- Students can review the Key Terms in Chapter 11 using **BLM 11-1 Chapter 11 Key Terms.**

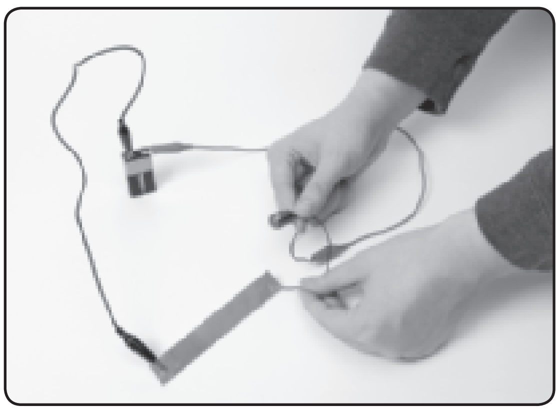
Activity Notes and Troubleshooting

- Tell students to never connect the negative and positive terminals of a cell with a wire. This will create a short circuit, which will quickly cause the cell and wire to heat up.
- Review the correct way to unscrew a light bulb, that is, counterclockwise.
- It may be difficult for students to observe the difference in bulb brightness when the aluminum foil is used instead of one of the wires. Since copper has a higher electrical conductivity than aluminum, the bulb will be slightly dimmer when the strip of aluminum foil is used. Dimming the lights in the classroom will make it easier.

Additional Support

- For students with vision impairments, replace the light bulb with a buzzer or another audio device.
- ELL Pair English language learners with a partner who can help them. Before you begin, demonstrate each step, emphasizing the verbs: *unscrew, tighten,* and *replace.*
- Enrichment—Have students investigate whether the length of the wire affects the brightness of the bulb. They can extend the length of one of the connecting wires using the strip of aluminum foil. Does it make a difference where the longer "wire" is connected in the circuit? You may also challenge students to replace the strip of aluminum foil with other types of material to test the materials' conductivity.

Answers

1. 

2. The bulb can be unscrewed, a wire can be disconnected, or the switch can be opened. Each action results in a break in the circuit.
3. Both are good conductors.

Study Toolkit		
Strategy	**Page Reference**	**Additional Support**
Identifying Cause and Effect	Have students use the strategy described on page 436 to map the cause-and-effect relationships of the factors that affect electrical resistance on page 465.	To familiarize English language learners with cause-and-effect maps, develop one with them that shows the effect "doing well in science," and the causes that lead to that. Students can use **BLM G-33 Cause-and-Effect Map,** to record on.
Comparing and Contrasting	Have students create a table that lists the similarities and differences between ammeters and voltmeters, listed on page 458.	**BLM G-39 Venn Diagram** **BLM G-38 T-chart**
Multiple Meanings	Have students use the strategy described on page 436 to complete a glossary list of all the words in this chapter that have scientific meanings different from their everyday meanings.	Allow English language learners some time to rehearse the words with a partner, in order to understand both meanings. They can play a game where one partner states a sentence excluding the word with more than one meaning. The other partner attempts to guess the word and its meaning (either everyday or scientific).

Section 11.1 Cells and Batteries

(Student textbook pages 437 to 445)

Specific Expectations

- **E2.1** use appropriate terminology related to electricity

In this section, students will learn how a voltaic cell works, and they will have the opportunity to build one. They will examine the properties of different types of cells and batteries, and apply the knowledge to make informed judgments as to which ones are best for various applications.

Common Misconceptions

- **Some students will believe that a battery eventually dies when it runs out of charges, since batteries are "rechargeable."** They think that the charge that moves from the battery to operate a device is consumed or used up, so there are fewer charges flowing out of the device than going into it. This belief is incorrect. When a battery no longer works, it is because it is out of energy (or chemicals to react), not charges. Remind students that charges are neither destroyed nor created. For every charge that leaves the battery, another charge enters at the opposite terminal.

Background Knowledge

A cell or battery changes chemical energy into electrical energy. Cells and batteries are classified in two ways: dry or wet, and primary (non-rechargeable) or secondary (rechargeable). Cells differ from one another based on the material nature of their electrodes and electrolyte.

The electrodes are the terminals in the cell, are made of two different metals, and have different abilities to hold on to electrons. Chemical reactions take place at the surface of these electrodes where they are in contact with the electrolyte, a conductive solution or paste/gel. The first invented cell, Volta's pile, consisted of silver and zinc electrodes immersed in a salt water solution that served as the electrolyte. Subsequent developments in cell technology have led to different types of metals being chosen for the electrodes and different conductive media used for the electrolyte. For example, the commonly used alkaline battery consists of zinc and manganese dioxide for the electrodes, and potassium hydroxide for the electrolyte. Each different type of cell has its own advantages and limitations over other types of cells.

Fuel cells and solar cells are different from the traditional voltaic cell or battery because their source of reactants is stored outside of the cell. In a fuel cell, electricity is generated when hydrogen gas is brought into the cell on the anode side (positive terminal) and oxygen is brought into the cell on the cathode side (negative terminal) to react in the presence of the electrolyte. In a solar cell, energy from sunlight is converted into electricity.

Literacy Support

Using the Text

Preview new vocabulary before students begin reading. Many of the Key Terms can be illustrated in a diagram: electric circuit, voltaic cell, battery, and electrode. Draw a large diagram and identify each of these terms, placing labels as you do. Leave this diagram on display to help students as they read. To review the terms with English language learners, create the labels on cards, then remove them and have students place them on the diagram again.

Before Reading

- Have students preview the headings, figures, and Key Terms in this section, and predict some things they will learn about. Invite a few students to share their predictions with the class. Refer students to Study Toolkit 1, Preparing for Reading: Previewing Text Features, on page 563 of the student textbook.

During Reading

- Students can write questions based on each heading and then look for answers to their questions as they read each subsection. For example, "What are the different types of cells?", "What are the different parts of a cell?", "How does a cell work?", and "Which applications use cells?" Remind students to use all the text features to find the answers.
- Hand out **BLM A-2 Asking Questions Checklist,** and/or **BLM A-41 Questioning Process Skills Rubric,** to guide students.
  - ELL Allow English language learners to work in a group to develop questions.

After Reading

- Have students use a T-chart to compare the advantages and disadvantages of primary cells and secondary cells. See **BLM G-38 T-chart.**
- Have students suggest one question for further study.
- ELL Pair English language learners with other students who have stronger language skills, to help them with this exercise.

Using the Images

- Have students examine the photograph of the lemon clock in Figure 11.3, on page 438. Ask them to name and describe the different parts of the cell.
- ELL For English language learners, you might draw a simplified version of the clock on the chalkboard and add labels as students provide them.
- ELL After reading the paragraph about chemical reactions in an aluminum-copper cell, have students look at the corresponding image shown in Figure 11.3, on page 438.
- Ask students to point to the electrode that is the source of the electrons, and trace the path that the electrons take to reach the other electrode. Ask, "What visual evidence is there that a gas is being produced during the chemical reactions?" (Answer: Bubbles appear on the positive electrode or copper strip.)
- Have students look at the various images of the different types of cells in Figure 11.4, on page 439 (a zinc-carbon cell, an alkaline cell, a silver-oxide cell, and a zinc-air cell). Ask them to list some of the physical differences they see. Brainstorm how these characteristics could be beneficial to the cell's applications.

Assessment FOR Learning

Tool	Evidence of Student Understanding	Supporting Learners
Learning Check questions, page 443 Section 11.1 Review questions, page 445	Students list different types of cells (wet, dry, primary, secondary), and discuss some of the cells' advantages and disadvantages. Students draw a diagram of a voltaic cell and label the two electrodes and electrolyte solution.	Have students draw a concept map to organize the different terminology introduced in this section. Have students write a glossary list of the bolded terms. See **BLM G-34 Concept Map.** You might have English language learners work in pairs, and provide them with page numbers and/or headings under which the information can be found. You might also point out "signal words" in the text, for example, *as well, one concern, another concern,* and *however*. These signal words help English language learners locate the pros and cons in a given passage. Before they answer Review questions 1 to 3, have English language learners use a pro/con T-chart to organize their ideas. See **BLM G-38 T-chart.**
Inquiry Investigation 11-A, Constructing and Comparing Voltaic Cells, pages 472 and 473	Students name the different parts of a cell and explain how a cell works.	Ask students to copy and label a diagram of the aluminum-copper cell shown in Figure 11.3 on page 438. Then below their drawing, have students summarize how a cell works.

Instructional Strategies

- Bring in a variety of voltaic cells for students to see. Discuss the similarities, differences, and possible uses of the cells.
- In small groups, have students read about voltaic cells in their textbook, then assign the Learning Check questions on page 443.
  - ELL English language learners should be grouped with other students who have stronger English skills.
- In the same groups, have students conduct Inquiry Investigation 11-A, Constructing and Comparing Voltaic Cells, on pages 472 and 473 of the student textbook.
- On the chalkboard, write the heading "Types of Cells" and list the following terms beneath it: dry cell, wet cell, primary cell, and secondary cell. Have students copy and define or illustrate these terms in their notes.
- Introduce Activity 11-2, Make a CELLection, on page 441 of the student textbook. Depending on the availability of the school's library or computer room, allow students to begin brainstorming their answers with a partner, and then give them research time to finish the activity. Alternatively, have students finish the activity at home.
- Have students define fuel cells and solar cells. Hold a discussion about their use and environmental impact.
- The Case Study, on pages 442 and 443, introduces students to one example of an innovative use of voltaic cells—the electric car—and to the advantages and disadvantages of electric cars.

Activity 11-2 Make a CELLection (Student textbook page 441)

Pedagogical Purpose

The purpose of this activity is to provide students with the opportunity to research, and compare the advantages and disadvantages (limitations) of, different types of cells or batteries. In order to recommend a particular cell to be used in a specific application, students must consider the properties of each individual cell, including its storage, capacity, and recharge life (where applicable), as well as reflect on the cell's cost and environmental impact.

Planning	
Materials	**BLM G-23 Data Table** (optional) • A few days before the activity, book the library and/or computer room.
Time	Approximately 30 min in class

Background

When choosing a cell or battery for a specific application, several factors should be considered, including storage, capacity, recharge life, cost, and environmental impact.

Storage, Shelf Life, and Self-discharge Rate

The slight conductivity of the battery housing allows electrons to travel to the cathode, slowly discharging the battery. The rate at which a battery self-discharges is affected by the moisture in the air and the temperature at which the battery is stored. At room temperature (20°C), nickel-cadmium (NiCd) batteries have a self-discharge rate of approximately 20 percent per month, while Nickel-metal (NiMH) batteries have a higher self-discharge rate of 25 percent per month. These batteries can be stored for up to five years and three years, respectively. Alkaline batteries, however, have a self-discharge rate of only 5 to 10 percent per year, giving them a shelf life of several years. Lithium batteries have a self-discharge rate of 5 percent per month. Generally, if batteries are stored at a higher temperature, they will self-discharge at a higher rate.

Storing batteries in the refrigerator will help make them last a few months longer. When rechargeable batteries are placed in the freezer after being fully charged, they will retain 90 percent of their charge for several months. However, they must be brought back to room temperature before using them in an electrical device.

Capacity

The capacity of a battery is a measure of the total amount of energy output from a fully-charged battery. It is usually expressed in ampere-hours or watt-hours. The capacity is measured by observing the time it takes to discharge a battery at a constant current until a specified cut-off voltage is reached. NiMH batteries have a 30 to 40 percent higher capacity than NiCd batteries. The energy density of a battery refers to the amount of energy stored per unit volume.

Recharge Life and Cycle Life

The cycle life of a battery is the total number of discharge/recharge cycles the battery provides before its capacity is reduced to the point where it can no longer hold a useful amount of charge. A battery is considered non-useable when its capacity drops below 60 to 80 percent. Typically, NiCd batteries have a cycle life of 600 to 900 recharge cycles, and NiMH batteries have a cycle life of 300 to 400 recharge cycles. Overcharging any rechargeable battery will reduce its cycle life significantly.

Cost and Environmental Impact of Some Common Cells and Batteries

Name of Cell or Battery	Cost	Environmental Impact
Alkaline	Moderate cost	Environmentally unfriendly: heavy metals may leach into landfills
Lead acid	Inexpensive	Environmentally unfriendly: lead content and corrosive electrolyte
Nickel-cadmium	Less expensive than nickel-metal hydride; low cost in terms of cost per cycle	Environmentally unfriendly: nickel-cadmium contains toxic metals
Nickel-metal hydride	Relatively expensive	Environmentally friendly: contains only mild toxins, which may be recycled
Lithium ion	Relatively expensive	Environmentally friendly

Activity Notes and Troubleshooting

- Do not assume that all students will know every application listed in the activity. You may decide to review the list with the class first and, if possible, show them pictures of the different applications.
- Students should work in pairs or small groups. Before deciding which cells they would recommend, students should discuss how each application works in order to determine the type of battery best suited for its function.
- Based on their brainstorming session and the information in Table 11.1, Cells and Batteries in Common Use (page 441 of the student textbook), students should complete as much of the table outlined in Procedure step 1 as possible. Then, they could divide the list of applications among the group members to conduct further research that will help them complete the entire table.
- Research can be conducted at the library or on the Internet or by talking to people who use each application. You may suggest websites for students to visit and/or keywords for which students can search on the Internet. For example, “battery types and uses,” “glossary of battery terms,” or “batteries for [name of application].”
- It may be that more than one type of cell or battery is suitable for a particular application. In that case, have students come to a consensus as to which one is best, by considering other factors such as cost and environmental impact.

Additional Support

- Form groups that consist of learners with a variety of strengths. Students with difficulty navigating the Internet should team up with those who are more comfortable working with computers.
- Enrichment—Have students research a specific type of cell or battery to learn more about it (for example, who invented it, when was it invented, and so on). Students can share their findings with the rest of the class, and then record information from the presentations in the form of a chronological time line of when the cells or batteries were invented.

Answers

1. Secondary cells have the least impact on the environment, because they can be recharged. Primary cells are discarded after they have been discharged.
2. On the basis of overall cost and environmental impact, secondary cells should be recommended most often.
3. Various answers may be given, and will be influenced by how often a particular device is used. Below is a sample table of possible answers.

Application	Properties of Cells That Could Be Used	Recommended Cell	Reasons for Recommendation
Key holder with a light	• small size • long-lasting	Silver-oxide	• button cell; small and long-lasting
Golf cart	• delivers high current	Lead acid	• provides moderate power for a long period of time • good shelf life
Travel alarm clock	• long-lasting	Alkaline	• long-lasting
Camcorder	• provides moderately high power (for electric motor) over a continuous recording period	Nickel-metal hydride or lithium-ion	• high capacity for current delivery • efficient under continuous drain for high-energy device
Portable drill	• delivers high current to drive a torque • withstands shock and vibration	Nickel-cadmium	• provides power for a long period of time • good at low and high temperatures • rugged
Child's singing teddy bear	• high capacity • efficient under continuous drain	Nickel-metal hydride	• good for high drain devices (rechargeable)
Flashlight	• long shelf life (device is used infrequently)	Alkaline	• has a low self-discharge rate (which means the battery will not go dead between periods of use)
Pacemaker	• high energy density • long shelf life	Lithium ion	• long shelf life
Snowblower	• delivers high current for motor • long shelf life • good at low temperatures	Lead acid or nickel-cadmium	• delivers high current
Engine starter	• delivers quick burst of high current	Lead acid	• delivers high current
Scuba diver's light	• good at low temperatures • good in high pressure	Alkaline or nickel-metal hydride	• long-lasting
Road-hazard warning light	• efficient under continuous moderate drain	Alkaline	• long-lasting

Learning Check Answers (Student textbook page 443)

1. Students' sketches must include, with labels, the electrodes and an electrolyte.
2. a. zinc-carbon, alkaline, silver-oxide, or zinc-air cell
   b. lead-acid cell
3. A fuel cell is a primary cell because it cannot be recharged by passing an electric current through it. A fuel cell does not store a charge, but uses outside fuel to create one.
4. The probe consists of two different metals. Moist soil acts as an electrolyte, and the probe metals act as electrodes for a cell. The current generated by this "cell" moves the needle.

Section 11.1 Review Answers (Student textbook page 445)

Please see also **BLM 11-2 Section 11.1 Review (Alternative Format).**

1. electric car—powered only by batteries; emits no greenhouse gases
   hybrid car—powered by batteries and a fossil-fuel engine; produces few emissions
2. One metal must give up electrons, and different metals hold on to their electrons with different strengths. If the two electrodes were made of the same material, then neither would give up its electrons to the other.
3. Batteries are classified as wet or dry cells, and as primary or secondary cells.
4. An electrolyte is a solution or a paste that conducts charge. The electrolyte allows positive ions to move from one electrode to the other.
5. a. Electrons leave the zinc electrode and move through the circuit toward the copper electrode. At the copper electrode, electrons combine with zinc ions in the electrolyte.
   b. The zinc electrode loses mass because zinc ions enter the electrolyte solution.
6. The experiment could be as simple as placing cells in a flashlight, and timing how long they last. Experiments should be run using the same flashlight, and at the same temperature. Students should evaluate the relative cost and length of time that the cells last. Students may also factor in the reduced cost, over time, of the rechargeable cell.
7. Fuel cells are expensive, and hydrogen must be obtained from other sources. Wet cells contain sulfuric acid, which is a corrosive liquid that can cause injury. Dry cells would likely be the best option because zinc-carbon cells are inexpensive, and although alkaline cells are more expensive than zinc-carbon cells, alkaline cells last longer.
8. Hydrogen fuel cells are expensive, and require hydrogen gas, which must be produced from other sources.

Section 11.2 Electric Circuits: Analogies and Characteristics

(Student textbook pages 446 to 454)

Specific Expectations

- **E2.1** use appropriate terminology related to electricity
- **E3.1** identify electrical quantities, and list their symbols and their corresponding SI units
- **E3.4** identify the components of a simple DC circuit, and explain their functions

In this section, students will be introduced to the characteristics of a simple electric circuit. Analogies will be used to help explain the movement of charges through the circuit. Students will learn about current, electrical resistance, and potential difference, and their corresponding SI units. They will also discover that these electrical quantities can be measured using an ammeter and a voltmeter.

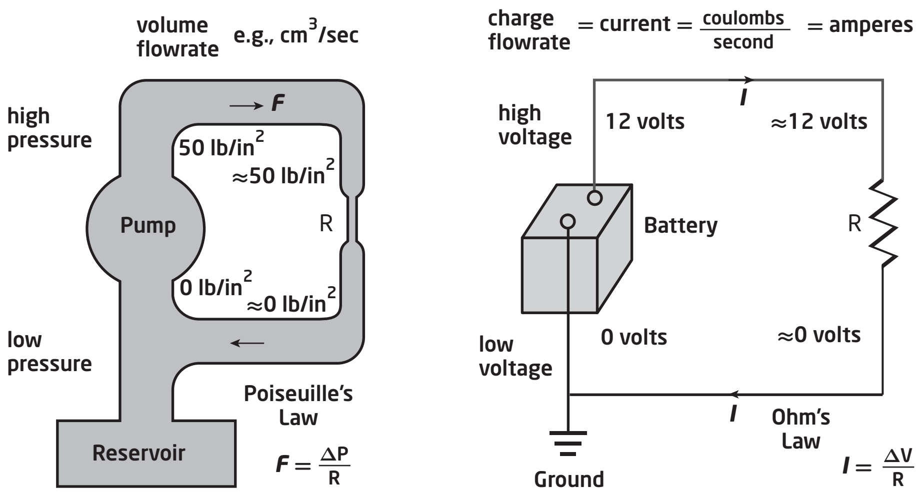
Common Misconceptions

- **Some students believe that current flows from the battery to the load (for example, a light bulb), but not from the load to the battery.** Have students connect a battery to a light bulb with one wire. Students will discover that the bulb will not go on since there is no path for the charges to travel from the bulb back to the battery.
- **Some students, especially English language learners, may interpret the terms *open circuits* and *closed circuits* differently because an *open* door lets people through and a *closed* door does not.** Use the analogy of a bridge that can lift on one end. When the bridge "opens," the cars cannot pass. When it comes back down ("closes"), the cars can continue on their way. The bridge represents the switch in a circuit.
- **Some students think that the connecting wires in a circuit are hollow, allowing electrons to flow through them very quickly from the negative terminal of the battery to the positive terminal.** This belief is not true. The scientific explanation is that the wires are already full of free electrons that begin to move simultaneously when the switch is turned on and energy is provided. Use the analogy of water pipes in a house, which deliver water stored in the basement's water tank to all parts of the house. When the shower is turned on upstairs, the water comes out of the faucet with little delay. This result occurs because the water is already in the pipes.

