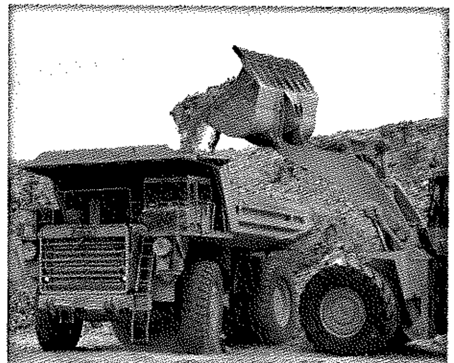
OPTION B

Impacts of Metal Mining

In what forms are copper, lead, and zinc found, and how does their mining affect the land and people, nearby and beyond?



OPTION C

Industrial Minerals

What are the chemical formulas, properties, extraction methods, and applications of industrial minerals such as limestone and magnesite?

Assessment Criteria

Did I and my group...

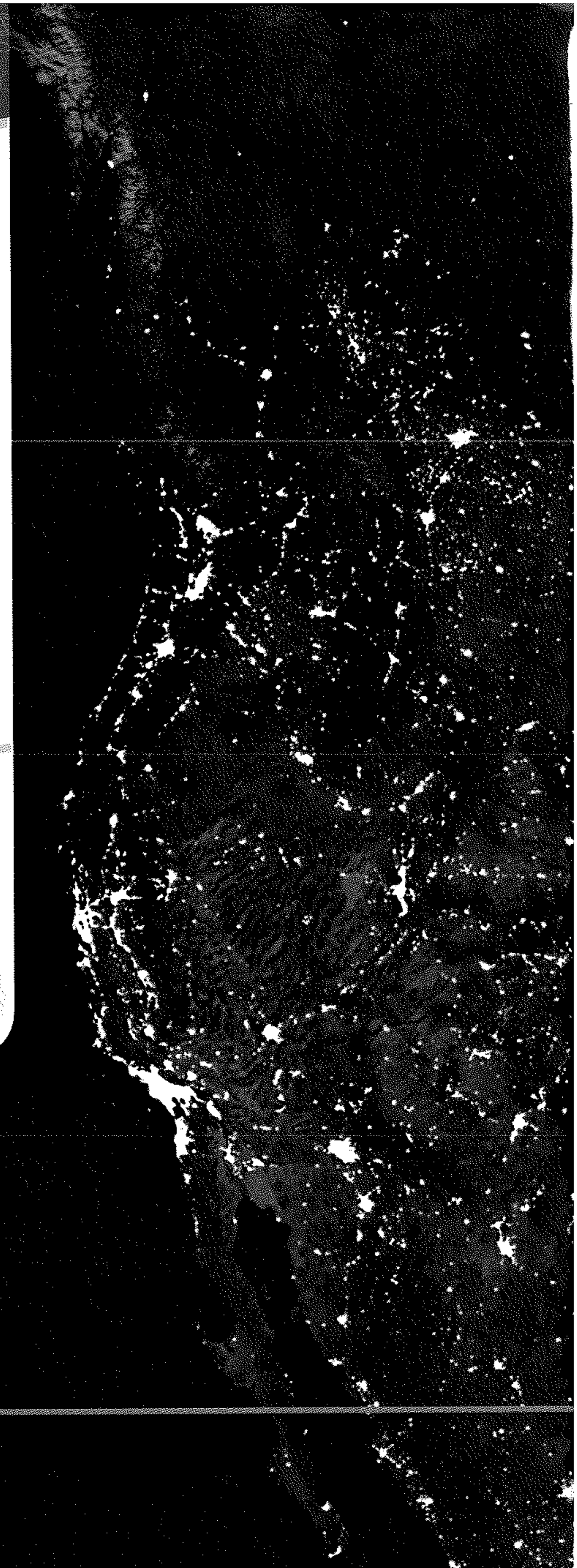
- Develop one or more questions that provided opportunities for rich investigation? OP
- Develop effective methods to collect and record reliable data and information? PC
- Apply different ways of knowing to analyze, reflect, and draw meaningful conclusions that are consistent with evidence? PA
- Consider and demonstrate an awareness of assumptions, bias, and social, ethical, and environmental implications over the whole process of our inquiry? E
- Propose alternative courses of thought and/or action that contribute to care for self, others, community, and world? AI
- Construct evidence-based arguments using language, conventions, and representations appropriate for a specific purpose and audience? C