Background Knowledge

Scientists use analogies and models to help describe systems that may be very small, very large, or very complex. An analogy or model is a way of looking at something from a different point of view that helps scientists to better understand the system and make inferences. Although they are useful tools, analogies and models are not perfect. Some parts of the analogy or model will apply while others will not. Nonetheless, analogies and models allow scientists to make predictions that can be tested, which then lead to further development and understanding of ideas.

A common analogy that is used to explain properties of an electric circuit is the water flow through a pipe system in our homes. The water represents electron flow, and the water pump represents the cell in an electric circuit. The current in a circuit, which measures the amount of charge that flows past a given point in one second, is compared to the rate at which a specific volume of water (or number of water molecules) flows past a given point. The potential difference (or voltage), which measures the difference in potential energies of two points in the circuit, is analogous to the water pressure in the pipes.



Literacy Support

Using the Text

- To preview new vocabulary, add the following Key Terms to the diagram you displayed in Section 11.1: *terminal, switch, open circuit.*

Before Reading

- Discuss the importance of using analogies and models in science. Ask students which analogies they are already familiar with, such as the particle theory of matter, model of the atom, and the wave model of light.
  - ELL Some students, especially English language learners, may not have been exposed to or may not recall these scientific models. As an alternative, you could suggest that they share some similes and/or metaphors that they have heard of. Many cultures have their own sayings that compare one thing or event to another.

During Reading

- This section can be read in two parts: electric circuits; and electric current, resistance, and potential difference. Have students set up and complete two tables:
  1. In the first table, students can list the circuit components in the first column and describe their function in the second column (for example, cell, switch, resistor, connecting wire).
  2. In the second table, students can list the terms (current, potential energy, potential difference, and resistance) in the first column, and then write the corresponding definitions, symbols, and SI units in adjacent columns. Note: units for resistance (Ohms) appear in Section 11.3.

  Students could work in pairs to complete these tables.
- ELL English language learners can write unfamiliar terms on blank cards, and include simple definitions on the backs of the cards. They can practise the meaning of these words by playing word games with other students. For example, one partner can place the cards on a surface. Another student can select a card and attempt to provide the information on the opposite side of the card. If students are successful, they can keep the card, trying to accumulate as many cards as they can.

After Reading

- Have students summarize their understanding of electric circuits using an analogy (for example, water in a pipe system, or cars on the road). The analogy must explain the concepts of charges, current, potential difference (or energy), and resistance. Encourage students to be creative while still modelling the concepts of electricity. Have students share their analogies with the rest of the class.

- ELL English language learners could complete this activity as a diagram or model with labelled parts. Also, you might allow some English language learners to use an alternative setting for sharing their analogies (that is, with you or with a small group). English language learners might also benefit from analogies that use concrete or familiar experiences to understand more complex ideas. For example, when introducing amperes, an analogy between amperes and vehicles travelling on a road can be used. (The road = the circuit; cars = electron flow or current; each car = 1.0 coulomb; a house near the road = the given point being passed; construction on the road = the resistor, and so on.) It is important to emphasize that an analogy is only *similar* to another idea or concept. Students could use **BLM A-6 Developing Models Checklist,** to guide them.

Using the Images

- Have students examine and compare Figures 11.11 and 11.12, on page 448, which show the movement of electrons in a conductor before and after it is connected to a source of energy. What difference do they see?
- Figures 11.11, 11.12, and 11.14, on pages 448 and 451, show models. Have students describe what happens in each model and how it is similar to electrical current.

Assessment FOR Learning

Tool	Evidence of Student Understanding	Supporting Learners
Learning Check questions, page 451	Students identify basic electrical properties in an analogy.	Use **BLM 11-3 Electricity and the Highway,** as another analogy to help explain the concepts of an electrical circuit. For most students, this analogy may be more personal and easier to grasp, as they have probably been in a car or on a bus travelling on a highway (or a multi-lane road) at some time in their life.
Activity 11-3, Charged Cereal and Moving Marbles, page 449	Students use the analogies to explain how energy is transmitted by charges moving in a circuit.	Review the bolded terms in the relevant section in the textbook. English language learners can work with a partner. One partner can say the procedure aloud while following the directions and pointing to the items referenced, in order to reinforce the meaning of objects and actions.
Section 11.2 Review questions, page 454	Students identify components in a circuit and describe their functions. Students define *current, potential difference,* and *resistance in a circuit*, and know the corresponding symbols and SI units.	Refer students to Study Toolkit 4, Organizing Your Learning: Using Graphic Organizers, on page 566 of the student textbook. Have students create tables or other graphic organizers to summarize the information that they are having difficulty with.

Instructional Strategies

- Begin by reading the introductory paragraph of this section on page 446 of the student textbook to lead into the following simple demonstration: Ask for 10 volunteers to form a circle and hold hands. Select one student to represent the source of energy or cell in the circuit. Tell this student to squeeze the hand of the person standing to the right. Once this person on the right feels the squeeze, she will squeeze the hand of the next person on the right. This process continues around the circle until the squeeze is passed back to the source.
- As a follow-up to the demonstration, have a discussion with students about what the hand-squeezing analogy represents. (The squeezing of hands is like the movement of negative charges along a circuit. The movement is continuous and orderly along a closed path.) The ideas presented by students will give you an indication of students' prior knowledge on the subject.

- As a class, have students take turns reading aloud the information under the headings: Electric Circuits, Switches and Wires, and Open Circuits. Alternatively, students can be placed into small groups so that students will receive the information verbally. Have students make a glossary in their notes of the highlighted terms in the textbook.
- Have students carry out Activity 11-3, Charged Cereal and Moving Marbles, on page 449 of the student textbook.
- Have students continue reading the information in the textbook (pages 446 to 454).

Activity 11-3 Charged Cereal and Moving Marbles

(Student textbook page 449)

Pedagogical Purpose

The purpose of this activity is to demonstrate the nature of energy and electron flow in an electric circuit, using two analogies. The visual representations allow students to realize the difference between the movement of electrons and the transmission of energy across a conductor. The activity will help students understand that even though a light bulb glows immediately when the lamp is turned on, the electrons do not flow at the speed of light.

Planning		
Materials	Ebonite rod 4 pieces cereal Scissors Marbles or ball bearings	Fur Insulating thread Retort stand with a clamp and rod Tubing (open at both ends) (enough to fill the tubing, plus one)
	• Gather the materials a few days before the activity.	
Time	Approximately 20 min in class	
Safety	• Remind students who are allergic to fur not to handle it. • Remind students that the scissors are sharp and to handle them with care.	

Background

Cereal Analogy

The cereal analogy is used to demonstrate how energy is transmitted by an electric field. When the charged ebonite rod is brought near the cereal piece hanging at one end of the line, the cereal repels away from it. This repulsion is repeated between the like charges of each of the subsequent cereal pieces hanging in a row. The cereal pieces swing only a little and do not make contact, yet the force of repulsion is transmitted quickly down the line, causing the cereal pieces to move one after the other. This process is similar to how electrical energy passes through an electric field.

Marble Analogy

The marble analogy is used to demonstrate how quickly energy can travel through an electric circuit compared to how slowly electrons actually move through the components of the circuit. The tube full of marbles represents a conductor (for example, a connecting wire) full of free electrons that are ready to move when an outside source of energy is introduced. When a marble is inserted into the tube on one end, a marble will immediately exit on the other end. Even though each marble moves only a short distance, the transfer of motion through the tube is almost instantaneous from one end to the other. This process is similar to how electrical energy travels through wires, almost at the speed of light, even though each electron flows through the conductor at a rate of only a few millimetres per minute (approximately 8.4 cm/h).

Activity Notes and Troubleshooting

- Have students work in pairs or small groups.
- When students set up their apparatus for the cereal analogy, the hanging cereal pieces should not be touching one another, as shown on page 449. Tell students to tie the cereal pieces approximately 2 cm apart. If the pieces are tied too far from one another, the force of repulsion may not be strong enough to make the entire row of cereal pieces swing together.
- As with any activity that involves electrostatics, remind students not to over-handle the cereal and ebonite rod once they have been charged.
- For the marble analogy, try to use tubing that is only slightly larger in diameter than the marbles being used, and make sure to fill the tubing completely. Doing so ensures that the marbles stay in a straight line from one end of the tube to the other. Otherwise, when the extra marble is pushed into one end of the tube, the marble at the other end may not necessarily come out immediately.

Additional Support

- Some students may have trouble tying the cereal pieces to the threads, or they may have trouble tying the threads to the rod. You may need to prepare these materials before assigning the activity, or ask for volunteers to help others after they have set up their own apparatus.
- **ELL** English language learners may not yet have the English proficiency to answer the questions related to the two analogies. Try to form groups in which these students can receive help from other students who have strong language skills. Encourage English language learners to draw diagrams of their observations. They can answer questions 1 to 4 by drawing labelled diagrams, possibly accompanied by oral explanations.

Answers

1. In the cereal analogy, the external source of energy is a charged ebonite rod. The charge on the rod repels a piece of cereal, and then moves toward the adjacent piece of cereal, and so on. The pieces of cereal do not touch, but they move due to the repulsion of like charges. In the marble analogy, the external source of energy is the action of placing another marble into a tube filled with marbles. Marbles move as the result of collisions.
2. The movement of particles—pieces of cereal or marbles—represents energy moving through the conductor.
3. Each piece of cereal or marble "electron" moves very little, while interactions between these particles carry energy very quickly.
4. In the cereal analogy, the charged ebonite rod represents the cell. In the marble model, the last marble placed in the tube represents the cell.
5. The analogies ignore the effect of metal atoms and ions in the conductor. Also, while energy travels rapidly in each conductor, its speed is much less than the speed at which an electric force is transmitted through an electric field.
6. Students may mention that both show that electricity flows; that marbles in a tube move like electrons—from one atom to the next, while the electricity flows in one end of the tube and out the other; that the tube is like a wire; or that the cereal shows that electricity can be used to do work. It causes the cereal to move.

Learning Check Answers (Student textbook page 451)

1. A closed circuit is a circuit in which electric charges can flow in an uninterrupted pathway around the complete circuit. An open circuit is one that has a gap or break in it.
2. The coulomb (C) is the unit of electric charge and is equal to the charge on a large number of electrons. The unit is used because very large numbers of electrons are involved in static charges and current.
3. the electric field
4. It is not a circuit because the charge does not return to its source.

Section 11.2 Review Answers (Student textbook page 454)

Please see also **BLM 11-4 Section 11.2 Review (Alternative Format).**

1. It is similar because a tap controls the flow of water, while a switch controls the flow of electrons. However, when a switch is open, electrons do not flow out of a circuit, whereas when a tap is open, water does flow out of it.
2. A D cell lasts longer than an AA cell because it has the most electrolyte material.
3. It is fixed, because the potential difference between the cell terminals depends only on the materials used to make the cell.
4. **a.** A = C/s
   b. V = J/C
5. Current is charge per second. Thus, the conductor carrying the larger current has greater charge moving in it per second. One conductor could have a greater diameter, and carry a larger current.
6. **a.** In bulbs A and B, the energy will be the same because the same current flows through both bulbs at the same voltage.
   b. If a wire is connected between points P and Q, the intensity of bulb A will not change. The intensity of bulb B will decrease to 0. It is no longer part of the circuit.
7. An electrical load is any device that converts electrical energy into other forms of energy (for example, radio, TV, microwave, stove, hair dryer, and so on).
8. Potential difference is the work done in moving a unit of charge between two points in a circuit. The work required to move charge along a good conductor is so small that it can be ignored.

Section 11.3 Measuring the Properties of Simple Circuits

(Student textbook pages 455 to 461)

Specific Expectations

- **E2.1** use appropriate terminology related to electricity
- **E2.5** design, draw circuit diagrams of, and construct series circuits, and measure electric current and potential difference at various points in the circuit
- **E3.7** explain what different meters measure and how they are connected within an electrical circuit to measure electrical quantities

In this section, students will learn how to read and draw circuit diagrams, using standard symbols to represent the various components in the electric circuit. They will measure the current and potential difference in a circuit using an ammeter and a voltmeter, respectively.

Common Misconceptions

- **Some students may confuse the current measured by the ammeter with the number of electrons moving through the circuit.** Review the definition of *current* in Section 11.2. Current is the rate of movement of electric charges.
- **Some students may think that a large current means that a charge is moving quickly.** This belief is not true. Consider a conductor with a large cross-sectional area; a large amount of charge will pass through a given location without the charge moving quickly.

Background Knowledge

Electric circuits can be described in various ways: with words, with a quick drawing, or with a circuit diagram. For example, if you say, "A D-cell is connected to a light bulb," one would have the following mental image:

The corresponding circuit diagram would consist of replacing the components with circuit symbols: **BLM 11-5 Circuit Symbols,** shows some circuit symbols commonly used when drawing circuit diagrams.

There are meters designed to measure the current and potential difference in a circuit. These meters may show the electrical quantities by the motion of a pointer on a scale, or by a digital display of numerical digits. An ammeter is used to measure the current flowing through a specific point in the circuit, while a voltmeter is used to measure the amount of potential difference across two points in the circuit.

Some meters can be used to measure current, potential difference, and electrical resistance. These meters are called multimeters. A multimeter works the same way as an individual meter. When the meter selection is set to read current as an ammeter, it must be connected in series. When it is set to read potential difference as a voltmeter, it must be connected in parallel across the load.

Literacy Support

Using the Text

Before Reading

- Have students preview the headings in this section. Use each heading as a topic for discussion. What is students' prior knowledge of the topic? Ask students to make a prediction about what each subsection will be about. Upon reading the subsection, ask students to compare or verify their predictions with what they learned.

During Reading

- Help students identify the main idea of each subsection. For each subsection, have students analyze the text and summarize the key ideas. They must reduce the passage to just 20 words that capture the gist of the text, and include diagrams where appropriate (for example, circuit symbols and circuit diagrams). Refer students to the main idea web in Study Toolkit 4, Organizing Your Learning: Using Graphic Organizers, on page 566 of the student textbook, and to **BLM G-36 Main Idea Web.**
- ELL English language learners can make point-form notes for each section. Be sure to demonstrate for English language learners how to make point-form notes, prior to suggesting this format. It may be helpful to offer a list of key verbs that they can use in the summary. Encourage these students to use diagrams to summarize text wherever possible.

After Reading

- Have students summarize the similarities and differences between ammeters and voltmeters in a table or in a Venn diagram. See **BLM G-39 Venn Diagram.**

Using the Images

- Have students study and copy the circuit symbols shown in Figure 11.21 on page 457 into their notes. Ask them to explain how they will associate each symbol with the circuit component that it represents. For example, a switch looks like a door that is opened or closed.
- ELL Create cards for English language learners, to be used throughout the rest of the chapter to introduce and review the terms listed in Figure 11.21 on page 457 of the student textbook. On one set of cards, write only the words for each circuit component. On another set of cards, draw the symbols. On a third set of cards, draw the circuit components. Ask students to look at Figure 11.21 for several minutes, and then pass one card to each student and have them find the matching cards. Once students have found all three matching cards for each component, ask them to read pages 458 and 460 to prepare definitions for their circuit components, which can then be written on a fourth set of cards. You might play a five-minute trivia game at the beginning of class, where you read a definition and ask students to say the corresponding word or symbol.

Assessment FOR Learning		
Tool	**Evidence of Student Understanding**	**Supporting Learners**
Learning Check questions, page 458	Students draw circuit diagrams using the correct circuit symbols.	Have students review the correct symbols used to draw circuit diagrams by completing **BLM 11-5 Circuit Symbols,** and **BLM 11-6 Designing Circuits.**
Activity 11-4, Measuring Current and Potential Difference in a Series Circuit, page 459 Inquiry Investigation 11-B, Loads in Series, pages 474 and 475	Students construct series circuits and measure current and potential difference using an ammeter and a voltmeter, respectively.	Use **BLM G-21 Using Ammeters and Voltmeters; BLM G-22 Reading an Analogue Meter;** and/or Science Skills Toolkit 9, Using Electric Circuit Symbols and Meters, on page 548 of the student textbook, to review the proper way to use these meters.
Section 11.3 Review questions, page 461	Students design and draw circuit diagrams. Students predict the total potential energy of a battery made up of cells with specific voltages.	Have students refer to Figure 11.22, on page 460. The batteries shown are composed of a specific number of cells connected in series to provide each battery's total voltage output.

Instructional Strategies

- Have students begin the section by reading the information under the following headings: Circuit Diagrams, and Symbols for Specific Components. Students should copy Figure 11.20, on page 456, into their notes.
- After reading about series circuits and parallel circuits, ask students to write the terms and definitions into their notes. Have them compare the similarities and differences of the two types of circuits by using a table or Venn diagram.
  - ELL English language learners could work with a classmate to complete this task.
- ELL Students are introduced to this section using the example of the Blackout in Ontario in August, 2003. Be sensitive to the fact that many English language learners may be unfamiliar with this event, but may be able to offer similar stories about their experiences in another country. Encourage them to share their stories.
- Read the Measuring Current and Potential Difference section on page 458. Demonstrate how each meter is used. Have students conduct Activity 11-4, Measuring Current and Potential Difference in a Series Circuit, on page 459 of the student textbook.
- Read the Electrical Energy and Gravitational Energy section.

Activity 11-4 Measuring Current and Potential Difference in a Series Circuit (Student textbook page 459)

Pedagogical Purpose

The purpose of this activity is to provide students with the opportunity to practise measuring current and potential difference in a circuit using an ammeter and a voltmeter, respectively.

Planning		
Materials	Switch 6 connecting wires Cell • Gather the materials a few days before the activity.	Flashlight bulb Voltmeter Ammeter
Time	Approximately 30–35 min in class	
Safety	• Tell students not to close the switch until you have checked their connections.	

Background

An ammeter is used to measure the current that travels through a certain point in the circuit. The meter must be placed in series with the rest of the components in the circuit so that the electron flow will travel through the device. The unit of measurement for current is the ampere (A).

A voltmeter is used to measure the potential difference across two points in the circuit. It is connected in parallel with the load that it is measuring, so that the meter measures the potential energy going into the load, and compares it with the potential energy coming out of the load. The voltmeter displays a single reading that shows the difference of the two potential energies. The unit of measurement for potential difference is the volt (V).

Activity Notes and Troubleshooting

- Have students work in pairs or small groups. It is important that they all have the opportunity to use the two meters, so if there are not enough meters for all the groups, try to order some before the activity. Consider purchasing multimeters, which can be used as ammeters and voltmeters.
- It is easy to damage an ammeter and a voltmeter if they are not properly connected or set up. Remind students that they must set their range switch to the highest range before they close the circuit switch. It is especially important not to connect the ammeter directly across the source. Otherwise a short circuit will be created between the ammeter and the battery, which could cause the fuse inside the ammeter to blow.
- Traditionally, the black wire is used to connect to the negative pole connection of the meter, and the red wire is used to connect to the positive pole connection. Remind students that the pole connections must trace back to the same terminal on the electrical source.

Additional Support

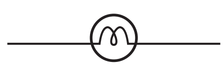
- ELL Model the activity for English language learners, before asking them to complete it. List and show the materials to be used, and then demonstrate the process and the safety aspects of working with electricity. Have students create their own basic circuit following your example. As students are working, circulate and ask questions to elicit the appropriate vocabulary.
- For students experiencing difficulty setting up the circuit and the ammeter and voltmeter in the correct places, have them draw the circuit diagram first, labelling the wires and connection points.
- Enrichment—Have students practise using the ammeter and voltmeter to measure the current and potential difference of bulbs with different voltages.
- Enrichment—Have students design a one-page instructional manual that explains how an ammeter or a voltmeter is connected, used, and read. Spatial learners and students who experience difficulty with the written language could produce a poster instead that depicts the dos and don’ts of handling an ammeter or a voltmeter.
- **BLM G-21 Using Ammeters and Voltmeters; BLM G-22 Reading an Analogue Meter;** and Science Skills Toolkit 9, Using Electric Circuit Symbols and Meters, on page 548 of the student textbook, can help students review the skills they will need to conduct this activity.

Answers

1. Within experimental error, the two readings are the same. This result is because there is negligible potential difference along the length of connecting wires.
2. The potential difference across the switch is zero, because a closed switch is a good conductor. The potential difference across a good conductor is negligible.
3. Within experimental error, the readings are the same. The current in a circuit that contains only series connections is constant.