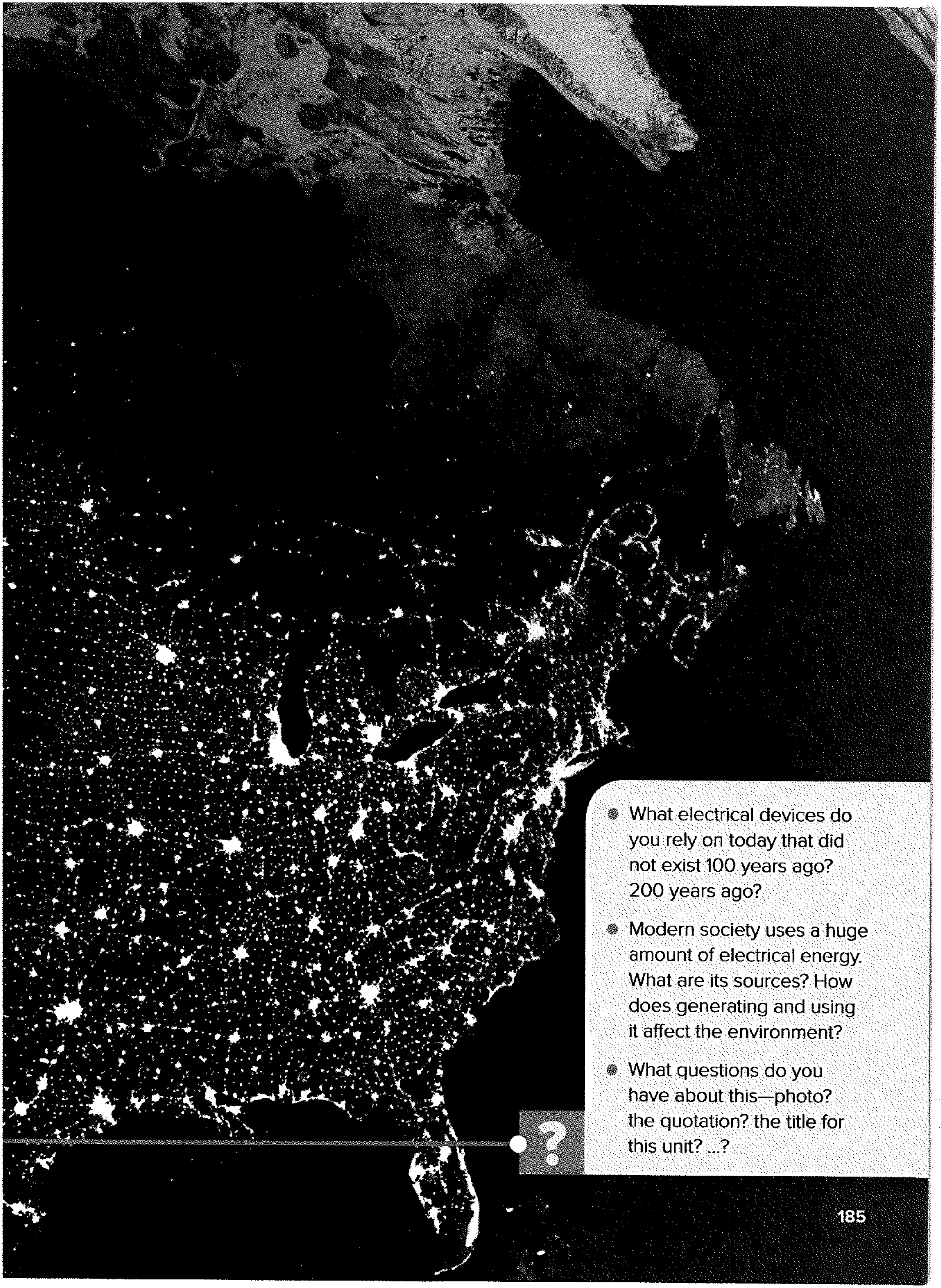
UNIT 3

Electric current is the flow of electric charge

The first generator to provide a constant source of electrical energy was developed in 1844. This development made it possible to use the first practical light bulb, patented in 1879. Less than 150 years later, North America is lit up by so many electrical lights that it can be seen from a satellite at night. Despite the convenience they provide, these lights also have a dark side: light pollution.

> **“Light pollution seems to have a widespread, negative impact on many different species. The evidence for the impact of light pollution in migratory birds, hatchling sea turtles, and insects is striking.”**
>
> *Biologist Sharon Wise*





- What electrical devices do you rely on today that did not exist 100 years ago? 200 years ago?
- Modern society uses a huge amount of electrical energy. What are its sources? How does generating and using it affect the environment?
- What questions do you have about this—photo? the quotation? the title for this unit? ...?

UNIT 3

At a Glance

You will demonstrate what you know, can do, and understand by being able to

- Perform investigations to explore how charges behave in specific circumstances
- Develop and use models and other methods to show connections between chemical energy, electrical potential energy, and electrical potential difference
- Seek patterns and connections to describe, explain, and evaluate the relationship between voltage, current, and resistance in a circuit
- Use scientific understandings to describe, explain, and evaluate the development of a sustainable energy system

ESSENTIAL QUESTION

How do we apply our understanding of charges to generate and use electrical energy?

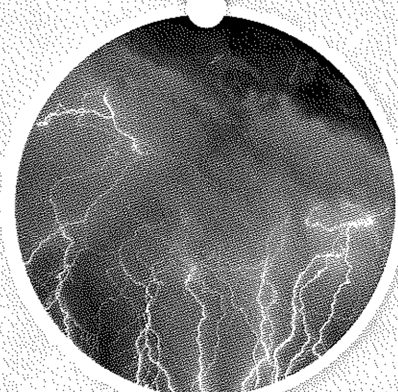
TOPIC 3.1:
How is electrical energy part of your world?

Some things you will do:

- co-operatively design projects
- make predictions about inquiry findings
- ensure safety guidelines are followed in investigations

Some things you will come to know:

- Some types of energy can be transformed into electrical energy.
- Electrical energy is generated from different sources.



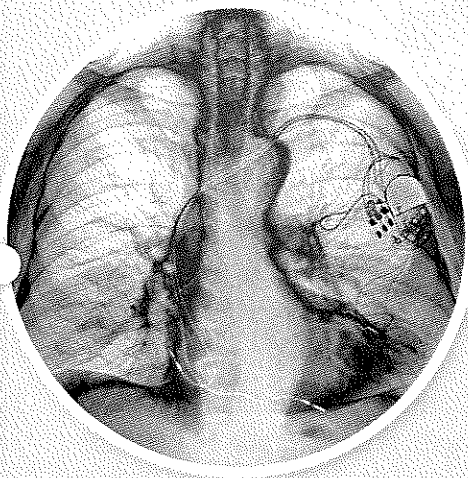
TOPIC 3.2:
How do electrical charges behave?

Some things you will do:

- identify questions you have about the natural world
- use scientific understandings to identify relationships and draw conclusions
- reflect on your investigation methods

Some things you will come to know:

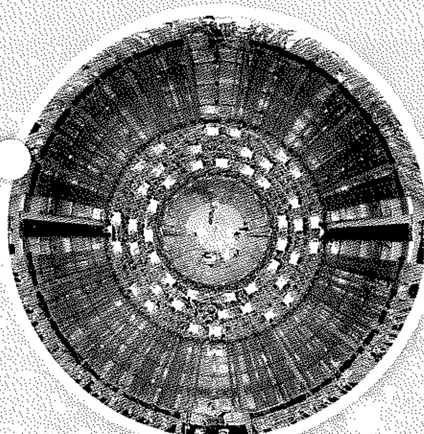
- Charges can transfer from one object to another.
- The law of electric charge describes how charges interact.



TOPIC 3.3:
How do charges flow through the components of a circuit?

Some things you will do:
- observe, measure, and record data
- measure and control variables through fair tests
- connect scientific explorations to careers in science

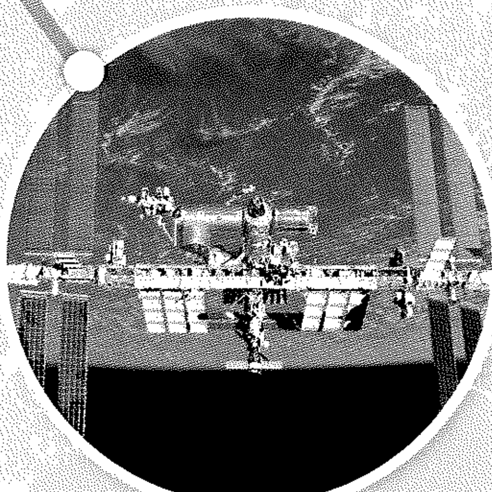
Some things you will come to know:
- Batteries and cells work by separating charges.
- Charges can move more easily through some materials than others.
- Each component in a circuit plays a specific role.



TOPIC 3.4:
How are circuits used in practical applications?

Some things you will do:
- use mathematical formulas to demonstrate relationships between variables
- seek patterns and connections in data
- construct and use a range of methods to represent patterns or relationships in data
- identify a question to answer or a problem to solve through scientific inquiry

Some things you will come to know:
- Ohm's law describes the relationship among voltage, current, and resistance in a circuit.
- Loads can be connected in different ways in a circuit.



TOPIC 3.5:
How can electrical energy be generated and used sustainably?

Some things you will do:
- contribute to care for self, others, community, and the world
- consider Aboriginal perspectives and knowledge
- communicate ideas, information, and a suggested course of action for a specific audience

Some things you will come to know:
- Electrical energy can be generated and used sustainably.
- Some resources for generating electrical energy are renewable and others are not.

TOPIC 3.1

How is electrical energy part of your world?

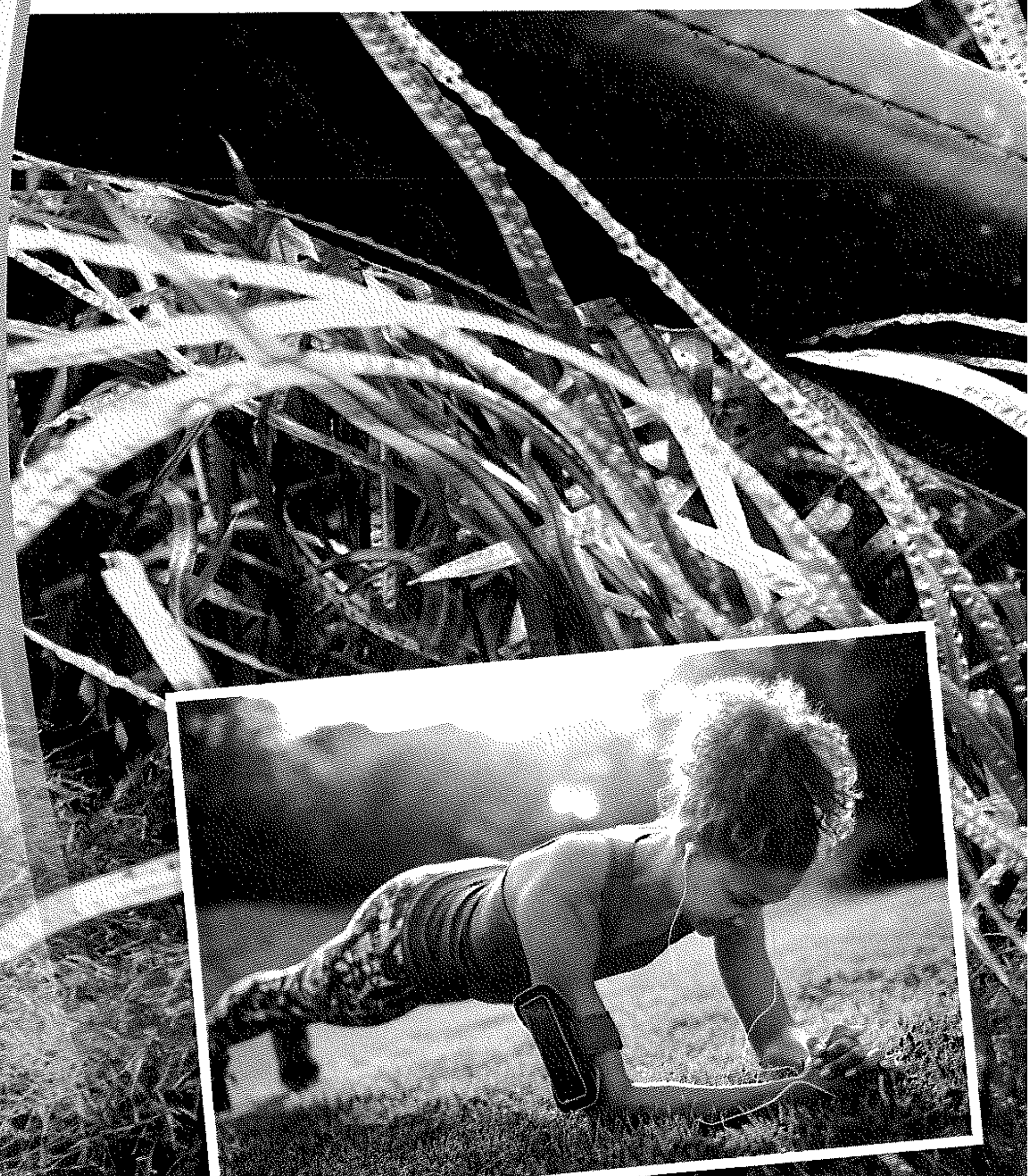
Key Concepts

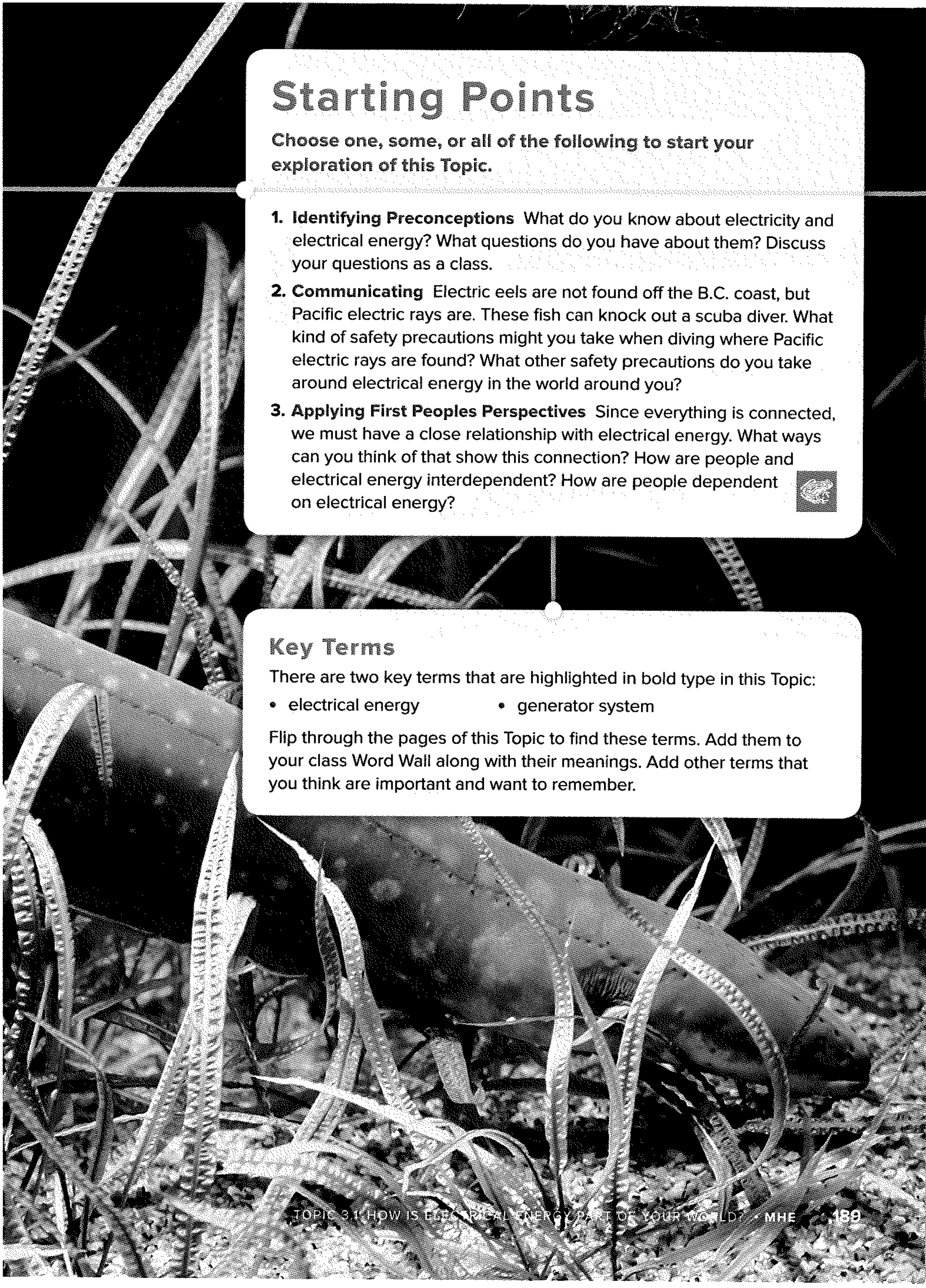
- Electrical energy has many applications.
- Many different types of energy can be transformed into electrical energy.
- Electrical energy is generated in different ways from different sources.