Learning Check Answers (Student textbook page 458)

1. a. 

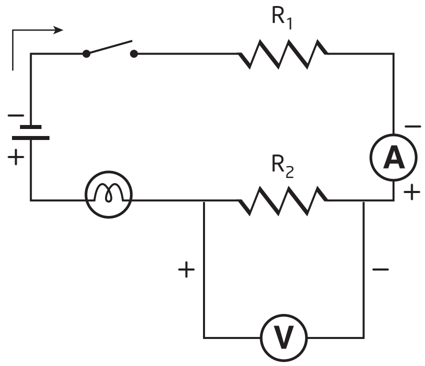
   b. 

   c. 

2. There is the same current through the ammeter and the load if they are in series. If the ammeter is in parallel with the load, current is divided between the two parallel pathways, and the ammeter readings are no longer a measure of what the current in the load originally was.
3. The diagram shows bulbs connected in a parallel circuit.
4. Series connections correspond to a single road or highway that links two locations. A parallel connection corresponds to two or more roads that join two locations.

Section 11.3 Review Answers (Student textbook page 461)

Please see also **BLM 11-7 Section 11.3 Review (Alternative Format).**

1. A parallel, B series, C series
2. If the connections are incorrect, the meter needle will appear to begin moving in the wrong direction, and the meter could be damaged.
3. 
4. 3.5 V
5. 

6. Gravity has no effect on the potential difference of a battery. The mass of electrons is negligible.
7. **a.** four 1.5 V cells, or three 2 V cells

   b. The 6 V battery will overheat a circuit designed for a 1.5 V “D” cell, and will damage components.
8. **a.** A quantity that is conserved remains unchanged.

   b. The total energy consumed by the bulbs must be six joules for every coulomb of charge moving through them.

Section 11.4 Measuring Electrical Resistance

(Student textbook pages 462 to 467)

Specific Expectations

- **E2.1** use appropriate terminology related to electricity
- **E2.7** investigate the qualitative relationships between current, potential difference, and resistance in a simple series circuit
- **E2.8** solve simple problems involving potential difference, electric current, and resistance, using the quantitative relationship *V* = *IR*
- **E3.6** describe, qualitatively, the interrelationships between resistance, potential difference, and electric current
- **E3.8** explain how various factors influence the resistance of an electrical circuit

In this section, students will investigate Ohm's law by constructing a series circuit, and graphing and analyzing the data measured with an ammeter and a voltmeter. They will describe the relationships among current, potential difference, and resistance, and solve problems using the formula $V = IR$. Students will be able to explain what factors affect the resistance of an electrical circuit, and learn about superconductors and non-ohmic conductors.

Common Misconceptions

- **Students may believe that connecting wires have no resistance.** This belief is not true. All conductors have some amount of resistance, but the resistance of the connecting wires is really quite insignificant compared to the electric loads in the circuit.

Background Knowledge

Electrical resistance is the property of a substance that hinders, or opposes, the current (or flow of charges) in a circuit, and converts the electrical energy to other forms of energy such as heat or light energy.

Factors that affect the resistance in a wire include the following: material of the wire, its length, its diameter (or cross-sectional area), and the temperature. In a conductor, the atoms form a lattice structure in which the outermost electrons are free to move from their parent atoms to other atoms. When a source of potential difference is applied across the conductor, the electrons move from one end of the conductor to the other under the influence of the electric field. This flow of electrons can be affected by the length of the conductor: the longer the wire, the higher the resistance because there is more chance for the electrons to collide with other ions and electrons along the way through the material. The flow can also be affected by the diameter of the conductor: the thicker the wire, the lower the resistance because there are many more atoms, and therefore more free electrons in the wire to carry the current through the material. Temperature is another factor that affects resistance: the higher the temperature, the higher the resistance because the increased movement of the atoms and ions (due to the higher temperature) creates more collisions with the electrons moving through the wire.

Ohm's law states that the ratio of potential difference to current is a constant called resistance. This relationship can be represented by the mathematical formula $R = V/I$.

But not all conductors obey Ohm's law. In non-ohmic conductors, the resistance decreases with increased temperature. Some examples of non-ohmic conductors include incandescent bulbs; and transistors and diodes used inside pocket calculators, portable radios, and CD players.

Resistors are colour-coded to describe the resistance and tolerance of each. There are four colour bands on the resistor, and the bands are read so that the gold (±5%) or silver (±10%) tolerance band is last. The first two bands give the digits associated with the resistance and the third band gives the power of 10 multiplier. The colours correspond with the digits 0 to 9 as follows: black (0), brown (1), red (2), orange (3), yellow (4), green (5), blue (6), violet (7), grey (8), and white (9). If the colour of the multiplier band is gold, the decimal point is moved one place to the left. For example, suppose the four-colour bands on a resistor are brown, blue, red, and gold. Then the value of this resistor is 16×10^2 (±5%). The 1 and 6 come from the brown and the blue bands respectively, while the exponent 2 comes from the red band. If the colours had been brown, blue, gold, and gold, the value of the resistor would be 1.6 (±5%).

Literacy Support

Using the Text

Before Reading

- Have students divide their note paper into four sections: Ohm's Law; Factors that Affect Resistance in a Wire; Problem-solving Using the Relationship $V = IR$; and Superconductors and Non-ohmic Conductors. Have students look for these key ideas by scanning the headings and highlighted terms in the textbook. Ask students to summarize the first statement that they come across for each of the four headings, orally.
  - ELL Before reading the Factors that Affect Resistance of Wires section on page 465 of the student textbook, draw an arrow pointing up and an arrow pointing down on the board. Tell English language learners that they are reading to determine and write the things that make resistance increase (arrow up) and decrease (arrow down) in a wire. You might want to review this concept before students complete the Learning Check questions on page 465.

During Reading

- Students must identify the main idea for each of the four headings they wrote earlier. For each section, have students analyze the text and summarize the key ideas. They must summarize the information in just 20 words that capture the gist of the text, and include diagrams where appropriate (for example, a resistor).
- ELL English language learners and spatial learners can make point-form notes and/or labelled diagrams for each section. It is possible to summarize each of the four topics using equations, sketches, and graphs. Check to see that students have captured the key ideas. If not, ask another student to share their summary, and have English language learners identify what they are missing, or conduct a discussion as a class.

After Reading

- Have students review their notes and choose two facts that they found most interesting. Ask them to write a paragraph to explain why these ideas caught their interest, and to propose questions for further research that they may conduct to learn more about these ideas.
  - ELL Instead of writing a paragraph, English language learners can list new words they encountered that relate to those ideas, and define or illustrate each one.

Using the Images

- Remind students to refer to the circuit diagrams on page 469 when they are building circuits in Inquiry Investigation 11-D, Testing Ohm's Law, on page 478 of the student textbook.
- The images can be used to consolidate the key ideas. After reading, have students use the graph on page 464, Figure 11.25 on page 465, and Figure 11.27 on page 466 to summarize the content of the section.

Assessment FOR Learning		
Tool	**Evidence of Student Understanding**	**Supporting Learners**
Learning Check questions, page 465 Section 11.4 Review questions, page 467	Students describe, qualitatively, the interrelationships between resistance, potential difference, and electric current. Students explain how various factors influence the resistance of an electrical circuit.	Have students use graphic organizers to organize (or summarize) their notes. Before answering the Section 11.4 Review questions, illustrate the variations of the root word *resist* on the chalkboard for English language learners. Write the words *resist, resistance,* and *resistor*. Have English language learners work with a partner to search for these words in the textbook (pages 462 to 465). When they find the words, have them read the entire sentence to their partner and challenge their partner to restate the sentence in a simple way or to draw a sketch to illustrate the meaning.
Practice Problems, page 464	Students solve simple problems involving potential difference, electric current, and resistance, using the quantitative relationship $V = IR$.	Assign **BLM 11-8 Calculating Resistance;** or **BLM 11-9 Calculating Resistance (Alternative Version),** so that students can practise calculating resistance.
Inquiry Investigation 11-D, Testing Ohm's Law, page 478	Students graph data and calculate the slope of a line, to confirm the relationship of Ohm's law.	Assign **BLM 11-10 Graphing Resistance,** for students to practise their graphing skills and calculations of slope.

Instructional Strategies

- If possible, bring in a circuit board. Have students locate things they recognize, such as resistors and wiring, and ask about others.
- ELL Have English language learners begin the investigation first, and then use the analysis to discuss Ohm's law. Following this task, they can read the section about Ohm's law on page 462 and follow up with Inquiry Investigation 11-D, Testing Ohm's Law on page 478 of the student textbook. Both approaches will engage students in developing the relationships between current, potential energy, and resistance in a circuit. Beginning the investigation will provide hands-on background experience that will help English language learners understand what they are reading.
- Write the relationship $R = V/I$ on the chalkboard and discuss the units involved. Since V is measured in volts and I is measured in amperes, then the unit for R is volts per ampere or 1 ohm = 1 V/A.
- As a class, examine the sample problems on pages 463 and 464. Assign the Practice Problems for students to work on. Consider solving the first one step-by-step together, writing the solution on the chalkboard. Remind students to show all their work and include the units in their answers. Refer students to Math Skills Toolkit 2, Significant Digits and Rounding, on page 556 of the student textbook.
- Have students read and make notes about factors that affect resistance in a wire, superconductors, and non-ohmic conductors. If time permits, allow students to construct simple circuits to test the different factors that affect resistance in a wire.

Practice Problems (Student textbook page 464)

1. 10 Ω
2. 82.8 Ω
3. 10.6 Ω
4. The current doubles.
5. 0.15 A
6. 3.0 V

Learning Check Answers (Student textbook page 465)

1. ohm (Ω), or V/A
2. length, diameter, and temperature
3. The bulb will dim. Charge flowing through the filament will have less energy than before.
4. The filament is very thin and is often coiled, increasing its length. A tungsten wire has greater resistance than a copper wire with the same dimensions. The filament is at a higher temperature than the copper wire.

Section 11.4 Review Answers (Student textbook page 467)

Please see also **BLM 11-11 Section 11.4 Review (Alternative Format).**

1. 15 Ω
2. 0.15 V
3. 13.5 A
4. The filament evaporates during operation and becomes thinner. A thinner wire has increased resistance and will glow more brightly. When the filament breaks, there is an open circuit and there can be no current.
5. Long extension cord connections increase the resistance of the circuit. The mower will not operate correctly if the resistance is too large. For safety reasons, the cord must have a large enough diameter to keep the wire's resistance from causing too much heat.
6. The brighter glowing bulb probably has a longer filament.
7. The diameter of the wire helps determine its resistance, which affects how brightly it shines. In addition, thin parts of the wire would have greater resistance, heat up more, and be more likely to melt and break.
8. A superconductor is non-ohmic, because it has zero resistance.

Section 11.5 Series and Parallel Circuits

(Student textbook pages 468 to 471)

Specific Expectations

- **E2.1** use appropriate terminology related to electricity
- **E2.5** design, draw circuit diagrams of, and construct series and parallel circuits, and measure electric current, potential difference, and resistance at various points in the circuit
- **E2.6** analyse and interpret the effects of adding an identical load in series and in parallel in a simple circuit
- **E3.5** explain the characteristics of electric current, potential difference, and resistance in simple series and parallel circuits, noting how the quantities differ in the two circuits
- **E3.6** describe, qualitatively, the interrelationships between resistance, potential difference, and electric current

In this section, students will learn about the characteristics of current, potential difference, and resistance in a series and a parallel circuit. They will observe the difference between these quantities in the two types of circuits when they carry out investigations to test the effect of adding loads in series and in parallel.

Common Misconceptions

- **Some students may believe that in a series circuit, when one component goes out, the loads that come before it will work, while those after it will not work.** You can demonstrate that this belief is not true by constructing a simple circuit of four light bulbs connected to a battery in series. Unscrew the third bulb and students will see that all bulbs will go out.
- **Students may believe that when loads are connected in parallel, the total voltage from the source is divided among the loads (just as the total current is divided).** Use a circuit diagram to emphasize that individual electrons take only one pathway to return to the source. Since each electron begins with the same amount of energy (equivalent to the total battery potential), each will lose the same amount travelling across the load, regardless of the pathway taken.
- **Students may believe that adding a resistor in parallel increases the total resistance of the circuit.** Refer students to a circuit diagram to show how each new branch in parallel draws some current from the other branches, so the total resistance must decrease. An analogy that may help students visualize this concept is customers waiting in line at the checkout stands in a busy grocery store. If a cashier opens up another checkout lane, some of the customers will redirect to form a new line, decreasing the overall wait time to pay for the groceries and leave the store.

Background Knowledge

In a series circuit, where there is only one path for electron flow, and the components are all connected end to end, the current remains the same throughout the circuit, no matter where it is measured. As more and more loads are connected in the series circuit, the current leaving the source decreases, and the potential difference across each load also decreases. The sum of the potential differences across the loads is equivalent to the voltage across the source.

In a parallel circuit, where there is more than one path on which electrons can flow and the components are connected parallel to each other, the potential difference remains the same across the loads. As more loads are connected in the parallel circuit, the current leaving the source increases. The sum of the current through the loads is equivalent to the current leaving the source.

Literacy Support

Using the Text

Before Reading

- Have students make connections to prior knowledge by reviewing the definitions of a series circuit and a parallel circuit, and then predicting the relationships for current and potential difference as more loads are connected in series and in parallel. If possible, have each type of circuit set up for students to refer to as they make their predictions. Upon reading the student textbook, ask students to compare or verify their predictions with what they learned.

During Reading

- Help students analyze the text, summarize the key ideas, and identify the main idea of each section. They must reduce the passage to just 20 words that capture the gist of the text, and include diagrams where appropriate (for example, series circuit, parallel circuit).
  - ELL Encourage English language learners to make point-form notes and labelled diagrams to summarize each section.
- Students can use a write around to create summaries. In a small group, each students begins a summary of one section, then the summaries are passed around until all group members have a chance to add to and comment on every section's summary. At the end, the group has a complete set of summaries.

After Reading

- After reading, have students draw a Venn diagram to compare and contrast a series and a parallel circuit. They can compare their diagram to a classmate's and change theirs as required. See **BLM G-39 Venn Diagram.**

Using the Images

- Examine the images that support the two Inquiry Investigations on pages 474 and 476 of the textbook. Have students orally explain how each of the circuits is connected.
- DI Bodily-kinesthetic learners may benefit from constructing each of the illustrated circuits on page 469 to check the information given in the captions. They could demonstrate for the class.

Assessment FOR Learning		
Tool	**Evidence of Student Understanding**	**Supporting Learners**
Section 11.5 Review questions, page 471	Students explain the characteristics of electric current, potential difference, and resistance in series and parallel circuits. Students describe, qualitatively, the interrelationships between resistance, potential difference, and electric current.	Have students create a table to compare current, potential difference, and resistance in series and parallel circuits.
Inquiry Investigation 11-B, Loads in Series, pages 474 and 475 Inquiry Investigation 11-C, Loads in Parallel, pages 476 and 477	Students construct series and parallel circuits, and measure electric current and potential difference at various points in the circuit. Students analyze and interpret the effects of adding an identical load in series and in parallel in a simple circuit.	Have students draw the circuit diagram for the circuit before attempting to construct it, and explain orally how the current will travel through the pathways. Review how to connect an electric meter with **BLM G-21 Using Ammeters and Voltmeters.** Ask students to draw a Venn diagram to compare and contrast the characteristics of a series and a parallel circuit. See **BLM G-39 Venn Diagram.**

Instructional Strategies

- Review the definitions and characteristics of series circuits and parallel circuits. If you wish, use analogies to explain the difference between the two circuits. For example, cars racing on a racetrack would represent a series circuit, whereas cars driving from destinations A to B on busy city streets would represent a parallel circuit.
- Have students conduct Inquiry Investigation 11-B, Loads in Series (student textbook pages 474 and 475) and Inquiry Investigation 11-C, Loads in Parallel (student textbook pages 476 and 477). Doing so will give them the opportunity to analyze the data and use the questions to guide them to develop some of the relationships, without being given the "answers" first.
- Discuss their results from the investigations and have them follow up by reading pages 468 to 470. Have students copy the quantitative relationships on pages 468 and 470 into their notes.
- ELL When assigning the Inquiry Investigations for this section, always partner English language learners with strong readers. Have the partners read the steps aloud and talk to the English language learners as they are working through the Inquiry. Expect active participation from English language learners in the procedural parts of the Inquiry, as this section is less linguistically demanding and at the same time, it teaches the concept in a real way.

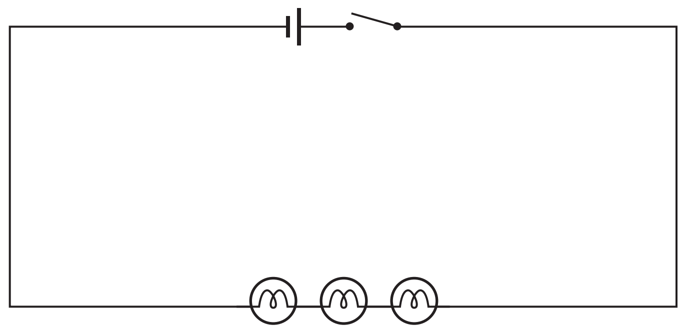
Section 11.5 Review Answers (Student textbook page 471)

Please see also **BLM 11-12 Section 11.5 Review (Alternative Format).**

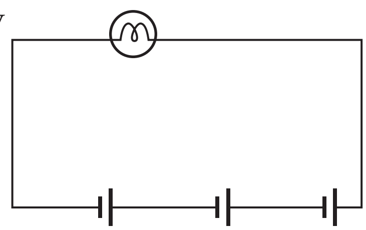
1. The potential difference between the connections on each load is not the same if the loads have different resistance. The current must be the same.

2. The potential difference between the connections on each load must be the same. The currents through each load will differ if the resistance is different.

3.



4. 1.5V



5. The current in the parallel circuit is greater.

6. The bulbs in parallel will each glow with the same intensity as the single bulb. The current through each bulb and the potential difference between each bulb's terminals will be the same in the parallel circuit as in the circuit with a single bulb.

7. The flashing bulb contains a switching mechanism and it is in series with the electrical source and the rest of the bulbs. The rest of the bulbs are wired in parallel.

8. **a.** both bulbs off

b. bulb X on, bulb Y off

c. bulb X off, bulb Y on

d. both bulbs on, each with the same intensity and equal in intensity to the situations described in parts b. and c.

Inquiry Investigation 11-A Constructing and Comparing Voltaic Cells (Student textbook pages 472 and 473)

Pedagogical Purpose

The purpose of this activity is for students to construct different voltaic cells using a variety of metal strips for the electrodes, and to compare them according to the potential differences produced.

Planning	
Materials	Variety of metal strips (for example, aluminum, copper, iron, zinc) Steel wool Small beaker (100 mL) Electrolyte: vinegar or dilute sulfuric acid (about 40 mL) 2 large paper clips Voltmeter or multimeter (if available, probeware may be used to measure voltages) Connecting leads Light-emitting diode (optional) Paper towel **BLM 11-13 Inquiry Investigation 11-A Constructing and Comparing Voltaic Cells** (optional) **BLM G-23 Data Table** (optional) • Gather the materials a few days before the activity. Store the sulfuric acid according the warning label and health and safety regulations.
Time	Approximately 20 min in class (if each group is assigned only one pair of electrodes to make a voltaic cell)
Safety	• The electrolyte is a caustic liquid. Remind students to wear safety goggles to protect their eyes, and to wash any spills on their skin or clothing by using plenty of cold water. • Tell students to wear gloves when using steel wool to clean the metal strips.

Background

In a voltaic cell, there are two electrodes made of different metals. Chemical reactions take place at the surface of these electrodes immersed in the conductive electrolyte. The metal electrode that has the greater ability to hold onto its electrons plays the positive electrode in the voltaic cell, while the metal that loses its electrons plays the negative electrode.

For example, in the aluminum-copper cell, the aluminum atoms break down into aluminum ions and electrons. The electrons travel from the aluminum electrode through the wires to the copper electrode. The positive aluminum ions enter the electrolyte solution and move toward the copper electrode where they react with electrons to form hydrogen gas. These bubbles of gas can be observed at the copper electrode. As the chemical reactions continue, the aluminum electrode will slowly disintegrate and the cell will reach the point where it can no longer produce electrical energy.