Curricular Competencies

- Contribute to care for self, others, community, and world through personal or collaborative approaches.
- Formulate multiple hypotheses and predict multiple outcomes.
- Describe specific ways to improve investigation methods and quality of data.
- Transfer and apply learning to new situations.

Underwater, the shock from an electric eel is strong enough to knock out a full-grown horse. Could this source of energy be harnessed to power electrical devices like a portable media player? Jiwan Toor, a student from Fleetwood Park Secondary School in Surrey, B.C., asked the same question. Working with researchers at UBC, the 16-year-old determined an answer. But it might surprise you. It would take 14 000 eels two hours to recharge a media player. Electrical energy doesn't always act the way you think it might. And since electrical energy is such an essential part of your world, it is definitely important to understand it better.





Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** What do you know about electricity and electrical energy? What questions do you have about them? Discuss your questions as a class.
2. **Communicating** Electric eels are not found off the B.C. coast, but Pacific electric rays are. These fish can knock out a scuba diver. What kind of safety precautions might you take when diving where Pacific electric rays are found? What other safety precautions do you take around electrical energy in the world around you?
3. **Applying First Peoples Perspectives** Since everything is connected, we must have a close relationship with electrical energy. What ways can you think of that show this connection? How are people and electrical energy interdependent? How are people dependent on electrical energy?

Key Terms

There are two key terms that are highlighted in bold type in this Topic:

- electrical energy
- generator system

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meanings. Add other terms that you think are important and want to remember.

CONCEPT 1

Electrical energy has many applications.

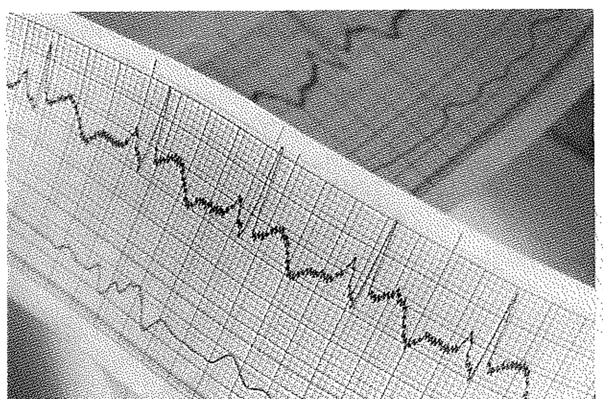
Activity

Power Failure!

What would a day in your life look like without electrical energy? What problems would you encounter, and how would you deal with them? (Yes, boredom is a problem.) Brainstorm with your group. Use your ideas to create a video or skit of what a typical day would be like if the power failed in your community for 48 hours or more.

From the first ring of your morning alarm clock to when you turn the light off to go to bed, your day is filled with different applications of **electrical energy**. Many of these are familiar, like your clock and a light bulb. Others may surprise you. For instance, Figure 3.1 shows how several functions of the human body use electrical energy. It also explores how this energy is harnessed by different types of technology, from robots to levitating trains to neon signs.

Figure 3.1 Some applications of electricity.



You could not read this book without the help of electrical energy, even in the daytime. Moving your eyes to read the page relies on electrical signals in your muscle and nerve cells. Breathing and maintaining a heart beat do, too.

Most touch-sensitive screens are resistive screens. These work a lot like transparent keyboards. The pressure from a touch command completes an electrical pathway. A computer chip inside the tablet then determines the command to be carried out. Other screens, called capacitive screens, actually make your finger part of the electrical pathway. When your finger touches the screen, a tiny electrical charge passes through it. This completes a pathway, and the command is carried out.

Neon signs are familiar sights in most urban centres. In this photo, the orange-red colour is unique to neon gas. When electrical energy causes electrons to pass through neon gas, the electrons collide with neon atoms, transferring energy to them. The atoms then give off some of this energy as visible light of a specific colour: orange-red. Other gases, such as helium, argon, and xenon, are also used in neon signs. The atoms of each gas give off a different colour of light.

Robots are becoming more like humans every day thanks to technology that reacts to electrical signals like your muscles do. Using a flexible plastic that expands and contracts slightly in response to electrical energy, scientists are able to create robots with hand and facial movements that are eerily human.

Train travel at 500 km/h, without an engine, is a reality in many countries, including Japan and Germany. Maglev trains levitate (hover) above electrified coils that run along tracks. The coils create magnetic fields that repel large magnets under the train, causing it to levitate. With no friction between the train and the tracks, the train can travel at very high speeds.

Before you leave this page . . .

1. Describe three ways that you have depended on electrical energy since you woke up this morning.

CONCEPT 2

Many different types of energy can be transformed into electrical energy.

Activity

Electrical Energy Detective

Where does the electrical energy used in your community come from? Discuss your ideas as a class. If you are not sure, how can you find out?

Energy is neither created nor destroyed. Instead, it is transformed from one kind of energy into another kind of energy. The electrical energy that runs your phone, hair dryer, and other electrical devices was transformed from another type of energy. Several types of energy are reviewed in Figure 3.2. Each can be transformed into electrical energy.