Activity Notes and Troubleshooting

- There are six different types of voltaic cells to construct: aluminum-zinc, aluminum-iron, aluminum-copper, zinc-iron, zinc-copper, and iron-copper. Divide the class into 12 groups consisting of two or three students each. Assign two groups to build each type of cell. In this way, students are able to compare different types of voltaic cells, as well as verify the observations made for the same type of cell.

- Tell students to rub the metal strips in one direction with the steel wool, until their surfaces are shiny. This action will enable the chemical reactions in the electrolyte to take place more effectively.
- Caution students that they could get splinters from the steel wool if they are not careful. They must wear gloves when handling the steel wool, including during the clean-up of their work area after the investigation.

Additional Support

- ELL Pair English language learners with fluent English readers.
- Enrichment—Have students build their own fruit (lemon, grapefruit) or potato battery. Challenge them to be resourceful when selecting materials for the electrodes (for example, copper penny, aluminum foil, iron nail, and so on). You may need to provide them with LED lights and connecting wires to test their batteries.

Answers

Analyze and Interpret

1. This answer will depend on the electrodes used. In the sample metals, the greatest voltage should be the combination of aluminum and copper.
2. Bubbles formed on one electrode.

Conclude and Communicate

3. When choosing the electrodes, students might consider the cost, safety, and chemical reactivity. One electrode should be a relatively reactive metal, and the other electrode should be relatively non-reactive.

Extend Your Inquiry and Research Skills

4. Students' results will vary depending on the strength of the electrolyte solution and other factors.
5. Two different metals are in contact with each other in two locations called junctions. When the junctions are at different temperatures, there is a potential difference between them. Thermocouples can be calibrated to measure temperature, or to operate temperature-sensitive switches.

Inquiry Investigation 11-B Loads in Series

(Student textbook pages 474 and 475)

Pedagogical Purpose

The purpose of this activity is for students to observe and compare the brightness of identical bulbs as they are connected together in series. Students will measure the current and potential difference, and use the data to make statements about the properties of a series circuit.

Planning	
Materials	Battery (6 V) Battery (9 V) (optional) Switch 8 connecting leads 3 identical flashlight bulbs in holders Ammeter Voltmeter **BLM 11-14 Inquiry Investigation 11-B Loads in Series** (optional) **BLM G-23 Data Table** (optional) • Gather the materials a few days before the activity.
Time	Approximately 45 min in class
Safety	• Tell students if the bulb glows very brightly to immediately open the switch in the circuit and inform you.

Background

Below are the sample data for three 18-Ohm resistors connected in series with a 6 V battery:

Number of Resistors Connected	Current Leaving Source, *I* (amperes)	Potential Difference, *V* (volts)			
		Across the Source	Across Each Resistor		
			#1	#2	#3
1	0.33	6	6		
2	0.165	6	3	3	
3	0.111	6	2	2	2

The relationships for current, potential difference, and resistance in a series circuit can be summarized with the following mathematical relationships:

$I_T = I_1 = I_2 = I_3$

$V_T = V_1 + V_2 + V_3$

$R_T = R_1 + R_2 + R_3$

Activity Notes and Troubleshooting

- Check that students connect the ammeters and voltmeters properly to avoid damage to the meters. Remind them to begin with the highest range on the measuring scale.
- There are several connections to make and disconnect in this investigation. Simplify the process by telling students that the ammeter is not moved until the last step in the procedure. The voltmeter is moved from the source to each of the flashlight bulbs as each additional bulb is added.
- Dimming the classroom lights will make it easier for students to compare the brightness of the bulbs.
- Review Ohm's law, $R = \frac{V}{I}$, to help students answer questions 3 and 4.

Additional Support

- ELL Students should work in small groups of three or four. Students (including English language learners) who require assistance in following written instructions should be grouped with classmates who have strong language skills.
- Each student within the group can be assigned a particular role according to their strengths: circuit builder, connections and safety checker, meter reader, and observations recorder.
- DI Bodily-kinesthetic, logical-mathematical, and spatial learning skills are all needed for this activity. Try to ensure each group includes learners with a variety of dominant styles.
- If students are not yet comfortable using ammeters and voltmeters, refer them to Science Skills Toolkit 9, Using Electric Circuit Symbols and Meters; **BLM G-22 Reading an Analogue Meter;** and/or **BLM G-21 Using Ammeters and Voltmeters.**

Answers

Analyze and Interpret

1. **a.** The brightness decreases.
   b. The current decreases.
   c. The potential difference across the source remains the same.
   d. The potential difference across each load decreases.
2. They are equal.
3. Answers will vary, depending on bulbs used.
4. Answers will vary, depending on bulbs used.
5. Students should include reasons why their data do or do not support their predictions.

Conclude and Communicate

6. The current leaving the source is the same as the current through each load in a series circuit.
7. $V_T = V_1 + V_2 + V_3$
8. $R_T = R_1 + R_2 + R_3$

Extend Your Inquiry and Research Skills

9. **a.** The brightness increases.
   b. The potential difference increases.
   c. The current increases.
10. Students should find that these switches waste a lot of energy heating up the resistor.

Inquiry Investigation 11-C, Loads in Parallel

(Student textbook pages 476 and 477)

Pedagogical Purpose

The purpose of this activity is for students to investigate the effect of adding loads in a parallel circuit. They will measure the current and potential difference, and use the data to make statements about the properties of a parallel circuit.

Planning	
Materials	1.5 V cell Switch 10 connecting leads 3 identical flashlight bulbs in holders Voltmeter Ammeter **BLM 11-15 Inquiry Investigation 11-C Loads in Parallel** (optional) **BLM G-23 Data Table** (optional) • Gather the materials a few days before the activity.
Time	Approximately 40 min in class
Safety	• Tell students if the bulb glows very brightly to immediately open the switch in the circuit and inform you.

Background

Below are the sample data for three 18-Ohm resistors connected in parallel with a 6 V battery:

Resistor Number in Parallel	Current, *I*, Leaving Cell (amperes)	Current, I_n, Through Resistor (amperes)	Potential Difference, *V*, Across Cell (volts)	Potential Difference, V_n, Across Resistor (volts)
#1	1.0	0.33	6	6
#2		0.33		6
#3		0.33		6

The relationships for current, potential difference, and resistance in a parallel circuit can be summarized with the following mathematical relationships:

$$I_T = I_1 + I_2 + I_3$$

$$V_T = V_1 = V_2 = V_3$$

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Activity Notes and Troubleshooting

- Check that students connect the ammeters and voltmeters properly. Remind students to begin with the highest range on the measuring scale.
- There are several connections to make and disconnect in this investigation. Simplify the process by telling students that the ammeter is always placed in the same branch, connected in series, with the load that it is measuring. The voltmeter is moved from the source to each of the flashlight bulbs as each additional bulb is added.
- Dimming the classroom lights will make it easier for students to compare the brightness of the bulbs.
- Review Ohm's law, $R = \frac{V}{I}$.
- Review the meaning of the colour bands on resistors, and the formula for the slope of a line.

Additional Support

- ELL Students should work in small groups of three or four. Students (including English language learners) who require assistance in following written instructions should be grouped with classmates who can help them.
- Some students may require assistance designing a suitable data table. They can use Science Skills Toolkit 7, Creating Data Tables, on pages 545 of the student textbook, to help them.
- DI Bodily-kinesthetic, logical-mathematical, and spatial learning skills are all needed for this activity. Try to ensure each group includes learners with a variety of dominant styles.
- Each student within the group can be assigned a particular role according to their strengths: circuit builder, connections and safety checker, meter reader, and observations recorder.

Answers

Analyze and Interpret

1. It is the same.
2. The current through each path is less than the current entering the parallel connection.
3. Students should use the potential difference and current they observed to calculate the resistance: $R = \frac{V}{I}$
4. Students should include an explanation why their data do or do not support their predictions.

Conclude and Communicate

5. The current through each load will be approximately one third of the current leaving the source in a parallel circuit with three loads.
6. Word equations should convey the relationship in the answer to question 5.

Extend Your Inquiry and Research Skills

7. Since $R = \frac{V}{I}$, it follows that the resistance of the circuit as a whole is equivalent to the total potential difference across the cell divided by the total current leaving the cell. That is, $R_T = \frac{V_T}{I_T}$
8. $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

   Note: Students who love a math challenge can be asked to show how this relationship can be obtained from $R_T = \frac{V_T}{I_T}$:

$$R_T = \frac{V_T}{I_T}$$

$$\frac{1}{R_T} = \frac{I_T}{V_T}$$

$$= \frac{(I_1 + I_2 + I_3)}{V_T}$$

$$= \frac{I_1}{V_T} + \frac{I_2}{V_T} + \frac{I_3}{V_T}$$

$$= \frac{I_1}{V_1} + \frac{I_2}{V_2} + \frac{I_3}{V_3}$$

$$= \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Inquiry Investigation 11-D Testing Ohm's Law

(Student textbook page 478)

Pedagogical Purpose

The purpose of this activity is for students to investigate the relationship between current, potential difference, and resistance. By analyzing a graph of their data collected, they will realize Ohm's law.

Planning	
Materials	Resistor Ammeter Voltmeter Cells, batteries, or a variable power supply 6 connecting leads **BLM 11-16 Inquiry Investigation 11-D Testing Ohm's Law** (optional) **BLM G-23 Data Table** (optional) • Gather the materials a few days before the activity.
Time	Approximately 30 min in class
Safety	• Before students take the first measurement, check their circuit connections, especially the locations of the ammeter and voltmeter. • Remind students to set the range selector switch on both the ammeter and voltmeter to the highest value. • Tell students to be aware of how hot the resistor becomes without actually touching it. If it seems to be getting very hot, have them open the switch immediately and notify you.

Background

By changing the potential difference of the energy source, students will be able to take several readings of the current through, and potential difference across, the resistor in the circuit. When the potential difference across the resistor changes, so does the current travelling through the resistor. A graph of the data showing current on the x-axis and potential difference on the y-axis will reveal a straight line whose slope is constant, $R = \frac{V}{I}$, or—in other words—Ohm's law.

Activity Notes and Troubleshooting

- Math Skills Toolkit 3, Organizing and Communicating Scientific Results with Graphs, on page 557 of the student textbook; **BLM G-25 Constructing a Line Graph;** and **BLM G-26 Interpreting Line Graphs,** are all useful for students who need to review graphing skills.
- Students should work in pairs or small groups. Each member in the group can be given a task: constructing the circuit, reading the current, reading the voltage, and recording the data. Ensure each group includes students with a variety of dominant learning styles.
- Review what a line of best fit means and how to calculate the slope of a line. Each student should make their own graph to practise their skills in graphing. You may decide to model creating a graph for the class: deciding on scale, labelling axes, discussing how to plot each point, and so on.
- Determine the resistance of the resistors by their colour bands, and have students compare their calculated results with the actual resistance. Any differences can be used as an opportunity to discuss experimental error.

Additional Support

- Students who have difficulty graphing or calculating slopes can be paired with students who have stronger mathematical skills.
- Enrichment—Have students use **BLM 11-17 What Is the Resistance of a Light Bulb?** They will measure the current and corresponding potential difference as they increase the voltage of the power supply in a circuit that includes a light bulb. A plot of the data this time will not produce a straight line, and students will conclude that a light bulb is a non-ohmic device.

Answers

Analyze and Interpret

1. The slope of a graph is the ratio of rise to run. In this case, the slope is the ratio of potential difference to current, which is equal to resistance.

Conclude and Communicate

2. As the potential difference in the circuit increases, the current also increases, while the resistance stays the same.

Extend Your Inquiry and Research Skills

3. Georg Simon Ohm (1787-1854) was a German mathematics teacher who aspired to be a university science professor. In 1825, after teaching many years in different high schools, Ohm decided to devote his time to research the field of electricity. He began by conducting a series of experiments. What is now known as Ohm's law, namely the relationship that the current through most materials is directly proportional to the potential difference across the material, was based on the experimental data that Ohm collected and analyzed. Unfortunately, Ohm's mathematical approach was not immediately embraced by other physicists at that time. It was not until 12 years before his death that Ohm's work was recognized by The Royal Society—an independent, international group of scientists dedicated to promoting and sharing science.

   Investigation 11-D is similar to Ohm's work in that it allows students to discover the relationship between current and potential difference by analyzing and graphing the data that they collect in the activity.

4. The value of non-ohmic resistors depends on the voltage and current used. If you plot the voltage versus the current on a graph, a non-ohmic resistor would not be in a straight line. Non-ohmic devices such as transistors and diodes are very important components of pocket calculators, portable radios, and other audio and video equipment. They do not obey Ohm's law. The amount of resistance they provide changes as the temperature increases.

Chapter Review Answers (Student textbook pages 481 and 481)

Please see also **BLM 11-18 Chapter 11 Review (Alternative Format).**

Make Your Own Summary

Use the Difference and Similarities table in the Study Toolkit on page 436 as a starting point to compare and contrast the properties of a series circuit and a parallel circuit.

	Differences	Similarities
Series circuit	There is *only one* path along which electrons can flow. $I_T = I_1 = I_2 = I_3$ $V_T = V_1 + V_2 + V_3$ $R_T = R_1 + R_2 + R_3$	Both are closed paths along which electrons can flow from, and return to, the energy source.
Parallel circuit	There is *more than one* path along which electrons can flow. $I_T = I_1 + I_2 + I_3$ $V_T = V_1 = V_2 = V_3$ $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$	

Draw a similar table to compare and contrast the properties of an ammeter and a voltmeter.

	Differences	Similarities
Ammeter	• used to measure the current through a load, in amperes (A) • must be connected in series with the load that it is measuring	Both meters have a negative pole connection and a positive pole connection.
Voltmeter	• used to measure the potential difference across a load, in volts (V) • must be connected in parallel with the load that it is measuring	

Reviewing Key Terms

1. voltaic; electrodes; electrolyte
2. secondary cell
3. open switch
4. ampere
5. load
6. parallel circuit
7. superconductor
8. resistance

Knowledge and Understanding

9. A wet cell contains a liquid electrolyte. The electrolyte in a dry cell is a paste.
10. A battery consists of two or more cells connected together.
11. A fuel cell requires fuel stored outside the cell, such as hydrogen stored in an external tank. Other cells contain all the materials needed to generate electricity inside the cell.
12. The wire that is long, thin, and made of silver has greater resistance. Resistance increases with length and decreased thickness.
13. In a circuit with only series connections, current travels along one path only. In a parallel connection, there can be current along more than one path.
14. Increase the potential difference by adding another cell or battery; decrease the resistance by adding another load in parallel.
15. Length: an increase in length causes an increase in resistance; Diameter: an increase in diameter causes a decrease in resistance; Type of material: metals usually have lower resistance than non-metals; Temperature: an increase in temperature causes an increase in resistance.
16. Smaller, because each additional pathway allows current. Thus, the total current is large and the resistance, $\frac{V}{I}$, will be small.
17. **a.** Graph 4. A wire's resistance is directly proportional to its length.
    b. Graph 2. The resistance is constant.
18. **a.** $V = IR$
    b. $R = \frac{V}{I}$
    c. $I = \frac{V}{R}$

Thinking and Investigating

19. **b.** The line of best fit is a curve with increasing slope.
    c. With one cell, there was too little current through the filament. With four cells, the current was greater.
    d. The slope of the graph is the resistance of the filament. The resistance increases as the temperature of the filament increases.
20. bulb D, because it is in series with the switch

21. **a.** bulb A
 b. There is the same current through each bulb.
 c. bulb A
 d. bulb A

Communication

22. A secondary cell is a renewable source of electrical energy since it can be recharged several times.

23. Students may include the following ideas in their essays: electric cars emit no greenhouse gases, although the generation of the electricity produces some carbon emissions; it takes about four hours to charge 80 percent of an electric car; when the car is not moving (for example, when it is stuck in traffic), it does not use stored power or produce any exhaust.

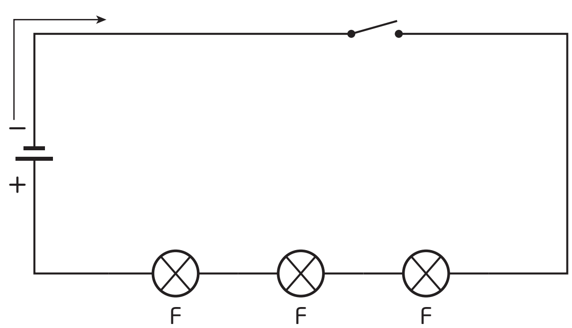
24. Static electricity is an electric charge that tends to accumulate on the surface of an object. Current electricity is an electric charge that travels, for example, through a wire.

25. Students may determine that an automotive service technician performs repairs or general maintenance on various components of automotive vehicles, including engines, steering, brakes, suspensions, electrical and air conditioning, and wheel alignments. An automotive service technician may need to be a registered apprentice or have a recognized trade certificate. The courses may include business training, interpersonal skills, and computer skills.

Application

26. **a.** A flashing light bulb flashes because it contains a bimetallic strip that bends away from the contact when it is heated (turning the light off), and straightens out and touches the contact again when it cools down (turning the light on again).

 The circuit symbol for a flashing light is a circle with an "X" inside of it.



 b. All the bulbs will flash on and off. Even if only one flashing bulb is connected in series with several non-flashing bulbs, they will all flash on and off since the flashing bulb works like a switch, alternating between allowing current to flow and preventing current from flowing through the circuit.

 c. Only the flashing bulb will go on and off. The other bulbs will stay lit with the same intensity.

27. When the mercury becomes ionized, the gas becomes conducting (it is a plasma). The ballast prevents the resistance of the circuit from becoming too small. Without the ballast, the current could become dangerously high and might cause a fire.

28. Connect the multimeter between the terminals of the load. A small current passes through the load from the meter, and the multimeter determines the $\frac{V}{I}$ ratio.

Chapter 12 Generating and Using Electricity

Materials
Please see the teaching notes for each activity for a list of the materials required. Please see page TR-35 for a summary of the materials required in this chapter and other chapters.

Advance Preparation

- Activity 12-1, on page 483 of the student textbook, requires wire coils, connecting wires, ammeters (with centre zero), and bar magnets. Gathering these materials a few days before the activity is recommended.
- Technology Investigation 12-A, on page 513 of the student textbook, involves designing a circuit to meet specified criteria. Students will need a 6 V battery, connecting wires, flashlight bulbs in holders, and three-connection switches. Gather enough materials for students to work in pairs or small groups. Ensure the batteries are of good charge.
- Real World Investigation 12-B, on student textbook page 514, and Plan Your Own Investigation 12-D, on student textbook page 516, require students to spend some time researching on the Internet. Book the library and/or computer room a few days before students complete the investigations.
- Students can review the Key Terms in Chapter 12 using **BLM 12-1 Chapter 12 Key Terms.**

In this chapter, students will learn how electricity is generated and the role they can play in reducing electrical energy consumption and its impact on the environment. Students will distinguish between direct current and alternating current, and examine electricity in their home. They will collect and analyze data to become informed electrical energy consumers, and produce a personal plan of action. Students will assess renewable and non-renewable methods of energy production.

Using the Chapter Opener (Student textbook pages 482 and 483)

- Some students take it for granted that when they flip the switch to turn on an electrical device at home, electricity will "magically" flow to it and it will always work. But where does the electricity in their homes or the school come from? Use the opening paragraph on page 482 to discuss generating plants. Brainstorm what forms of energy the generating plants convert into electricity (fossil fuel, water, nuclear, wind). Ask, "What impact do these forms of energy have on the environment?"
- Have students refer to Study Toolkit 4, Organizing Your Learning: Using Graphic Organizers, on page 566 of the student textbook, to draw a flowchart that shows how they think electricity travels from the generating plant to their home. They will modify and add to this flowchart as they learn the material in this chapter.
  - ELL English language learners can use their first language for words they do not know in English, and then consult a dictionary, a classmate, or you for the English equivalents.
- As an alternative, consider blackouts, rolling blackouts, and brownouts—how are students able to distinguish among these events? Have any students experienced one or more of them? Depending on where students have lived, some may have experienced first-hand one or two of these events. These personal experiences generally make for a good discussion since students are given the opportunity to share their stories and to hear those of their peers. Then you can link the discussion to the concept of sustainable energy.

Activity 12-1 Generating an Electric Current (Student textbook page 483)

Pedagogical Purpose
In this activity, students investigate the principle of electromagnetic induction, which is used by generating plants to convert mechanical energy into electrical energy.

Planning	
Materials	Wire coil (optional: coils of different size) 2 connecting wires Ammeter (centre zero) Bar magnet (optional: magnets of different strength)
Time	Approximately 15 min in class
Safety	• Caution students that magnets could be damaged if dropped.

Background
The apparatus used in this activity is the same as that used by Michael Faraday in 1831 to study electromagnetic induction. In his experiment, Faraday confirmed that a moving magnetic field induces a current in a coil of wire. When the north pole of a magnet is pushed into a coil of wire, the needle on the ammeter deflects to the positive side of the scale. When the magnet is pulled out, the needle deflects in the opposite direction. The current stops flowing once the magnet stops moving relative to the coil.

The size of the current induced when a magnet moves into a coil of wire can be increased by using a stronger magnet, moving the magnet more quickly, increasing the number of turns of wire on the coil, or reducing the diameter of the coil of wire.

The principle of electromagnetic induction is used by generating plants to make electricity. The large AC generators consist of two parts: an outer shell with strong magnets, which rotates around a stationary armature that is wound with heavy wire. As the outer shell moves, the magnets induce an electric current in the wire.

Activity Notes and Troubleshooting

- This activity is best carried out by students working in pairs or small groups. One student can move the bar magnet in and out of the wire coil, while the others observe the movement of the needle on the ammeter.
- An analogue ammeter whose scale shows both positive and negative readings is needed. The "zero" must be in the centre of the scale. Otherwise, when the bar magnet is pulled out of the wire coil, the deflection of the ammeter's needle in the opposite direction (into the negative current) would not register.
- If there are not enough ammeters for students to carry out the activity on their own, or if they are having difficulty making observations, an alternative would be to show students a computer simulation of the experiment. There are a few websites that offer this simulation; see **www.scienceontario.ca**.

Additional Support

- ELL Encourage English language learners to visit the Ontario Science Centre website prior to completing this activity.
- ELL Have English language learners conduct this activity with a fluent English-speaking classmate. Partners can support English language learners by using key language as they participate in the activity (for example, *magnet, stationary, current*).
- Enrichment—Students can investigate how the amount of current induced depends on the strength of the magnet used, the speed at which the magnet is moving, the number of turns in the wire coil, and the diameter of the wire coil.

Answers

1. The needle moved in opposite directions.
2. No, there is not a current in the circuit when the magnet and the coil are stationary, relative to each other, since the ammeter points to zero.
3. Electrons must be moving back and forth in the wires.
4. The needle moves back and forth in both cases.

Study Toolkit

Strategy	Page Reference	Additional Support
Making Inferences	Read page 485. Use the Making Inferences strategy to write three questions about information that may be missing, and then make three inferences.	Model this strategy by analyzing one page as a class. Use this opportunity to explain academic language, such as *inferences*, to English language learners. Refer students to **BLM G-4 Making Observations and Inferences.**
Using Graphic Organizers	Select a graphic organizer to **1.** compare and contrast direct current (DC) and alternating current (AC) (page 486). **2.** summarize the information on pages 507 to 510	See Study Toolkit 4, Organizing Your Learning: Using Graphic Organizers, on page 566 of the student textbook, and **BLMs G-33–G-39.**
Creating a Word Map	Create a word map to organize information about the word *efficiency* on page 497.	If you introduced a graphic organizer at the beginning of Unit 4, build on it now. English language learners can also make connections related to new vocabulary using a word map.

Section 12.1 Electricity at Home (Student textbook pages 485 to 491)

Specific Expectations

- **E2.1** use appropriate terminology related to electricity
- **E3.3** compare and contrast static electricity with alternating current and direct current
- **E3.4** identify the components of a simple DC circuit, and explain their functions

In this section, students will learn about the electricity that powers their home. They will study the characteristics of direct current and alternating current, and describe the process by which electricity travels from generating plants to the electric meter. Students will explain how safety devices, such as circuit breakers, fuses, and surge protectors, work to provide electrical safety in the home. By completing Technology Investigation 12-A, on student textbook page 513, they will apply their technological problem-solving skills to design and build a circuit that controls a light from two locations.

Common Misconceptions

- **Some students may think that batteries and generators create, or "generate," the electrons that flow through the wires in a circuit.** But no new electrons are made; current is the movement of electrons that already exist in the conductors. This concept can be shown with a hand-crank flashlight or a hand-crank radio. If possible, bring one to class and open it up; students will see only some wires inside. The wires form a closed loop with the rest of the circuit. There is no "source" of electrons.
- **Some students may confuse direct current (DC) with alternating current (AC), thinking that DC comes directly from the wall outlet, while AC refers to the alternative energy source stored in batteries.** Extra explanation may be needed to help these students understand that the electrons flow in one direction only in DC, and they flow back and forth (alternating directions) in AC. Refer students to their observations of the ammeter in Activity 12-1, on student textbook page 483, where the needle alternated between positive and negative current.

Background Knowledge

There are two types of current: direct current (DC) and alternating current (AC). In DC, electrons flow in only one direction. For example, in a simple DC circuit consisting of a battery and a light bulb, the electrons flow from the negative terminal of the battery to the positive terminal until all the chemical energy in the battery has been depleted. In AC, the electrons move back and forth in the circuit in response to alternating voltages provided by the energy source.

In AC circuits, most loads will operate regardless of the direction in which the electrons flow. As the electrons flow through the load (for example, the light or the appliance), energy is deposited in the resistive element (for example, the light bulb filament) of the load. For some loads that require current to flow in only one direction (such as electronic devices using rechargeable batteries), a transformer is used to convert the AC provided at the wall socket to DC for use by the load.

The advantage of using AC is that it allows power companies to transmit electricity at high voltages over large distances with little loss of energy in the process. The money spent transmitting electricity using this method is much less than the money that would be needed to build local power plants to generate the electricity.

Electrical safety in the home is an integral part of the practical application of electricity and electrical circuits. Safety features (circuit breakers, fuses, and so on) are installed in homes to prevent electrical hazards such as electrical fires (caused by overheating in the wires) or dangerous electric shocks.

Literacy Support

Using the Text

Before Reading

- Have students preview the headings in this section. Use each heading as a topic for discussion. What is students' prior knowledge of the topic?

- ELL Preview the following Key Terms: *alternating current* and *direct current.* Have English language learners make a T-chart to note the similarities and differences. Work with these students to list other contexts in which the words *alternating* and *direct* are used, and have students draw diagrams where appropriate. See **BLM G-38 T-chart.**

During Reading

- For each subsection, have students analyze the text and summarize the key ideas, including the main idea. They must reduce the passage to just 20 words that capture the gist of the text, and include diagrams where appropriate.
  - ELL English language learners can make point-form notes for each section.

After Reading

- After reading, have students create a T-chart to summarize the similarities and differences between DC and AC, and draw a Venn diagram to compare circuit breakers and fuses. See **BLM G-38 T-chart,** and **BLM G-39 Venn Diagram.**

Using the Images

- Use the photograph in Figure 12.1, on page 485, to help students realize the magnitude of the role that electricity plays in our lives. Have students brainstorm some of the social, economical, and environmental impacts associated with building a generating station.
- Have students make connections to Figure 12.3, on page 487, from their own experience. Ask them where they have seen high-voltage wire and transformers like these in their community.
  - ELL As students make connections, repeat key vocabulary, print the words on the chalkboard, and explain what each word means.
- Review the terms *series* and *parallel,* for students. Use Figure 12.5, on page 488, to examine how household circuits are connected. Tell students to cover the caption with one hand, and use their finger on their other hand to trace the path along which current flows in the circuit. Ask them the following questions: "Are the electrical outlets connected in series or parallel?" "What is the significance of this connection?" "Is the circuit breaker connected in series or in parallel with the other components in the circuit?" "Why must the circuit breaker be connected this way?"
- The information displayed in Table 12.1, Electrical Safety Equipment in the Home (page 490), describes and compares the different safety features installed in homes. Have students read this information and then discuss the importance of such devices in the home.

Assessment FOR Learning

Tool	Evidence of Student Understanding	Supporting Learners
Learning Check questions, page 487 Section 12.1 Review questions, page 491	Students describe the difference between direct current and alternating current. Students explain how safety devices, such as circuit breakers and fuses, work.	Students can review their results from Activity 12-1, Generating an Electric Current, on student textbook page 483, and work with a partner to contrast DC and AC from the information in the textbook. Use **BLM 12-2 Fuses and Circuit Breakers,** to review how each of these safety devices work. Ask students to trace the path of the current to determine the location where it stops flowing when the fuse blows or the circuit breaker trips.
Technology Investigation 12-A, Designing a Staircase Circuit, page 513	Students are able to apply technological problem-solving skills to design and test a circuit that meets specified criteria.	Review what a typical series circuit looks like, and the function of a switch in a circuit. Have English language learners complete **BLM 12-3 Using a Three-way Switch.**

Instructional Strategies

- Teachers can start the lesson with a fun electrical safety quiz that students can take online. See **www.scienceontario.ca**.
  - Students examine scenarios in the different rooms of a house to pick out the electrical hazards depicted in the images. The correct answers are evident in the multiple-choice answers provided, but if students determine the answers from the images, without first looking at the multiple-choice answers, then the activity provides a good way to determine students' preconceived ideas about electrical safety at home.
  - ELL This activity is beneficial to English language learners because it provides visual support and familiarizes students with key vocabulary and concepts. Have English language learners visit the website prior to using the quiz in class.
- ELL Before students read about the transmission of electricity from the generating plant to their homes (pages 486 to 488), create a large flowchart to trace the path of electricity (that is, power generating station → step-up transformer → sub-station → local distribution station → step-down pole transformer → electric meter → distribution panel → electrical outlet). This flowchart will support English language learners as they read, and it keeps the most important information in focus.
- You may choose to conduct Technology Investigation 12-A, Designing a Staircase Circuit (page 513), before or after addressing the topic of Electrical Safety in the Home. In the investigation, students apply their knowledge of current flow and switches to design and test a circuit to meet certain criteria.
- Discuss Electrical Safety in the Home, and the importance of using safety devices such as circuit breakers, fuses, and surge protectors (page 490). You might assign students a mini-project to create safety posters that make people aware of the electrical hazards in the home, and suggest tips to avoid them.

Learning Check Answers (Student textbook page 487)

1. In direct current, the movement of electrons is in one direction along the conductor. In alternating current, the electrons move back and forth along a conductor, but there is no net movement in either direction.
2. a step-down transformer
3. Transmitting electrical energy at high voltages (as you can do with AC) reduces energy loss, and transformers can be used to decrease the voltage supplied to consumers.
4. Students' answers should be similar to what is shown in Figure 12.2, on page 486 of the student textbook: power generating station (where electricity is generated) → transformer (step-up transformer to increase the voltage) → substation → distribution station → pole/green-box transformer (step-down transformer to distribute electricity to groups of users) → your home.

Section 12.1 Review Answers (Student textbook page 491)

Please see also **BLM 12-4 Section 12.1 Review (Alternative Format).**

1. The electrons in an alternating current move back and forth, but they do not flow. An alternating current has the same effect as a direct current where electrons do move around a circuit, away from the negative electrode and toward the positive electrode.
2. The microwave oven contains a step-up transformer.
3. Copper is a better conductor, and the cable could be made thinner. Aluminum is less dense, and although an aluminum wire with the same conductivity as a copper wire will be thicker, it will weigh less. Students may infer that aluminum is used today because it is cheaper.
4. In the event of an unsafe current, the circuit breaker can be reset. The fuse must be replaced.
5. too many appliances operating on the same circuit; a loose wire in an appliance; an appliance that is wet; power line struck by lightning
6. The round prong will not be plugged into the socket, and thus the appliance will not be grounded. If the appliance is faulty and a live wire touches part of the case housing it, the person using the appliance could receive a severe electrical shock.
7. Students' safety sheets will vary, but might include instructions to avoid too many appliances on the same circuit, to keep appliances away from water, and to repair or discard any loose wires.
8. There is negligible potential difference between the bird's feet, both of which are on the wire. Someone trimming a tree is part of a circuit to the ground, and thus there is a large potential difference and a large current will flow through his or her body.

Section 12.2 Using Electrical Energy Wisely

(Student textbook pages 492 to 500)

Specific Expectations

- **E2.1** use appropriate terminology related to electricity
- **E2.9** determine the energy consumption of various appliances, and calculate their operating costs
- **E2.10** calculate the efficiency of an energy converter
- **E3.1** identify electrical quantities, and list their symbols and their corresponding SI units

In this section, students will examine an energy bill to learn how the utility company charges a client for the use of electricity. They will conduct a personal electrical energy audit to help discover which appliances or devices use most electricity and how they could cut down on their consumption. Students will carry out calculations relating to energy consumption, cost, and electrical efficiency.

Common Misconceptions

- **Some students may believe that transmission lines are insulated (since birds can land on them without being electrocuted), so it is safe to touch them, or—for example—lean a ladder against one when climbing to the roof to cut a tree branch.** This belief is not true; transmission lines are not insulated. Birds are not harmed because they do not represent a path to the ground; however, humans and ladders do. Review with students the concept of grounding.
- **Many students think that when a device is turned off, electricity is not being used.** Unfortunately, this assumption is not true. For many appliances, some part of the appliance or device continues to consume energy when it is turned off. For example, the clock on the DVD player or the remote signal on the TV continues to operate in stand-by mode. This phenomenon, in which energy is still being used when the device is turned off, is called *phantom load.* The only way to completely turn off a device with phantom load is to unplug it.
- **Some students confuse the terms *power* and *energy*, and use them interchangeably.** For example, students may describe the power/energy produced by a generating plant, or the power/energy of the electrical device being used. Have students look up the terms in the glossary to compare their definitions and units of measurement. You might also use an analogy: Power : Energy = Speed : Distance. Both power and speed are rates. To calculate energy or distance, you need to multiply by a unit of time.
- ELL Discuss the concepts of grounding, phantom load, power, and energy with English language learners. Provide examples and non-examples.

Background Knowledge

The amount of electrical energy used in a home depends on three factors: the power rating of the appliance or device; the settings on the appliance or device that are used; and the amount of time the appliance or device is used. Electrical energy is calculated by multiplying the power of the appliance or device (in kW) by the time it is used (in hours). Mathematically, the relationship can be expressed as $E = P \times t$, with energy measured in kilowatt-hours.

Electric meters outside the home keep track of the amount of electricity that enters the home. Every time a load is turned on, current is drawn through the meter. Until recently, about every two months, an employee from the power company would read the numbers on the dial, and determine the electrical energy used during that period. This method is still used in some areas. In many places, the cost for the electricity consumed in Ontario is based on a tiered flat-rate. Customers are charged according to their total electrical energy consumption during the billing period.

By 2010, Ontario power companies plan to have all homes outfitted with smart meters. These meters will be able to record the total electricity used hour-by-hour, and send the information to the utility company automatically. The cost for the electricity will be based on time of use pricing. Customers pay according to *when* they use their electricity during the day. For example, they may pay 4.0¢/kW•h during off-peak hours, 8.8¢/kW•h during on-peak hours, and 7.2¢/kW•h during mid-peak hours.

No electrical device is ever 100 percent efficient. Inevitably, there will be some energy loss (usually in the form of heat) during the energy conversion from electrical energy to the desired form of energy. The efficiency of an electrical device is the ratio of useful energy output to total energy input, expressed as a percentage:

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

Literacy Support

Using the Text

Before Reading

- Have students use questions to focus their thinking about electricity consumption and costs associated with it. Ask students to record their answers to the questions: “How do utility companies determine how much electricity has been consumed?” “How is the cost of electricity calculated?” “How do you calculate the energy used by certain appliances or devices?”
- Bring in a few small appliances (or packaging from appliances or light bulbs) that show the power rating in kilowatts to introduce the vocabulary *electrical power, watt,* and *kilowatt* to students, and to show students where to find this information.

During Reading

- Help students address the questions posed before reading by having them identify the main idea of each section. They must reduce each passage to just 20 words that capture the gist of the text, and include examples or sample problems where appropriate. Refer students to the Identifying the Main Idea and Details strategy in the Study Toolkit appendix on page 561.
- ELL Have English language learners read with a strong English-speaking peer. Invite them to read small chunks of text, use sticky notes to identify words and concepts that they do not understand, and then discuss concepts as they proceed through the passage.

After Reading

- Have students review their notes to identify where electricity is used most and suggest ways to reduce and conserve energy. Allow students to share their responses in a short oral presentation to the rest of the class or in a graphic organizer or graphic poster of their choice.

Using the Images

- Figure 12.8, on page 492, shows a typical electrical energy bill. Have students examine the different columns to familiarize themselves with the information presented to consumers. Explain any vocabulary with which students are not familiar. Ask, “How much energy was consumed during the billing period?” “What charges did the total cost include?”
- Table 12.2, Typical Power Ratings of Appliances (page 493), and Table 12.3, Annual Energy Used for Common Household Appliances in Canadian Homes (page 494), provide information about different appliances in the home. Ask students to compare the two tables: Ask, “How are they different?” “How are they connected to each other?” (Table 12.2, Typical Power Ratings of Appliances, lists the power ratings of different appliances, and Table 12.3, Annual Energy Used for Common Household Appliances in Canadian Homes, lists the annual energy used by the appliances. They are connected by the relationship $E = P \times t$.) Invite students to share information in the tables that surprises them, and to explain where they found that information.

- Figure 12.13, on page 496, shows a graph of the cost of electrical energy at different times of the day. Have students practise extracting information from a graph by asking questions such as, "At what times during the day are the mid-peak hours?"

Assessment FOR Learning

Tool	Evidence of Student Understanding	Supporting Learners
Practice Problems, page 495 Learning Check questions, page 496 Real World Investigation 12-B, An Electrical Energy Audit, page 514	Students explain and calculate the energy consumption and operating costs of various appliances.	Review the mathematical relationships: • $E = P \times t$ • Cost = $E \times 1$ pt unit rate Assign **BLM 12-5 The Price of Electricity,** for extra practice problems.
Practice Problems, page 498	Students calculate the efficiency of an electrical device.	Review the sample problem for calculating percentage efficiency on page 498. Have students make up questions for each other to solve.
Section 12.2 Review questions, page 500	Students list factors that affect energy consumption in the home, calculate the cost of using electricity, and determine the efficiency of an electrical device.	Have students draw a word map to organize information about energy consumption for an "electrical device." Review the relevant mathematical relationships. Have students work in pairs to make up questions for each other to solve.

Instructional Strategies

- Begin this section by asking students to make a list of all the electrical devices that they use at home. Discuss what it would be like if they had lived in the past when there was no electricity. How would they be affected?
  - **ELL** English language learners can draw devices, or name them in their first language, if they do not know the English words for them. Help them to create a glossary of English terms for electrical devices.
- Have students take turns reading aloud the information on pages 492 to 494, about electrical appliances and the factors that affect their total energy consumed. Stop after each subsection to answer any questions, and to clarify concepts.
- Assign Real World Investigation 12-B, An Electrical Energy Audit (page 514), for students to complete at home over the course of one week.
- Examine the energy bill shown in Figure 12.8, on page 492, and focus on how the cost for the electricity is computed. Explain the Sample Problem on page 495 and assign the corresponding Practice Problems.
- For added reinforcement and practice solving problems, assign Data Analysis Investigation 12-C, A "Dry" Investigation, on page 515 of the student textbook.
- Read the information about smart meters and time of use pricing on page 496. What advantage does this type of billing have? (It encourages conservation by making consumers think about the electrical energy they use. It also reduces the need for expensive energy and imported energy, which—as students will learn in Section 12.3—are used to meet peak demands.)
- Preview new vocabulary by writing the terms *phantom load* and *efficiency* on the chalkboard. Ask students to brainstorm what these terms mean. Have students read the explanation on page 497.
- Explain the Sample Problem on page 498, and assign the Practice Problems.
- Have students examine Figure 12.16, on page 499, and rank the types of lighting according to their percent efficiency.

Practice Problems Answers (Student textbook page 495)

1. a. 1.300 kW
   b. 0.060 kW
   c. 0.900 kW
2. a. 0.08 h
   b. 0.33 h
   c. 1.2 h
3. 3.75 kW•h
4. $65.20
5. 4.0 ¢

Learning Check Answers (Student textbook page 496)

1. the power rating, the setting, and the length of time it operates
2. The clothes dryer uses 5.0 kW × 0.5 h = 2.5 kW•h. The freezer uses 0.34 kW × 24 h = 8.2 kW•h. Thus, the freezer uses more energy.
3. A refrigerator with a lower EnerGuide rating will cost less to operate. This factor should be considered along with purchase price, size, and options.
4. Using electricity to operate devices in the home during off-peak hours will reduce the total cost on a family's energy bill.