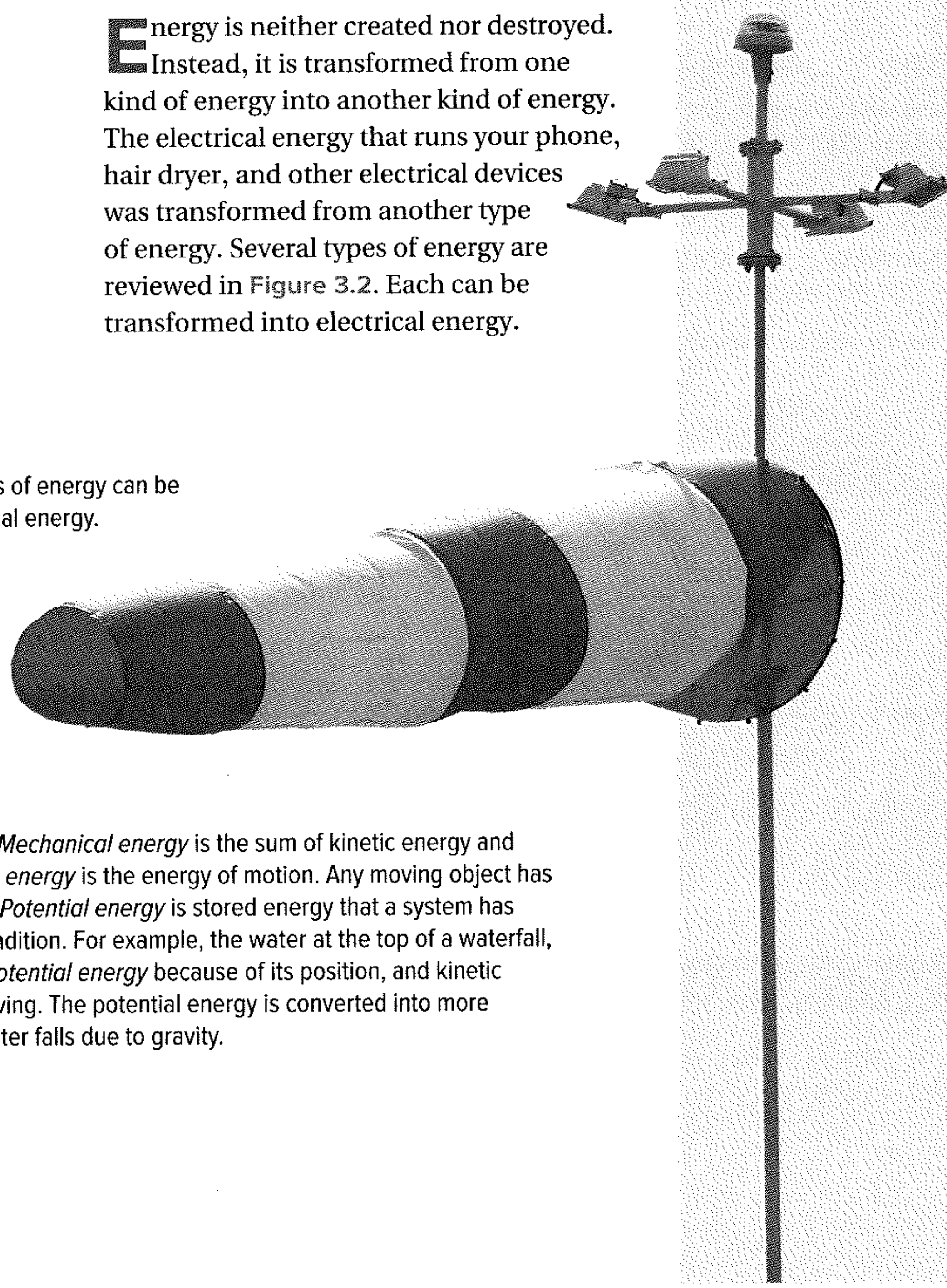


Figure 3.2 Many types of energy can be transformed into electrical energy.

Mechanical Energy *Mechanical energy* is the sum of kinetic energy and potential energy. *Kinetic energy* is the energy of motion. Any moving object has kinetic energy, even air. *Potential energy* is stored energy that a system has due to its position or condition. For example, the water at the top of a waterfall, just before it falls, has *potential energy* because of its position, and kinetic energy because it is moving. The potential energy is converted into more kinetic energy as the water falls due to gravity.

Chemical Energy

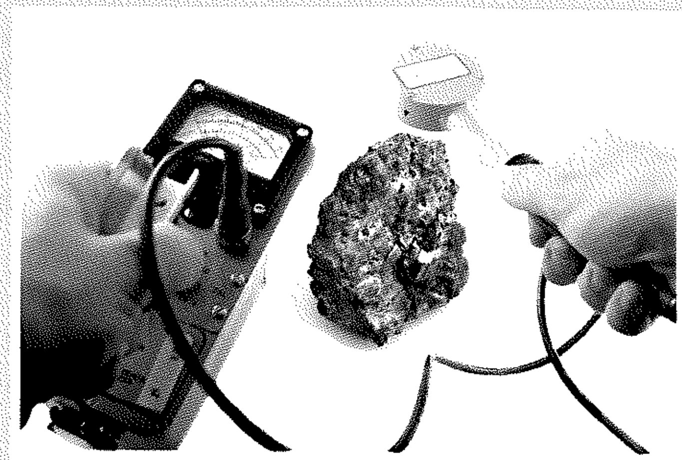
Chemical energy is stored in chemical bonds. It is released when a chemical reaction occurs. Batteries store chemical energy. Chemical energy stored in animals and in plants, such as these trees near Bowron Lake Provincial Park, is called biomass. Fossil fuels (coal, oil, natural gas) also store chemical energy.

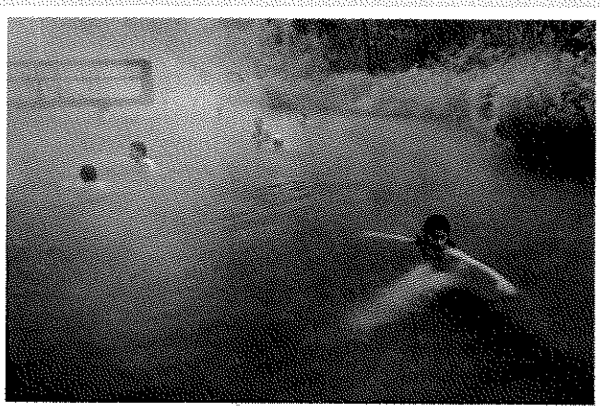
Solar Energy

Solar energy is energy carried by electromagnetic radiation given off by the Sun. Fossil fuels and biomass are the result of energy from the Sun being captured by plants and plant-like organisms.

Nuclear Energy

Nuclear energy is generated by forming new atoms. In *nuclear fusion*, new atoms are made as smaller atoms collide and fuse. Fusion reactions occur in the Sun and other stars. In *nuclear fission*, new atoms are made by splitting larger atoms. Fission reactions are carried out in reactors on Earth.





Thermal Energy

Thermal energy is the energy due to the rapid motion of particles that make up an object. We detect it as heat. It can come from many sources, such as nuclear reactions or from Earth's interior (geothermal energy), where steam and hot water form naturally. These are seen in geysers, volcanoes, and hot springs, like those at Liard River Hot Springs Provincial Park shown here.

Before you leave this page . . .

1. Explain the difference between kinetic energy and potential energy.

2. Describe the relationship among solar energy, biomass, and fossil fuels.

CONCEPT 3

Electrical energy is generated in different ways from different sources.

Activity

Charge It

You are at school working on a group science project late one afternoon. An unexpected snowstorm hits your region. It knocks out all the electrical energy, and none of the school phones work. It looks like you may be here a while. Luckily the cafeteria is stocked with food, and you have warm clothing. You do have one cellphone, but it needs to be charged. As a group, brainstorm how you could charge the phone to tell your families that you are safe. You can only use materials and objects found in your school. When you are done, share your ideas as a class.

Many different types of energy can be transformed into electrical energy, but how? Several different methods are explored in this Concept.