Practice Problems Answers (Student textbook page 498)

1. 74%
2. 3.64%
3. 3 037 MW
4. 160 kW•h

Section 12.2 Review Answers (Student textbook page 500)

Please see also **BLM 12-6 Section 12.2 Review (Alternative Format).**

1. Power is a rate of energy that, depending on the context, is either produced, supplied, or used per unit of time. Energy is the product of power and time.
2. the power rating, the setting, and the length of time it operates
3. Lighting is required and people are using electrical appliances to cook meals.
4. The answer should mention various phantom loads. In addition, the family will likely leave their refrigerator and freezer running, and they may set lights on a timer.
5. 39%
6. 19.2 watt-hours
7. Record and tally the wattage and the total hours that the lights are being used, and calculate the energy used. Find the cost of the lighting alone, and then express it as a percentage of the total home electricity cost.
8. incandescent: $1.25 + $7.20 = $8.45; compact fluorescent: $4.00 + $12.00 = $16.00
9. You would have had to replace the incandescent bulb seven times (since you cannot buy six light bulbs plus a fraction of a light bulb) to equal the life of the fluorescent bulb. Thus, the total cost of using incandescent bulbs for 10 000 h would be much greater. (Actually, 7 × $1.25 + [6.667 × $7.20] = $56.75)

Section 12.3 Meeting the Demand for Electricity

(Student textbook pages 501 to 505)

Specific Expectations

- **E1.2** assess some of the social, economic, and environmental implications of the production of electrical energy in Canada from renewable and non-renewable sources
- **E2.1** use appropriate terminology related to electricity

In this section, students will examine three ways in which electricity is generated: hydroelectric generation, nuclear power, and the burning of fossil fuels. They will compare the advantages and disadvantages of each form of electricity generation in terms of production costs and environmental impact.

Background Knowledge

Since electricity is a form of energy that cannot be stored, it is a delicate balancing act to ensure that the demand for electricity is always met by the supply. In Ontario, the Independent Electricity System Operator (IESO) manages the generation, transmission, and distribution of electricity.

The three main sources for electricity generation are hydroelectric power, nuclear power, and fossil fuels (coal). The table below summarizes their advantages and disadvantages.

Sources for Electricity Generation	Advantages	Disadvantages
Hydroelectric power • capacity to supply 21 percent of province's demand for electricity	• no fuel costs and no combustion emissions • low operating costs • process is about 90 percent efficient • hydroelectric generators can be brought on line quickly to meet peak-load demands	• large areas of land are flooded to create reservoirs • submerged vegetation decays, producing methane and releasing mercury
Nuclear power • capacity to generate 51 percent of province's demand for electricity	• produces great amounts of energy but no greenhouse gases • relatively inexpensive; suitable to meet base-load demand • small amount of nuclear fuel can replace huge amount of fossil fuel	• high cost to build • highly radioactive waste must be properly stored • cooling water discharged into the lake raises temperature of water
Fossil fuels	• coal is an inexpensive energy source • can be brought on line more quickly than nuclear, so it is used to meet intermediate load demands	• produces carbon dioxide, a greenhouse gas • produces emissions of other gases that contribute to acid rain • about 70 percent of the energy is lost as heat by the time it reaches the customer

Literacy Support

Using the Text

Before Reading

- ELL Provide a graphic organizer such as a main idea web to explain the purpose of the section and to keep students focussed on the big idea. See **BLM G-36 Main Idea Web.**

- Have students divide their note paper into three horizontal sections: Hydroelectric Power; Nuclear Power; Fossil Fuels (Coal). Have students look for these key ideas by scanning the headings and highlighted terms in the textbook. Ask students to find and copy the definitions for each of the three headings. (Although the definition for *hydroelectric* is in a marginal box, students will have to look carefully for the others.)
- ELL Preview the terms *peak load* and *base load* by finding other uses of the words *peak* and *base* in English. Have students predict what they might mean in this context.

During Reading

- Students should ask themselves the following questions: "How is electricity generated from each of these sources?" "What are the advantages and disadvantages of this type of power generation?" Have students try to find the answers as they read. Refer students to the Asking Questions strategy in the Study Toolkit appendix on page 561 of the student textbook.

After Reading

- Have students summarize their answers to the questions above under each of the three headings.
- ELL English language learners can make point-form notes for each section.
- DI To help students who have difficulty organizing written answers, you could provide **BLM 12-7 Comparing Sources of Electricity Generation,** for them to complete.

Using the Images

- Figure 12.17, on page 501, includes a graph and a pie chart. Have students examine the data displayed, and ask questions to help students with their skills in reading graphs and charts. For example, for the graph, ask them the following questions: "What amount of energy is the projected peak demand?" (about 20 000 MW) "At what time was the least amount of energy consumed during that day?" (at about 4:00 A.M.) "Between 1:00 P.M. and 2:00 P.M. on November 20, how much electricity from hydroelectric sources was used, compared to electricity from nuclear sources?" (Answer: less than half) "What does each graph show that the others do not?"
- Have students examine Figure 12.18, Figure 12.19, and Figure 12.20, on pages 502 to 504, simultaneously to compare the three different generating stations. In pairs, have students discuss the diagrams and answer these questions: "What parts of the processes are similar?" "What parts are different?" Students could organize their responses in a Venn diagram. See **BLM G-39 Venn Diagram.**

Assessment FOR Learning		
Tool	**Evidence of Student Understanding**	**Supporting Learners**
Section 12.3 Review questions, page 505	Students understand base load, intermediate load, and peak load. Students can describe the advantages and disadvantages associated with the three methods of generating electricity.	Have students create a table. They can label three rows *base load, intermediate load,* and *peak load;* label two columns *causes* and *fuels;* then refer to the textbook to help them find information for each cell. English language learners can be paired with students who have strong language skills.

Instructional Strategies

- Have students write the following three terms in their notebook: *base load, intermediate load*, and *peak load.* Discuss what each term might mean in the context of electricity. Ask students to write a sentence or two to differentiate these terms as they read the textbook. Use an analogy to help them understand the concepts. If your community has a public transit system, the buses that run all day could represent base load, and the transit company adding more buses at rush hour could represent peak load.
- Draw a table on the chalkboard with the headings: *Source of Electricity Generation, Advantages,* and *Disadvantages.* Have students copy the table into their notes, and list the three sources in the first column: *hydroelectric power, nuclear power,* and *coal.* Have students read and summarize the information on pages 502 to 504 to fill in the table.
- Enrichment—Use **BLM 12-8 Become an Energy Consultant,** to become an expert on a specific method used to generate electricity. To complete the worksheet, English language learners can be paired with students who have strong language skills.

Section 12.3 Review Answers (Student textbook page 505)

Please see also **BLM 12-9 Section 12.3 Review (Alternative Format).**

1. **a.** Base load is the continuous minimum demand for electrical power.
   b. On holidays and weekends, most industries and businesses are closed, so the minimum amount of electrical power is generated.
2. They use the least expensive fuel, making them ideal for base load. They can be brought on line, or taken off line, quickly, which is very desirable for peak load generation.
3. Saskatchewan has good supplies of fossil fuel, especially coal. Other reasons why Saskatchewan does not have a nuclear plant may be the large costs required to construct a nuclear plant.
4. nuclear, 50.2%; hydro, 21.9%; gas, 13.3%; coal, 12.3%; wind, 0.6%, and other, 1.8% (because of rounding, the total is 100.1%).
5. Pumping water into a dam reservoir is done to raise the height of water in the dam, essentially saving the energy that can be supplied later, when demand increases.
6. **a.** least effect on the environment: hydroelectric, because the fuel is renewable
   b. greatest effect: either nuclear or fossil fuel; Students may argue for nuclear because the products are radioactive for a long time. They may argue for fossil fuels because of the emission of carbon dioxide and gases that cause acid rain.
7. Base load is likely to increase the most as people recharge batteries overnight.
8. The data given in Figure 12.13 and Figure 12.17, on pages 496 and 501, show that mid-peak rates are for 11:00 A.M. to 5:00 P.M., and 8:00 P.M. to 10:00 P.M. During those intervals, the load is projected to be roughly 18 500 MW to 20 000 MW.

Section 12.4 Renewable Sources of Electricity

(Student textbook pages 506 to 512)

In this section, students will study the different renewable sources of energy and propose how electrical energy can be conserved. By completing Plan Your Own Investigation 12-D, Every Kilowatt Counts (student textbook page 516), students will develop a plan for action that will help reduce their family's electricity bill.

Specific Expectations

- **E1.2** assess some of the social, economic, and environmental implications of the production of electrical energy in Canada from renewable and non-renewable sources
- **E1.3** produce a plan of action to reduce electrical energy consumption at home, and outline the roles and responsibilities of various groups in this endeavour
- **E2.1** use appropriate terminology related to electricity

Common Misconceptions

- **Students may believe that renewable sources of energy have no environmental impact.** This belief is not the case. Renewable sources of energy have a much smaller impact than other sources, but energy from wind can be dangerous to birds, energy from biomass adds carbon dioxide to the atmosphere, and all sources of energy require the production and transportation of components to function.

Background Knowledge

Generating electricity from renewable energy sources (instead of fossil fuels or nuclear power) has a significant positive impact on the environment. The emission of air pollutants is reduced, and the need to spend money and energy to extract fuels from the ground, as well as transport and lay pipelines, is reduced or eliminated. Below is a short summary of each source of renewable energy. You might provide English language learners with a version of this table to use as a guide for this section.

Renewable Energy Sources used for Generating Electricity	How Does It Generate Electricity?	Disadvantages or Limitations
Wind energy	Blades on a wind turbine turn when the wind is blowing, and drive a generator that produces electricity. Wind speeds must be maintained between 13 km/h and 55 km/h.	• lack of reliability, since wind speed at any location could change throughout the day • wind turbines can spoil the view and the rotating blades create a lot of noise • rotating blades are a danger to birds
Solar energy	Sunlight can be used to heat water to create steam, which powers turbines that generate electricity. Also, photovoltaic cells, or solar cells, can convert sunlight directly to electricity by generating a direct current.	• electricity cannot be produced when the Sun is not shining • solar cells are about 33 percent efficient • solar cells generate DC, which must be stored in batteries for use at night or on cloudy days, and special electronics are required to convert DC to AC • photovoltaic cells are relatively expensive
Biomass energy	Biomass fuels (plant and animal matter) can be burned to generate electricity.	• combustion process adds carbon dioxide to the atmosphere • large supply of biomass fuels is not readily available for use
Ocean energy	The rise and fall of ocean waves is used to compress an air column. The compression and release of air pressure drives a turbine connected to a generator.	• needs access to consistently strong waves • equipment must withstand salt water and rough conditions • could alter sediment flow patterns on the ocean floor
Tidal energy	Water is trapped in a basin at high tide. When the tide retreats, the water level lowers, and as the water leaves the basin, it turns turbines.	• tides vary on a 15-day cycle according to the movement of the Moon around Earth and Earth's rotation • electricity can be generated only for about 10 hours each day, as the tide moves in or out
Geothermal energy	The steam and hot water trapped in reservoirs below Earth's surface are pumped to the surface to turn turbines that generate electricity.	• can be accessed only in areas where the steam or hot water sources are relatively close to Earth's surface • sometimes the water contains pollutants that need to be removed before it is used in a power plant

Literacy Support

Using the Text

Before Reading

- Preview vocabulary by having students draw a word map to organize information related to the word *renewable.*

During Reading

- Ask students to identify the main idea for each of the renewable energy sources. For each section, have students analyze the text and summarize the key ideas. They must reduce the passage to just 20 words that capture the gist of the text, and include diagrams where appropriate. English language learners can make point-form notes for each section.
- ELL Provide scaffolds for English language learners. For example, distribute a paragraph with the key concepts left out, and have students find the missing words as they read. (For example, When wind turbines are installed and connected, the __________ of running them is very _________.) Or, rewrite the paragraph with the key concepts bolded. (For example, **Ocean waves** can be used to generate **electricity**.) Explain that in the English language, words are sometimes added to give more description or to give examples, but that when students are reading, they should pick out the main ideas, and leave out the extra words. (For example, **A single turbine,** which may supply electricity to a farm, home, or small business, **operates** in much **the same way**. → A single turbine operates the same way.)

After Reading

- Have students review their notes and choose two facts that they found the most interesting. Ask them to write a paragraph to explain why these ideas caught their interest, and to ask questions that they would be able to answer with further research.
  - ELL Instead of writing a paragraph, English language learners can list three questions for each of the facts that they would like to learn more about.

Using the Images

- As students read How Wind Turbines Work, on page 507, have them follow the explanation by looking at Figure 12.22, on page 507, which shows the parts of a wind turbine.
- Ask students to look at Figure 12.23, on page 509. Where have they seen solar cells in use? Have them compare this parking meter to other objects that rely on solar cells, such as solar-powered calculators or solar-panel homes.

Assessment FOR Learning

Tool	Evidence of Student Understanding	Supporting Learners
Plan Your Own Investigation 12-D, Every Kilowatt Counts, page 516	Students suggest ways in which electrical energy can be conserved, and develop a plan of action to save electricity at home.	Assign **BLM 12-10 Conserving Energy,** or **BLM 12-11 Conserving Energy (Alternative Version),** which helps students focus on certain areas in the home where electricity can be conserved. Read the instructions with English language learners to ensure they understand what to do. English language learners could conduct research in their first language.
Section 12.4 Review questions, page 512	Students describe some of the social, economic, and environmental impacts of using renewable energy sources to generate electricity.	Refer students to Study Toolkit 4, Organize Your Learning: Using Graphic Organizers on page 566 of the student textbook. Have students review their notes and complete a summary table with the following headings: renewable energy source; social impact; economic impact; and environmental impact. **BLM 12-12 Impacts of Renewable Energy,** provides a template for such a table.

Instructional Strategies

- Ask students when they have used renewable energy. If necessary, guide the resulting discussion to include solar calculators, Ontario's electricity grid (some of which is from renewable energy), riding a bicycle, buses that use biofuels, and other areas.
- Have confident readers take turns reading aloud the information about the different types of renewable energy. Ask students to make summary notes for each heading. English language learners can make point-form notes instead of writing complete sentences.
- Energy conservation should be a collective effort between individuals, utility companies, and the government. On page 511, some of the actions taken by the Ontario government toward conserving electrical energy are described. Make a list of the incentive programs and/or legislated regulations that are mentioned, and add any that students can think of. Divide students into small groups and assign one incentive or regulation to each group. Then ask each group to conduct further research about their incentive or regulation. Have students prepare a short presentation to share their research. See **BLM G-12 Scientific Research Planner;** and **BLM G-13 Research Worksheet.**
  - ELL Provide English language learners with the opportunity to rehearse before presenting, or to share their research with one group rather than with the whole class.
- Assign Plan Your Own Investigation 12-D, Every Kilowatt Counts, on page 516 of the student textbook.
- The Case Study on pages 508 and 509 provides a review of what students have learned about electricity generation and use in Ontario.

Section 12.4 Review Answers (Student textbook page 512)

Please see also **BLM 12-13 Section 12.4 Review (Alternative Format).**

1. Renewable energy sources, such as wind, solar, hydro, and so on, can be replaced within a relatively short time. Non-renewable energy sources, such as fossil and nuclear fuels, are not replenished in a reasonable time, if at all.
2. The controller has two functions: (1) It activates a brake to shut down the turbine when the wind speed reaches 90 km/h or more; (2) It contains circuits that maintain output from the generator at 60 cycles a second alternating current.
3. Photovoltaic cells use a renewable source of energy. However, they are expensive, and they supply energy only while the Sun is shining.
4. The home or business is probably far from transmission lines, and connecting to the grid would be expensive.
5. The energy received in space is greater than on Earth's surface. Also, the energy received is almost constant, and does not go through daily or seasonal variations.
6. Biomass combustion returns only as much carbon dioxide to the atmosphere as was absorbed during the plants' growth.
7. Students' answers will vary. Most utilities offer energy-saving tips on their website or in brochures. Currently, refrigerator removal plans and peaksaver® incentives are offered in many regions. Some utilities offer coupons for fluorescent bulbs.
8. There is a large natural basin and very large tides that can be used to drive turbines.

Technology Investigation 12-A Designing a Staircase Circuit

(Student textbook page 513)

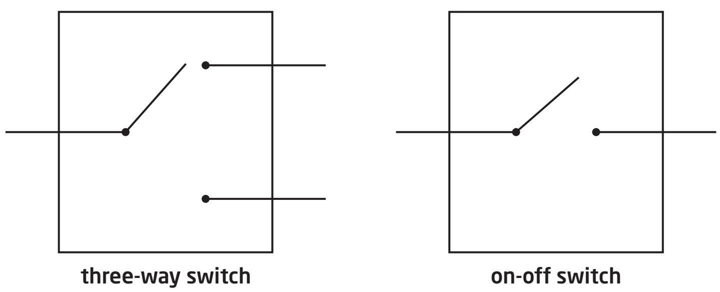
Pedagogical Purpose

The purpose of this investigation is for students to design and build a circuit that will allow a single light to be turned on and off by operating either of two switches. Students will need to apply their technological problem-solving skills to create a circuit that meets the specified criteria.

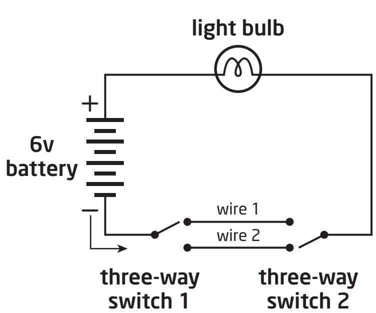
Planning	
Materials	Battery (6 V) Connecting wires Flashlight bulb in holder 2 three-connection switches **BLM 12-14 Technology Investigation 12-A, Designing a Staircase Circuit** (optional) • Gather the materials a few days before the activity.
Time	Approximately 30 min in class
Safety	• If any wire becomes hot, students should disconnect it immediately.

Background

Three-connection switches, or three-way switches, have three connected terminals inside them, instead of the usual two terminals found in a regular on-off switch. When the three-connection switch is in one position, it connects to a wire. When it is in the other position, it connects to a different wire. See the diagram below:



Two three-connection switches can be connected in the same circuit so that when the light is off, either switch can turn it on. When the light is on, either switch can turn it off. The circuit diagram below shows the typical way in which two three-connection switches are connected to achieve the desired function.



The bulb goes on when both switches are in the top positions, or when both are in the bottom positions. The bulb goes off when the switches are at opposite terminals.

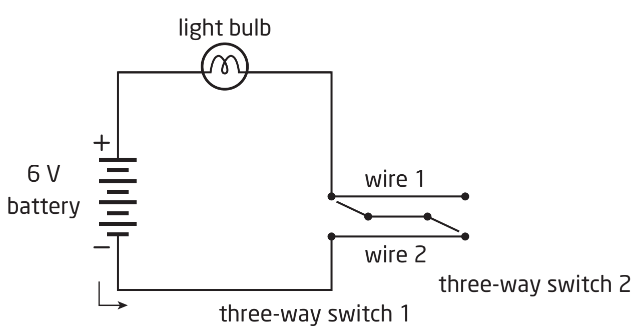
A practical application of this kind of circuit is to control a staircase light with switches at the top and bottom of the staircase. The light can be turned on at the bottom of the staircase and can be turned off using the switch upstairs.

Activity Notes and Troubleshooting

- Refer to Science Toolkit Skill 3, Technological Problem Solving, on page 536 of the student textbook; **BLM G-10 Technological Problem-Solving Organizer;** and/or **BLM A-36 Problem-Solving Process Skills Rubric,** to review, or teach, students the process of Technological Problem-Solving.
- Not all students will have experience with staircase switches. Use the illustration on page 513 to explain their function.
- Ask students to keep all their rough ideas and sketches together, as they will be asked to assess why earlier circuit designs did not work.
- You may decide to hand out the circuit-building materials after students have shown you their work. Emphasize to students the importance of planning and analyzing their circuit designs before they begin constructing and testing.
- When students demonstrate the circuit that they have constructed, each group member should be prepared to explain how the two three-connection switches control the current flowing through the circuit.

Additional Support

- Students should work in small groups of three or four. After brainstorming ideas together, each group member can be assigned a task, according to their strengths: drawing the circuit diagram, building and testing the circuit, and explaining to the class how it works. Everyone in the group should be able to explain how the circuit works.
- Enrichment—Have students try to design other ways in which the two three-connection switches can be connected to operate the light bulb. The circuit below, for example, uses six connecting wires. The light bulb goes on when switch 1 and switch 2 are at opposite terminals. (Note how this result is different from the working mechanism of the circuit described earlier in the Background Information.) Students could also design a circuit for more than two light bulbs.



Answers

Evaluate

1. If students' circuits did not work properly, they should include an explanation of why they did not.
2. An electrician would trip the appropriate circuit breaker or remove the fuse to the circuit being worked on.

Real World Investigation 12-B An Electrical Energy Audit

(Student textbook page 514)

Pedagogical Purpose

The purpose of this investigation is for students to write an electrical energy audit to monitor the energy that their family uses in one week. Students will record the data in table format, and analyze the results to compare the total energy used to operate different appliances or devices in their home. A personal energy audit will help students realize where most energy is used and where they can make changes to conserve energy.

Planning	
Materials	**BLM 12-15 Real World Investigation 12-B, An Electrical Energy Audit** (optional) **BLM G-23 Data Table** (optional) **BLM A-28 Real World Investigation Rubric** (optional)
Time	Approximately 15 min in class to explain the investigation and have students set up the data table. Students will monitor their energy consumption at home for one week. Approximately 25 min in class to complete and discuss the activity.
Safety	Remind students that electricity is flowing through the appliances they will be including in their audit. If they need to touch them, they must do so carefully.

Background

An electrical energy audit is a tally of all the electricity used in a home for a specified period of time. It provides a record of how much electricity is used by every electrical device. An analysis of the data will show where electricity is used most, and the information can be used to propose ways to conserve some of the energy.

Students' audits will be partial, since they will not be able to include some energy uses (such as the furnace fan) and some appliances used when the student is not home.

Activity Notes and Troubleshooting

- Refer to Science Skills Toolkit 7, Creating a Data Table, on page 545 of the student textbook, to review for, or teach, students how to create data tables.
- In order for students to complete the "Time on" and "Time off" columns of the table, they will need to list the name of the appliance or device in the first column *as it is being used*. That is, some devices like the television, which is probably used several times throughout the week, will be listed several times on the table. Alternatively, the headings could be changed to "Average Time on in a Day (h)" and "Number of Days on." Then the appliance or device only needs to be listed once in the table.
- Review with students how to calculate some of the information needed to complete the columns in the table. Specifically,
  1 kW = 1000 W
  Energy Used (kW•h) = Power (kW) × Time Used (h)
  Students can record these equations on the back of their data tables for reference.
- It may be a good idea to complete a sample set of data with students on the chalkboard. For example, show them how to calculate the total energy used when an LCD television with a power rating of 120 W is turned on from 7:00 P.M. to 9:00 P.M. (120 W = 0.12 kW; Time used = 2 h; Energy = Power × Time = 0.12 kW × 2 h = 0.24 kW•h)
- You can guide and assess students' work using **BLM A-XX Real World Investigation Rubric.** Distribute the rubric to students before they begin to plan their investigation.

Additional Support

- Some students may not have access to their family's electrical meter reading. It is still worthwhile for them to record energy use for a week. They will not, however, be able to complete steps 1 and 5. Discuss the results of these steps as a class so that all students have the opportunity to consider reasons for discrepancies.
- Students may choose to keep a record of their energy consumption on a spreadsheet, and set up formulas in the spreadsheet to calculate the total energy used for each particular appliance or device.
- ELL It may be easier for English language learners to record energy use in their first language, or to list only the top 10 appliances or devices that are regularly used at home. Some English language learners may be living in conditions with limited access to appliances or devices. Consider partnering these students with students who do have access to these appliances or devices, or providing a sample audit (of the classroom or school library).
- Students with recording or mathematics difficulties may also find the investigation more accessible if they keep track of only the top 10 appliances.
- Enrichment—Ask students to draw a bar graph or pie chart to display their family's energy consumption. Refer to Math Skills Toolkit 3, Organizing and Communicating Scientific Results with Graphs, on page 557 of the student textbook.

Answers

Conclude and Communicate

5. This answer will change with the seasons. In the summer, air conditioning may consume the greatest amount of energy. In the winter, electrical heating (if used) is likely to consume the greatest amount of energy. Refrigerators and freezers are on all the time, and are likely to be in the top six. Clothes dryers also consume a lot of energy.

6. The list is likely to include incandescent bulbs and an older refrigerator, a freezer, or a stove.

Extend Your Inquiry and Research Skills

7. Students can visit **www.scienceontario.ca** for information on time of use prices in Ontario that were in effect during their audit.

Data Analysis Investigation 12-C A "Dry" Investigation

(Student textbook page 515)

Pedagogical Purpose

In this investigation, students analyze a set of data and perform calculations related to energy use to determine whether paper towels or hot-air hand dryers are the better choice for drying their hands. Students must factor in financial and environmental considerations in their decision.

Planning	
Materials	Calculator **BLM 12-16 Data Analysis Investigation 12-C, A "Dry" Investigation** (optional) **BLM A-29 Data Analysis Investigation Rubric** (optional) **BLM A-5 Investigating an Issue Checklist** (optional)
Time	Approximately 40 min in class

Background

Many individuals and organizations today try to make a "greener" choice when it comes to purchasing products. They weigh the financial cost of the product with the environmental impact it has during its manufacturing process, usage, and disposal. Making the decision to use either hot-air hand dryers or paper towels is one example of making a greener choice.

Activity Notes and Troubleshooting

- One day before the investigation, remind students to bring in their calculators. Students may work individually or in pairs.
  - **ELL** Some English language learners may not have a calculator. These students can work with partners who do have calculators, or borrow some from a classroom that has calculators.
- Review with students the necessary mathematical relationships that are required to answer the questions. (See Sample Problem: Cost of Using a Hair Dryer, on page 495.) Remind students to show all their work.
- Refer to Math Skills Toolkit 2, Significant Digits and Rounding, on page 556 of the student textbook, to review, or teach students about, rounding and significant digits.
- You can guide and assess students' work using **BLM A-29 Data Analysis Investigation Rubric.** Distribute the rubric before students begin their investigation.

Additional Support

- Students with weak skills in mathematics could be partnered with students who could help guide them through the questions.
- For a mathematical exercise, have students calculate and compare the costs for one drying usage by each method.

  Cost for using a hand dryer for 30 s
  = energy used × rate
  = (power rating × time used) × rate
  = (1.5 kW × 0.5 min/60 min/h) × \$0.08/ kW•h
  = \$0.001;
  Cost for using 2 sheets of paper towel
  = cost per sheet × 2 sheets
  = (\$30/case ÷ 4000 sheets/case) × 2 sheets
  = \$0.015]

- Enrichment—Ask students to consider the environmental impact of the use of paper towels and that of hot-air hand dryers. Financially, it is clear that the paper towels cost more than electric hand dryers, but it is not so clear when it comes to the environmental impact. Trees have to be cut and manufactured to make paper towels, and in the end, the paper towels are sent to a landfill. Carbon dioxide is emitted by generating electricity for the hand dryers. Ask, "Which is worse for our environment?" Have students write one or two paragraphs to explain their choice. You can use **BLM A-5 Investigating an Issue Checklist,** to guide students' work.
  - ELL Some English language learners may not have learned to express an opinion in writing. Consider creating a table with the following headings: Pros, Cons, and Impacts. Have English language learners use the table to express their opinion, rather than writing a paragraph.

Answers

Analyze and Interpret

1. **a.** 1500 × 4 × 2 × 200 = 2 400 000 sheets (2.4 million)
   b. 2 400 000 sheets/4000 sheets/case = 600 cases
   c. 600 × 10 kg = 6000 kg (6 tonnes)
   d. 600 × $30 = $18 000
   e. 16 × $25 = $400
2. **a.** 0.5 min × 1500 × 4 × 200 = 600 000 min/60 min/h = 10 000 h
   b. 1.5 kW × 10 000 h = 15 000 kW•h
   c. 15 000 × $0.08 = $1200
   d. 16 × $80 = $1280
3. **a.** 8760 × 16 = 140 160 h
   b. 140 160 – 10 000 = 130 160 h
   c. 0.002 kW × 130 160 h = 260 kW•h
   d. 260 kW•h × $0.08 = $20.80

Conclude and Communicate

4. The electric hand dryers are much less expensive. Students may or may not include the costs of installing towel holders and hand dryers, since each should last many years.

Extend Your Inquiry and Research Skills

5. Total electrical energy used = 15 000 + 260 = 15 260 kW•h.
   Thus, about 15 260 × 0.5 = 7630 kg of CO_2 is emitted. This result compares with the 6000 kg of paper towels sent to the landfill. In addition, fuel is used to manufacture and transport the paper towels.

Plan Your Own Investigation 12-D, Every Kilowatt Counts

(Student textbook page 516)

Pedagogical Purpose

In this investigation, students apply what they have learned about electricity and its costs to develop a plan that will help reduce their family's electricity costs.

Planning	
Materials	Copy of a recent electricity bill Computer and spreadsheet program **BLM 12-17 Plan Your Own Investigation 12-D, Every Kilowatt Counts** (optional) **BLM A-27 Plan Your Own Investigation Rubric** (optional)
Time	Approximately 30 min in class, plus time at home for research

Background

There are different ways in which a typical family can conserve energy and reduce their electricity costs. For example, they can use energy efficient (Energy-Star rated) appliances, they can reduce phantom loads by unplugging appliances that are not being used, they can choose efficient settings on their appliances, they can turn off lights when they are not needed, and they can use devices less often or during off peak hours.

Activity Notes and Troubleshooting

- In order to complete this investigation, students must have already completed Data Analysis Investigation 12-B, An Electrical Energy Audit, on page 514.
- In Plan and Conduct step 4, students are asked to gather information from their family's utility company and the Internet. You may decide to book the computer room in advance for students to do part of their research at school.
- You can assess students' work using **BLM A-27 Plan Your Own Investigation Rubric.** Distribute the rubric before students begin to plan their investigation.

Additional Support

- ELL English language learners should be paired with students who have strong language skills. Pairs could select one family's data to work with.
- Enrichment—Students to design a home that is self-sufficient in terms of energy, water use, and waste management, by using **BLM 12-18 The Self-sufficient Home.**

Answers

Analyze and Interpret

1. examples: running the dishwasher in the evening, doing laundry on the weekend, running the air conditioner at mid- or off-peak times
2. Students can multiply their family's savings by 4.6 million.

Conclude and Communicate

3. Students should include things they did well, things they would improve next time, and how they would improve those.

Extend Your Inquiry and Research Skills

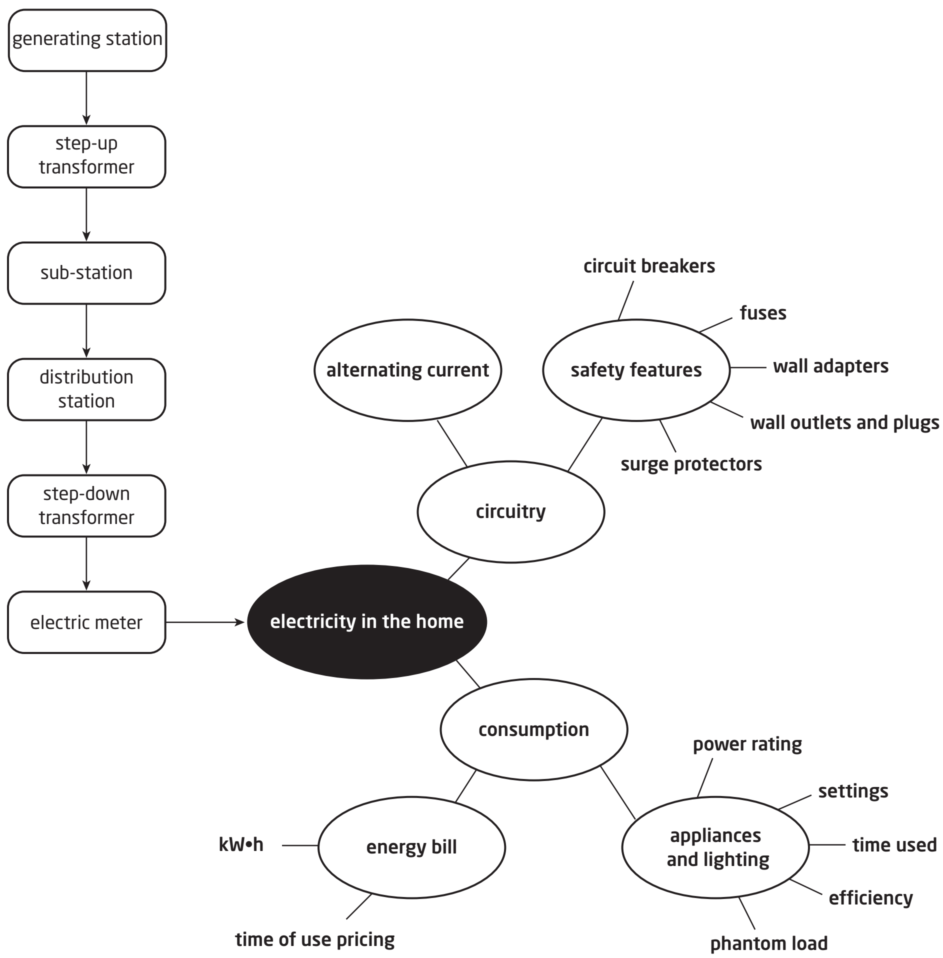
4. Students can divide the reduction by 500 MW to find how many medium-sized generating stations could potentially be shut down.

Chapter Review (Student textbook pages 518 and 519)

Please see also **BLM 12-19 Chapter 12 Review (Alternative Format).**

Make Your Own Summary

A concept map can be used to summarize information in Sections 12.1 and 12.2:



A table can be used to describe the different energy sources that are used to generate electricity:

Non-renewable Energy Sources	Renewable Energy Sources
Nuclear power • Heat from nuclear reactions generates steam, which turns turbines that are connected to generators.	Hydroelectric power • Water in a dam falls and turns turbines connected to large generators.
	Wind energy • Wind turbines drive generators.
	Solar energy • Photovoltaic cells collect and convert sunlight to electricity.
Fossil fuels (coal) • Heat from burning coal is used to boil water and create steam, which turns turbines connected to generators.	Biomass Energy • Plant and energy matter are burned to generate electricity.
	Wave energy and tidal energy • Movement of water in the ocean is used to turn turbines.
	Geothermal energy • Steam and hot water are harnessed from under Earth’s surface to turn turbines.

Reviewing Key Terms

Definitions	Terms
1. technology that is used to change the voltage of an alternating current	transformer
2. device that is used to protect a circuit by opening a switch when the current exceeds a safe maximum value	circuit breaker
3. the practical unit of electrical energy	kW•h
4. something that helps you choose a new electric washing machine	EnerGuide label
5. the clock on an electric coffee maker	phantom load
6. a demand that is met using fossil-fuel-burning generators, which can be turned on and off quickly	intermediate load
7. a renewable source of energy that involves the indirect conversion of energy from the Sun	biomass energy
8. its practical unit is the kW	electrical power

Knowledge and Understanding

9. Although there is no net movement of the electrons, the effect is like moving one object back and forth over another object that is stationary. Some of the energy causing the back and forth movement is transferred to the stationary object.

10. Electrical energy is sent through transmission wires at high potential difference to reduce energy losses. Transformers, which only operate with alternating current, can easily change the potential difference of an alternating current.

11. The larger, left slot is "neutral," the right slot is "live," and the round hole is "ground."

12. $20.40

13. Burning fuel and forming steam are the least efficient processes.

14. Both allow the insertion of a number of plugs, and all the appliances connected can be turned on or off using a single switch. A surge protector will detect a current that exceeds a pre-set maximum and send it to the ground, protecting the appliances.

15. The connection to a circuit breaker is in series, so when the breaker trips, it stops all current in the circuit it protects.

16. The Moon generates tides due to gravitational forces. The Sun contributes to tidal energy, but contributes much more to wave action by heating the atmosphere.

17. the size and efficiency of the panel; location; weather; seasonal and day-night cycles

18. fossil fuels, especially coal

Thinking and Investigation

19. 22%

20. 7.2 kW

21. Students' answers should include some of the following ideas: Wind, ocean wave, tidal, and geothermal energy all use turbines to generate power. Burning plant matter at biomass stations results in much less acid rain than burning fossil fuels, and no emissions of heavy metals. Hydroelectric power produces no combustion emissions, and is very efficient, but large areas of land need to be flooded. Nuclear fuel produces a lot of energy, and no greenhouse gas emissions, but it also produces uranium, which is difficult to store safely, and uranium-mining operations damage the environment. Wind and solar energy depend on weather and seasonal patterns, and are not very efficient.

22. **a.** A solar plant would have to occupy a much larger area of land compared with a wind farm generating the same amount of energy. Also, the environmental cost of manufacturing solar cells is greater than the environmental cost of manufacturing wind turbines.

b. There are different types of reactors with various advantages and disadvantages. In general, nuclear power plants are expensive to build, especially if the cost includes research and development. The construction cost becomes more competitive if it takes into account how long the plant operates. The operating costs of a nuclear plant are relatively low. Waste disposal costs can only be estimated, because radioactive waste is currently stored on site at power plants. Long-term disposal is still in the research stage. Even more difficult to estimate are the costs of closing down a nuclear reactor, because none have yet been closed in Canada.

23. Base load generation is required, especially at night, when the electric vehicles are recharged. The need for base load generation makes wind and nuclear generating plants the most probable choices.

Communication

24. Incandescent bulbs convert only 5 to 8 percent of electrical energy into visible light, and the rest is converted into heat. Lights are often placed in locations that are less than ideal as a heat source, such as close to the ceiling, so this heat is lost. Finally, electrical energy use is often high during the summer months when air conditioners are operating, and any extra source of heat should be reduced.

25. Wind energy and solar energy are each unreliable, due to daily and seasonable changes. Ocean energy is predictable but varies with the tides. Both wind and solar energy would require large areas of land to be used. Solar panels are expensive. Harvesting solar energy in Ontario can also pose problems because the average energy at Earth's surface is between 3.3 and 5.0 $kW \bullet h/m^2$ in Ontario. Energy could be transmitted from other regions, such as the Bay of Fundy area, if ocean energy were developed there.

26. The slogan makes the point that each kilowatt of electrical energy used has an associated cost. When consumers use less electricity, they will have a smaller energy bill. Reducing electrical energy results in less stress to the environment in terms of fuel mined and used, emissions released into the atmosphere, and solid waste.

27. Static charges tend to stay in one location, and thus the energy present in a static charge is not transferred around a circuit. The applications of static electricity make use of the attraction or repulsion between one or more charged surfaces. Electric current transfers energy through a conducting circuit. The transfer of energy can take place as long as there is a circuit present and a source of electrical energy.

28. Electricians' work generally falls into one of three categories: industrial and commercial, residential, or utility line work. In Ontario, electricians must complete an apprenticeship. The usual entrance requirement is Grade 12 with courses in Math, English, and Physics.

Application

29. More transmission lines could be constructed, or the existing lines could be increased in voltage to 700 kV.

30. A higher-rated fuse will allow more than 15 A current, which is the maximum safe current in most household circuits. The higher current could result in a fire.

31. Students may mention wind power, especially on the Great Lakes, and nuclear, because of our high base-load demand and the lack of greenhouse gases produced.

Unit 4 Projects

Inquiry Investigation
Designing an Electrical Makeover (Student textbook page 522)

Pedagogical Purpose

This investigation allows students to redesign a room in their home to become more "green," by using less electrical energy. Students first analyze the electricity usage in the room, then consider strategies they can use to reduce the amount of current drawn for the room (for example, type of lighting used, use of energy-efficient devices, and so on). Students must draw a schematic diagram of their design, and give an explanation of their electrical plan.

This project is an opportunity for students to demonstrate the understandings and skills they have developed in this unit about current electricity and energy consumption.