Kinetic Energy to Electrical Energy

generator system a system that transforms kinetic energy to electrical energy

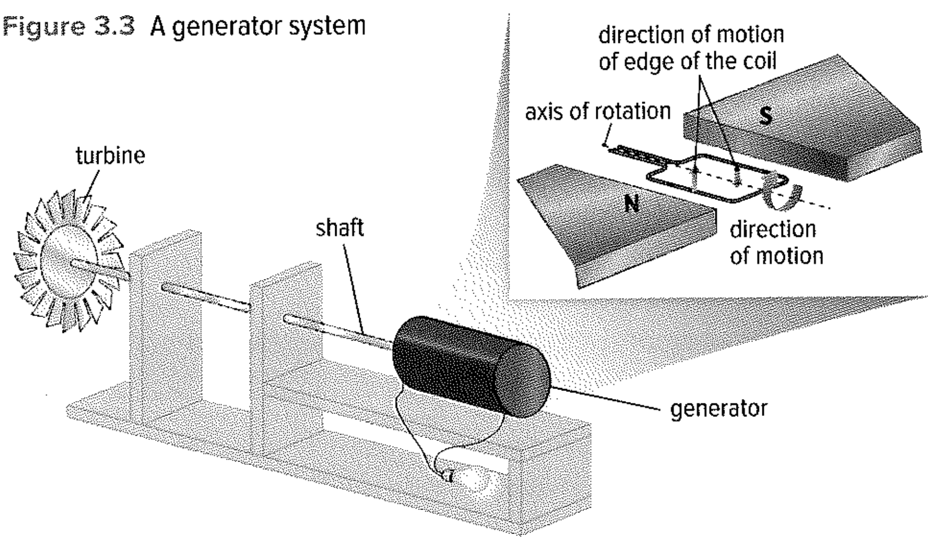
Most of the electrical energy in Canada is generated by transforming kinetic energy into electrical energy. The source of kinetic energy may be moving water or wind. It may also be moving steam produced by thermal energy generated in nuclear reactions, or by burning fossil fuels. In each case electrical energy is generated using a **generator system**. Figure 3.3 shows a model of a simple generator system. The system has three parts: a *turbine*, a *shaft*, and a *generator*.

Turbine: Steam, water, or wind cause the turbine to spin.

Shaft: The shaft connects the turbine to the generator. As the turbine spins, it makes the shaft spin.

Generator: The kinetic energy of the spinning shaft is transformed into electrical energy inside the generator. This happens when energy from the shaft turns a wire loop or coil. A magnet surrounds the rotating wire, as shown in the inset. As the wire turns, electrons flow in the wire. This flow of electrons powers electrical devices.

Figure 3.3 A generator system



Generating Electrical Energy in Canada

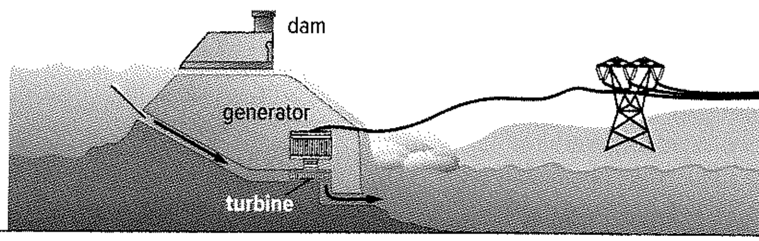
Most of the electrical energy used in Canada comes from river flow, fossil fuels, and nuclear reactions. In B.C., river flow is the main source. B.C. also uses fossil fuels to generate electrical energy, but it has no nuclear reactors. Figure 3.4 outlines how river flow, fossil fuels, and nuclear reactions generate electrical energy.

Figure 3.4 Comparing how river flow, fossil fuels, and nuclear reactions generate electrical energy

Hydroelectric Energy from River Flow

Electrical energy from river flow is called *hydroelectric energy.* Two systems generate hydroelectric energy. At the dam station below, water stored behind the dam has potential energy. As it flows downhill, it gains kinetic energy, which turns a turbine connected to a generator. At a run-of-river station, water flowing freely in a river turns a turbine.

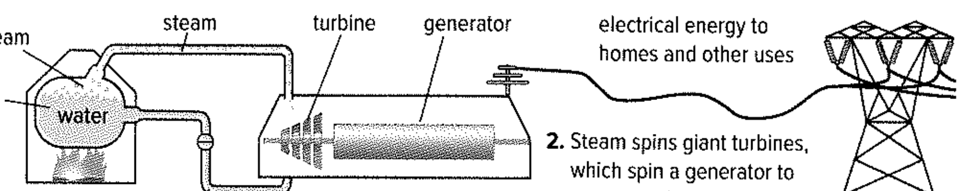
Water flowing through a dam spins giant turbines, which spin a generator to produce electrical energy.



Electrical Energy from Fossil Fuels

In the generating station shown here, thermal energy from burning coal is used to boil water into steam. Pressure associated with the moving steam turns the blades of turbines connected to generators.

1. Burning fuel boils water to make steam.

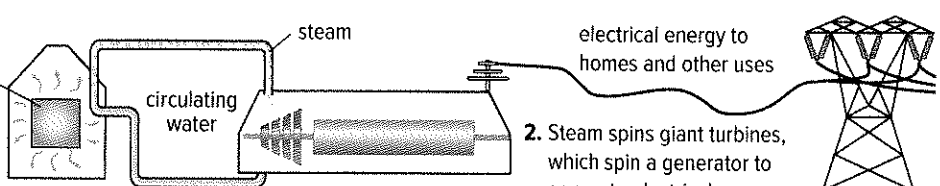


2. Steam spins giant turbines, which spin a generator to generate electrical energy.

Electrical Energy from Nuclear Reactions

Inside a nuclear reactor, uranium or plutonium atoms undergo fission reactions. Splitting one atom sets off a chain reaction that causes more atoms to split. The nuclear reactor contains and controls these reactions and the energy they release. Most of this energy is thermal energy, which is used to boil water into steam. Pressure associated with the moving steam turns turbines connected to generators.

1. Thermal energy from a nuclear reactor boils water to make steam.



2. Steam spins giant turbines, which spin a generator to generate electrical energy.

Generating Electrical Energy from Other Energy Sources

Connect to Investigation 3-A on page 200

Transformation of kinetic energy from wind and solar energy to electrical energy is on the rise in B.C. and Canada as a whole. These processes are described in Figures 3.5 and 3.6. Geothermal sources, waves, and tides are small players now, but they hold promise for the future. These sources are described in Figure 3.7 and Figure 3.8.

Figure 3.5 A wind turbine and generator transform kinetic energy to electrical energy.

Electrical Energy from Wind

The kinetic energy of wind is transformed into electrical energy as the moving air turns the turbine of a generator system. The most common type of wind turbine in Canada is mounted on a high tower to take advantage of greater wind speeds higher above the ground. This height also reduces turbulence from wind blowing around buildings.

A wind turbine starts to produce electrical energy when wind speed is about 13 km/h. Gears on the shafts increase the speed of the generator. This process increases until wind speed reaches about 55 km/h. For safety, a controller shuts the turbine down when the wind speed reaches 90 km/h. An anemometer is used to measure wind speed.

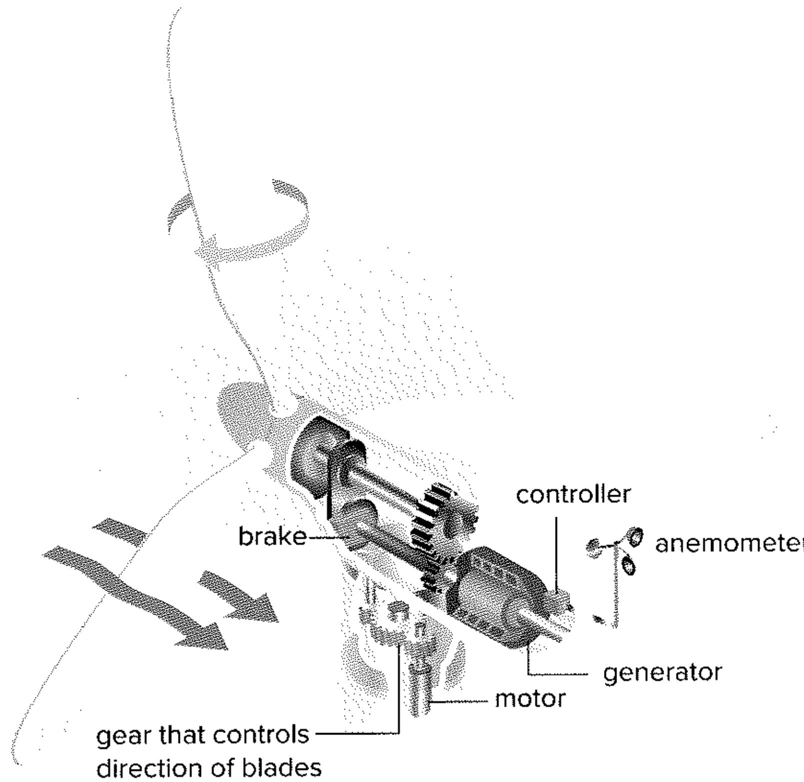
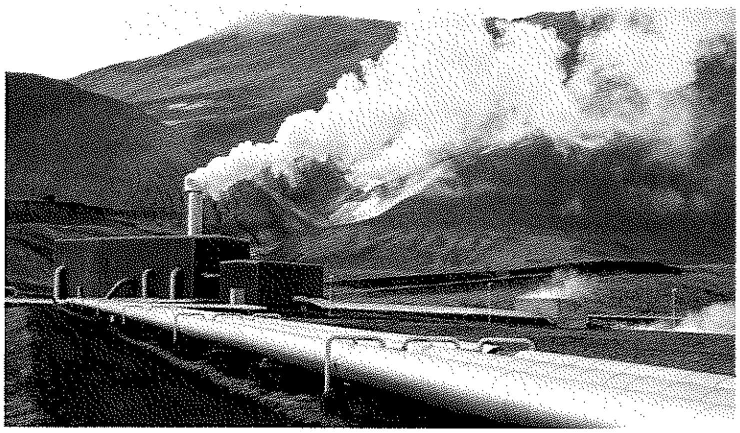


Figure 3.6 A photovoltaic cell transforms solar energy to electrical energy.

Electrical Energy from Sunlight

Some materials produce electrical energy when they are exposed to light. This is called the *photovoltaic effect.* Photovoltaic cells generate electrical energy when visible light strikes their surfaces. The cells are made of thin layers of silicon crystals. When visible light strikes electrons trapped in the cells, the electrons absorb just enough energy to flow freely and generate electrical energy. The Sun emits enormous amounts of solar energy, but converting this energy to electrical energy is a challenge. Currently, photovoltaic cells only transform the energy of visible light to electrical energy. However, scientists are working to create cells that transform other types of electromagnetic radiation into electrical energy.

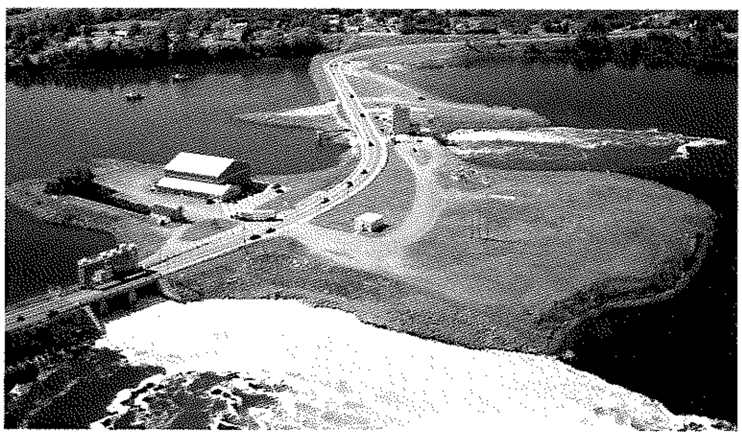
Figure 3.7 A geothermal generating station transforms thermal energy to kinetic energy to electrical energy.



Electrical Energy from Geothermal Sources

Where Earth's crust is thin and molten rock comes close to the surface, hot steam can be used to turn turbines to generate electrical energy. Some parts of the world have greater access to geothermal sources than others. For instance, the volcanic island nation of Iceland generates 25% of its electrical energy from these sources.

Figure 3.8 A tidal generating station transforms kinetic energy from tides to electrical energy.



Electrical Energy from Waves and Tides

The vertical rise and fall of the waves can compress an air column, which turns a turbine. The B.C. coast is considered one of the best places to generate electrical energy from waves. Tides can spin turbines to produce electrical energy. However, they are only effective where they vary by 5 m or more. At high tide the gates of the tidal generating station shown here close and trap water in a basin. When the tide goes out, the water is directed through pipes to turn a turbine. Such stations only generate electrical energy for about 10 hours a day, as the tide moves in or out.

Activity

What Are the Properties of an Ideal Energy Source?

1. In small groups, make a list of properties of an energy resource that you think makes it the best for all or most possible uses. Note: You are not being asked to name which source you think is best. Your task is to create a list of the most desirable properties that an energy resource should have.
2. Share your group's list with other groups in the class. See if your class can agree on a list of properties that make the ideal energy source.
3. Assess each energy source in this Concept with your final list. In your mind, which source is closest to being an ideal energy source? Explain.

Before you leave this page . . .

1. List the three key parts of a generator system. Briefly describe their functions.
2. Use a flowchart to explain how moving water can generate electrical energy.

TAKE Action

Make a Difference

People Power

British Columbia: Max Donelan of Simon Fraser University has designed a device that transforms human-generated energy into electrical energy. The PowerWalk® Kinetic Energy Harvester is secured around the knee. Each time we take a step, our leg muscles speed the movement of the leg and then slow it down at the end of the step. The Harvester could harvest the energy of leg motion at all times, but walking would become tiring. Instead, it extracts energy only when the muscles are slowing leg motion, making walking easier. How much electrical energy can be generated this way? An hour of walking can charge up to four smartphones.

Japan: Something unique happens when special materials, called *piezoelectric materials*, are compressed or pulled. The mechanical energy associated with the force or stress is transformed into electrical energy. Piezoelectric materials include quartz crystals, some ceramics, amber, and even cane sugar (although the crystals break too easily to be used in applications). It is possible to use these materials and human energy to generate electrical energy on a large scale. For instance, the floors in several Japanese subway stations are made out of piezoelectric materials. As people walk on the floor, they compress the materials, which generates electrical energy.