Planning	
Materials	Circuit board Circuit components (bulbs and resistors) Wires Cell or battery **BLM 12-20 Inquiry Investigation, Designing an Electrical Makeover** (optional) **BLM A-50 Unit 4 Inquiry Investigation Rubric** (optional) • Ensure there are ample materials for students to build their circuit models.
Time	10–15 min to examine the original electrical plan of two rooms in their home (could be assigned as homework) • 15–20 min to draw a schematic diagram of the circuitry in the two rooms, and to build and test a circuit board that models the wiring in the two rooms • 15–20 min to alter the design of the room so it will use less electricity, and to draw a new schematic diagram (could be assigned as homework) • 1 period to prepare presentation, and 1 period for all students to present their findings
Safety	Students should use caution when constructing their circuit boards. If a wire becomes hot, disconnect the cell or battery immediately.

Background

In the technological world we live in, the choices and actions we make can have direct impacts on the environment. Many of the devices we use in our daily lives require electrical energy. The production of electricity from coal-burning power plants adds pollutants into the air. So the amount of electricity we use, and how it is generated (renewable versus non-renewable energy source) are important factors we should consider to help keep our environment clean. Being energy-conscientious and living green are important for everyone living on Earth.

Activity Notes and Troubleshooting

- Steps 1, 2, 3, and 5 of the investigation require students to examine the electrical devices in two rooms in their home and to draw schematic diagrams of the circuitry. This part of the investigation can be assigned as homework, and Perform and Record step 4 can be carried out in the classroom.

- Students are asked to draw schematic diagrams to show how the devices are connected in a circuit. For reference or review, refer students to Sections 11.3 and 11.5 in the student textbook, which describe what different circuits look like and which list the symbols used to represent electrical components. Students can also refer to Science Skills Toolkit 9, Using Electric Circuit Symbols and Meters, on page 548 of the student textbook.
- The assessment criteria are printed in the student textbook. Make sure students understand what is required of them, and refer to the list or to **BLM 12-21 Inquiry Investigation, Designing an Electrical Makeover Rubric,** as they conduct their investigation and plan their presentation.
- In order to complete Analyze and Interpret question 3, students will need to include at least one room that has appliances with phantom loads.
- Some modifications to the investigation may need to be made:
    - In many homes, the electrical loads in any room will not be on their own circuit. Many rooms will include parts of two or more circuits. Students can create part circuits on their circuit board to show this.
    - Apartment dwellers may not have access to the fuses or circuit breakers for their home. These students can calculate the maximum draw in each room based on information on the back or bottom of each load, instead of referring to fuses or circuit breakers. Other students, including those whose homes include rooms without their own unique circuit, could also do this.

Additional Support

- DI This investigation will appeal to spatial learners and those students with problem-solving skills. Students who have difficulty drawing the schematic diagrams or building a circuit board that models the wiring in each room should be encouraged to draw a room plan first, showing the actual devices and their connection to the electrical sockets around the room. Then, as students begin to analyze the circuitry, they can ask themselves the following questions to guide them in the right direction:
    - How many devices and switches are there?
    - Which devices are connected in a series circuit?
    - Which devices are connected in a parallel circuit?
- Students who have attention or organizational difficulties may be overwhelmed by the number of tasks to complete in the project (that is, drawing schematic diagrams, designing and building a circuit board, altering the design of the room to be more energy-efficient, redrawing the electrical plan, preparing a summary, and presenting the summary). Explain the four sections of the investigation one at a time. After you explain one section, have students carry out that section, provide feedback on their results, and then explain the next section. This strategy will also help English language learners understand what to do.
- ELL English language learners may find this project more accessible than An Issue to Analyze: A “Greener” Power Generation Mix, on page 523 of the student textbook.
- ELL Wherever a written explanation is required, English language learners can write point-form notes instead of paragraphs. Check and provide feedback of students’ schematic drawings before they begin designing and constructing a circuit board. Encourage them to observe other students before attempting their own design.
    - English language learners and other students who are uncomfortable presenting in front of the class may choose a different visual format for their presentation, for example, a poster.
- Enrichment—Have students state beside each device that they listed in Step 1 the kind of energy into which the electrical energy is transformed.

Rubric

ACHIEVEMENT CHART CATEGORY	Level 1	Level 2	Level 3	Level 4
Knowledge & Understanding	The components of the electrical circuit in the selected room are described with limited accuracy.	The components of the electrical circuit in the selected room are described with some accuracy	The components of the electrical circuit in the selected room are described with considerable accuracy.	The components of the electrical circuit in the selected room are described with complete accuracy.
Thinking & Investigation	A functional circuit board is designed using limited safety practices. The room that uses the most electricity is identified using limited evidence.	A functional circuit board is designed using some safety practices. The room that uses the most electricity is identified using some evidence.	A functional circuit board is designed using considerable safety practices. The room that uses the most electricity is identified using considerable evidence.	A functional circuit board is designed using correct and accurate safety practices. Evidence is used with a high degree of effectiveness in identifying the room that uses the most electricity.
Communication	Schematic diagrams are drawn with limited accuracy. The details about the components of the circuit are organized with limited effectiveness. The "greener room" is summarized with limited effectiveness according to the criteria of using an appropriate visual format and proper scientific vocabulary and conventions.	chematic diagrams are drawn with some accuracy. The details about the components of the circuit organized with some effectiveness. The "greener room" is summarized with some effectiveness according to the criteria of using an appropriate visual format and proper scientific vocabulary and conventions.	Schematic diagrams are drawn with considerable accuracy. The details about the components of the circuit organized with considerable effectiveness. The "greener room" is summarized with considerable effectiveness according to the criteria of using an appropriate visual format and proper scientific vocabulary and conventions.	Schematic diagrams are drawn with thorough accuracy. The details about the components of the circuit organized with a high degree of effectiveness. The "greener room" is summarized with a high degree of effectiveness according to the criteria of using an appropriate visual format and proper scientific vocabulary and conventions.
Application	The circuit design for the "greener room" is evaluated according to the criteria with limited effectiveness.	The circuit design for the "greener room" is evaluated according to the criteria with some effectiveness.	The circuit design for the "greener room" is evaluated according to the criteria with considerable effectiveness.	The circuit design for the "greener room" is evaluated according to the criteria with a high degree of effectiveness.

Please also see **BLM A-50 Unit 4 Inquiry Investigation Rubric.**

An Issue to Analyze
A "Greener" Power Generation Mix (Student textbook page 523)

Pedagogical Purpose

The purpose of this analysis is for students to become aware of where our electricity comes from, and the environmental impacts created by the power generation companies. For this issue, students are asked, "In what ways can one power generation company be 'greener' than another?"

This analysis is an opportunity for students to demonstrate the understandings and skills that they have developed in this unit about electricity generation and analyzing the costs and benefits of various sources of electricity.

Planning	
Materials	Internet access, company brochures **BLM 12-22 An Issue to Analyze, A "Greener" Power Generation Mix** (optional) **BLM A-51 Unit 4 An Issue to Analyze** (optional) **BLM G-23 Data Table** (optional) • Book the computer lab for research. • A month before the assignment, contact various power companies to see it they have resources that students might use.
Time	• 1–2 weeks (in and out of class) for research • 15–20 min to reorganize information into a risk-benefit-cost analysis chart • 20–30 min to write a report that compares the two power companies

Background

Many power generation companies produce electrical energy using a mixture of different sources of energy. For example, Ontario Power Generation produces its electricity using hydroelectric, fossil-fuel, and nuclear energy, while Brookfield Power uses hydroelectric and wind energy. The impacts on the environment vary depending on the source of energy used to generate electricity. Over the years, there has been an increasing drive to use more renewable sources in the hopes of curbing the amount of greenhouse gases entering the atmosphere that cause global warming.

Activity Notes and Troubleshooting

- Students may not be aware of the different power generation companies that provide electricity to consumers in Ontario. From the name of the Ontario Power Generation (OPG) company, students may assume that OPG is the only company that generates electricity in Ontario, but there are many others. Consider providing a list of some of these companies on the chalkboard (for example, Ontario Power Generation; Bruce Power; Brookfield Renewable Power Inc.; and Algonquin Power Energy From Waste Inc.).
- The assessment criteria are printed in the student textbook. Make sure students understand what is required of them, and refer to the list, or to **BLM 12-23 An Issue to Analyze,** A "Greener" Power Generation Mix Rubric, as they conduct their analysis and write their report.
- Tell students how you would like them to list references. Provide examples.
- Encourage students to have a classmate read their completed project to ensure that they have met all of the assessment criteria.
- This information could become a useful display for teachers or for the wider community.

Additional Support

- ELL For English language learners or students with organizational difficulties, provide blank templates of the tables they must draw in Perform and Record steps 2 and 3, as well as the risk-benefit-cost analysis chart in Analyze and Interpret step 1.
- As an alternative to writing a report that compares the two companies in terms of their environmental impact, students with weaker language skills could revisit the table they completed in step 3. For each heading in the table, students will highlight the description for the company that is "greener." In this way, they can compare which company has more highlighted areas than the other.
- As an extension, students can research the options available for consumers to purchase environmentally-friendly "green power." This type of electricity has been 100 percent generated without contributing pollution into the environment. Two companies that offer green power in Ontario are Bullfrog Power and Oakville Hydro Energy Services Inc. More information is available at www.scienceontario9.com.
- Also as an extension, students could research the Canadian government's "green shift" carbon tax. Ask students to find out what is it, and if they agree or disagree with the government's strategy.

Rubric

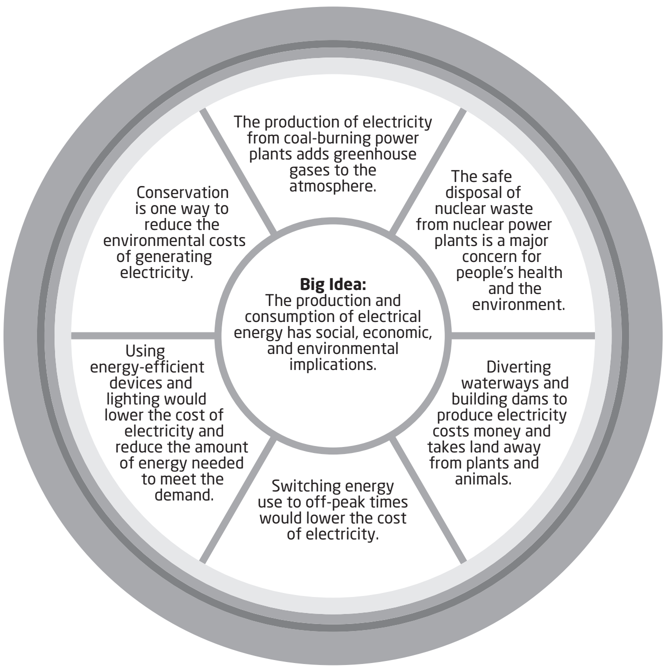
ACHIEVEMENT CHART CATEGORY	Level 1	Level 2	Level 3	Level 4
Communication	Includes information from a variety of sources using an accepted form of academic documentation with limited effectiveness. Uses scientific vocabulary with limited effectiveness. Communicates for the chosen audience and purpose with limited effectiveness.	Includes information from a variety of sources using an accepted form of academic documentation with some effectiveness. Uses scientific vocabulary with some effectiveness. Communicates for the chosen audience and purpose with some effectiveness.	Includes information from a variety of sources using an accepted form of academic documentation with considerable effectiveness. Uses scientific vocabulary with considerable effectiveness. Communicates for the chosen audience and purpose with considerable effectiveness.	Includes information from a variety of sources using an accepted form of academic documentation with a high degree of effectiveness. Uses scientific vocabulary with a high degree of effectiveness. Communicates for the chosen audience and purpose with a high degree of effectiveness.
Application	Identifies an issue with limited clarity. Supports a position with limited evidence. Describes multiple perspectives with limited accuracy. Draws a conclusion based on the risk-benefit-cost analysis with limited effectiveness.	Identifies an issue with some clarity. Supports a position with some evidence. Describes multiple perspectives with some accuracy. Draws a conclusion based on the risk-benefit-cost analysis with some effectiveness.	Identifies an issue with considerable clarity. Supports a position with considerable evidence. Describes multiple perspectives with considerable accuracy. Draws a conclusion based on the risk-benefit-cost analysis with considerable effectiveness.	Identifies an issue with a high degree of clarity. Supports a position with thorough evidence. Describes multiple perspectives with a high degree of accuracy. Draws a conclusion based on the risk-benefit-cost analysis with a high degree of effectiveness.

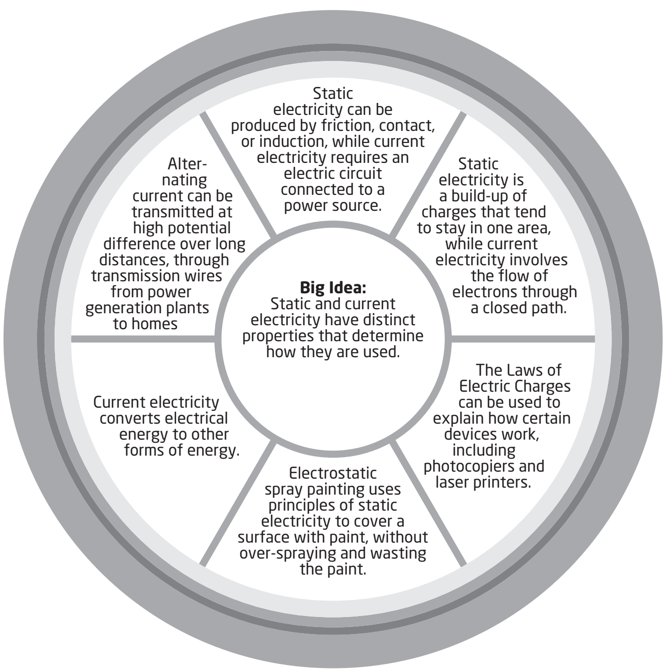
Please also see **BLM A-51 Unit 4 An Issue to Analyze Rubric.**

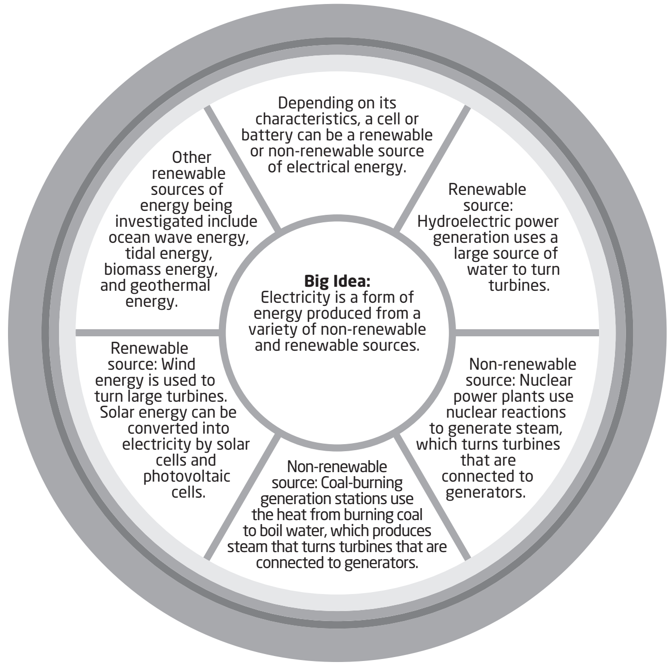
Unit 4 Review Answers (Student textbook pages 524 and 525)

Connect to the Big Ideas

Connect to the Big Ideas answers are also available as a Blackline master on the accompanying CD.







Knowledge and Understanding

1. d.
2. c.
3. d.
4. b.
5. Charging by friction will take place between the lens and the cloth. The charged lens will attract dust particles from the air.
6. **a.** The electric field of the negatively charged rod causes an induced charge on the pith ball. Electrons will be repelled from the side of the pith ball closest to the rod, leaving this side positively charged. Attraction between the negative rod and the positive side of the pith ball closest to it causes the pith ball to move toward the rod.

   b. Contact between the pith ball and the negatively charged rod allows some electrons to move from the rod to the pith ball. Both the pith ball and the rod will have negative charge, and because negative charges repel, the pith ball will move away from the rod.
7. **a.** dry, primary

   b. dry, secondary

   c. wet, secondary

8. The current through each load is the same. The potential difference between the terminals of the load with the greater resistance will be larger. The sum of the potential differences between the terminals of each load will equal the potential difference between the terminals of the battery.

9. The potential difference between the terminals of each load is the same, and the same as the potential difference between the terminals of the battery. The current through the load with the largest resistance will be the least. The sum of the currents through each load will equal the current from the battery.

10. mining uranium; warmed coolant water can damage aquatic ecosystems; short- and long-term radioactive waste

11.

Ocean Wave Energy	Tidal Energy
Source of energy: winds that derive their energy from convection caused by the heating effect of energy from the Sun How it works: vertical rise and fall of the waves can be used to compress an air column, which drives a turbine that is connected to a generator	Source of energy: gravity (mostly from the attraction between Earth and the Moon) How it works: Where large natural basins exist, dams are built to trap the water at high tide. When the tide retreats, the gates are opened and as the water leaves the basin, it turns turbines.

Thinking and Investigation

12. Charging by friction is probably taking place between the handset and your friend's clothing. The presence of charge on the handset could be demonstrated using an electroscope.

13. Friction between the plastic delivery tube and the electronic parts is probably causing the parts to become charged. When the parts strike the metal table, they will be rapidly discharged, which can cause damage to sensitive electronics. The problem can be easily solved by placing a non-conducting surface on the table, and by grounding the delivery tube.

14. $V_1 = 3.0$ V; $V_2 = V_3 = 1.5$ V; $V_4 = 3.0$ V

15. Current becomes four times greater.

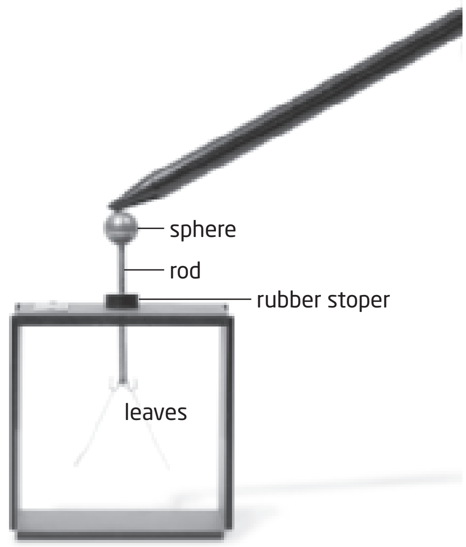
16. 10 kW·h

17. $1.51

18. Depending on the properties of the coal burned, a large coal-burning plant may produce ash with up to 100 times the amount of radioactivity emitted by a nuclear plant because there are small amounts of radioactive materials within the coal.

Communication

19.



20. The specific electrodes do not matter, but the cells must be shown connected at opposite electrodes. The load does not matter, but either a bulb or a resistor should be shown.

21. The direct current circle should include cells and batteries, current moving in one direction, and portable energy applications. The alternating current circle should include power stations, electron movement in alternating directions, and larger energy applications. The region of overlap should include energy, the electron, the electric field, and perhaps units (V, A, and Ω).

22. The increase would have been greater if people had not turned off appliances and lights. In fact, the estimated drop in use was about 5 percent across the province, as compared to the expected use for that date and time of day.

23. Students' answers should mention various effects of mining, gaseous emissions, waste emissions, and transportation, as well as the environmental costs of producing the necessary equipment.

24. Alberta obtains most of its energy by burning fossil fuels, and none from nuclear generation. Alberta also obtains less energy from hydroelectric sources. Alberta has much larger sources of fossil fuels compared with Ontario, but fewer river and dam sites suitable for hydroelectric generation.

Application

25. Use the shortest possible length of the thickest copper wires available.

26. The wire needs sufficient resistance for a relatively short length to become hot. Also, the wire must not oxidize (react with air) over time because this would change its resistance.

27. When the motor comes on or off, there will be a change in the resistance of the circuit, which will cause the current in other components to change. Sensitive equipment can be protected using a surge protector.

28. **a.** a cell that can be recharged

b. The lead-acid cell is a wet cell. The lithium-ion cell is a dry cell.

c. The lead-acid cell is used in automobiles, power chairs, and golf carts. The lithium-ion cell is used in cellphones and laptop computers.

29. **a.** to reduce the current to each bulb

b. no change

30. The polarity of the plug connections was reversed, and the metal casing was connected to *live* instead of *ground.*

Literacy Prep Test

Multiple Choice

31. c or d

32. d

33. b

34. a

Written Answer

35. One way to compare the environmental impacts of different electrical generating stations is to compare their life-cycle emissions of carbon dioxide to the atmosphere. Burning fossil fuels generates a great deal of CO_2 that is a significantly damaging greenhouse gas.