Apply and Innovate

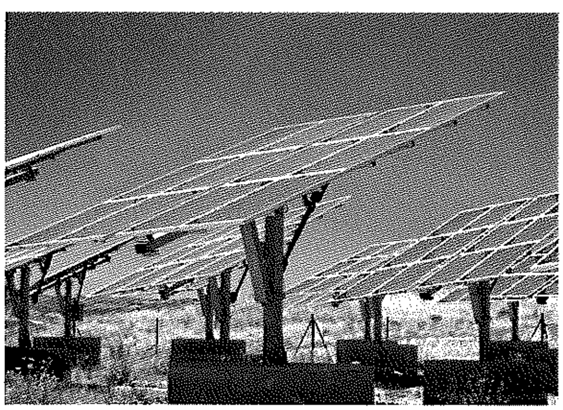
1. Come up with some possible applications for the two examples discussed in this feature. What factors would you need to consider?
2. Ann Makosinski, a 15-year-old student in B.C., designed a flashlight that transforms human body heat (thermal energy) into electrical energy.
   a) Why would this and other human-powered electrical devices be especially useful to people and communities in developing countries?
   b) Find out more about initiatives that are bringing human-powered electrical energy to people in developing nations. Choose a specific project. How could you get involved? Come up with an action plan.

Check Your Understanding of Topic 3.1

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. Describe the role electrical energy plays in robotics. PA AI C
2. Identify the type of energy associated with each source below. PA
   - a) the Sun
   - b) river flow
   - c) a battery
   - d) wind
   - e) uranium
   - f) hot springs
   - g) garbage
3. Use a table to compare the similarities and differences among the use of river flow, the burning of fossil fuels, and nuclear reactions to generate electrical energy. PA E C
4. Some photovoltaic cells, like the ones shown below, are mounted on towers that let them follow the Sun's path. What is the advantage of such designs? PA E AI



5. Consider a coastal community. QP E AI
   - a) Describe two cases in which a tidal generating system would be a good choice for the community.
   - b) Describe two different cases in which a wind turbine would be a good choice.

Connecting Ideas

6. Imagine that a wind turbine has a faulty controller. Predict a problem that could arise as a result of this manufacturing defect. QP PA E AI
7. You are waiting outside school for a friend. It is a cold day in January, and you reach into your bag for your gloves and phone. You are early and decide to send a text while you wait. However, the screen is not responding to your touch commands. You take off your gloves and find that your screen now works. What type of touch screen do you most likely have and why did it not work when you wore gloves? PA E AI
8. Photovoltaic cells are commonly used to provide electrical energy for satellites. Suggest an advantage that photovoltaic cells might have in space, compared with similar cells on Earth. PA E AI

Making New Connections

9. Imagine there was a large-scale power failure that left your region without electricity for two weeks during the summer months. E AI C
   - a) What would be the most serious consequences for you and for your community?
   - b) How might the problems be different if the event took place in January?
   - c) What alternative energy sources, if any, could be used?

INVESTIGATION

3-A

GUIDED AND OPEN INQUIRY

Investigating Generators and Turbines

Skills and Strategies

- Questioning and Predicting
- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Communicating

Safety

- Handle the meter with care.
- Use construction tools carefully.

What You Need

- 5 m of insulated copper wire (about 26 gauge)
- 2 alligator clips
- cardboard tube
- powerful bar magnets
- galvanometer
- other materials as determined by your design
- access to information resources (for example: online, in-print, interviews)

PART A: BUILD AND TEST A SIMPLE GENERATOR—GUIDED INQUIRY

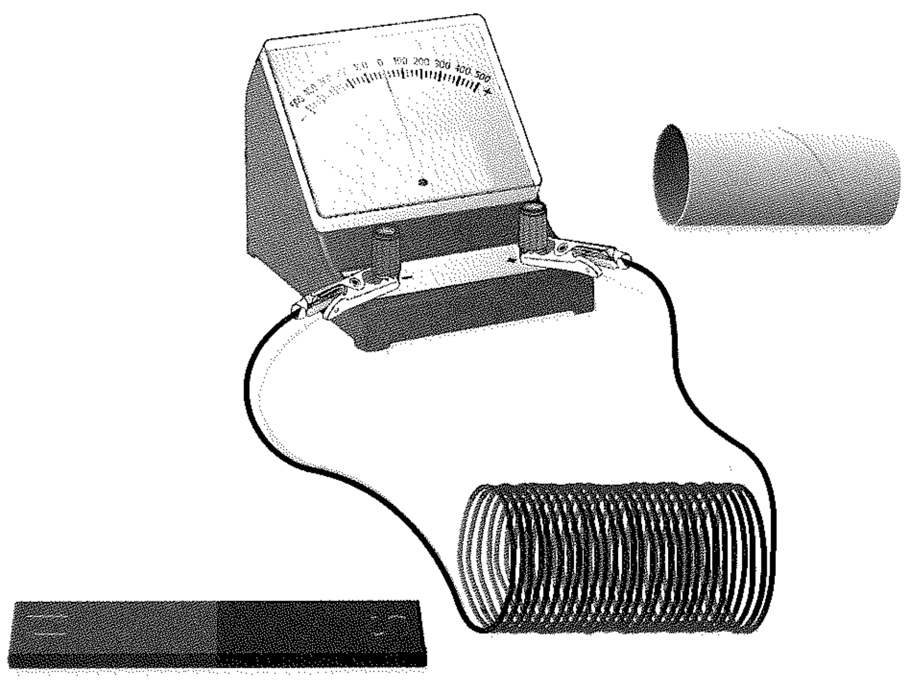
A generator uses a magnet and a coil of wire to transform kinetic energy into electrical energy.

Question

How can you investigate which factors affect the amount of electrical energy produced by a simple generator?

Procedure

1. Leaving about 15 cm for a lead at both ends of the wire, make a coil of about 25 turns by wrapping the wire around a cardboard tube. Remove the tube from the coil.
2. Strip the insulation off each end of the wire. Then connect the ends to the galvanometer with alligators clips. The galvanometer measures electrical activity.



3. While closely monitoring the meter, insert one end of the magnet into the coil and then pull it out. Record any movement you observe on the meter.
4. With your partner, brainstorm how you could increase the reading on the meter. Record your ideas. For each variable you decide to test, write a hypothesis to predict which possible outcome you think will occur.
5. Test your ideas and record your results.

Process and Analyze

1. Which condition or combination of conditions that you tested recorded the most electrical activity? Why do you think this was the case?

Evaluate

2. Were you surprised by your results? Explain.

PART B: DESIGN AND BUILD A TURBINE OR GENERATOR—OPEN INQUIRY

In Part B, your team will create a working turbine or generator based on your own design. If you build a generator, you can use the simple generator you built in Part A as a springboard, but your design must be your own. Think wind, water, human-generated energy, or any other source available to you.

Question

Read the Procedure. Determine the question that you will investigate.

Procedure

1. What questions do you have about how you could design, build, and test a turbine or generator? Brainstorm and record your ideas.
2. Use information resources to investigate answers to your questions.
3. Based on your research, develop a materials list, safety guidelines, and procedure for a specific turbine or generator that you will build. Your teacher must approve your plan before you build your device.
4. Once approved, build your device.
5. Test your device. Troubleshoot any problems that arise.

Evaluate

1. Did your device work as you expected? Why or why not?
2. If you were to repeat this investigation, what would you do differently? Explain why.

TOPIC 3.2

How do electrical charges behave?

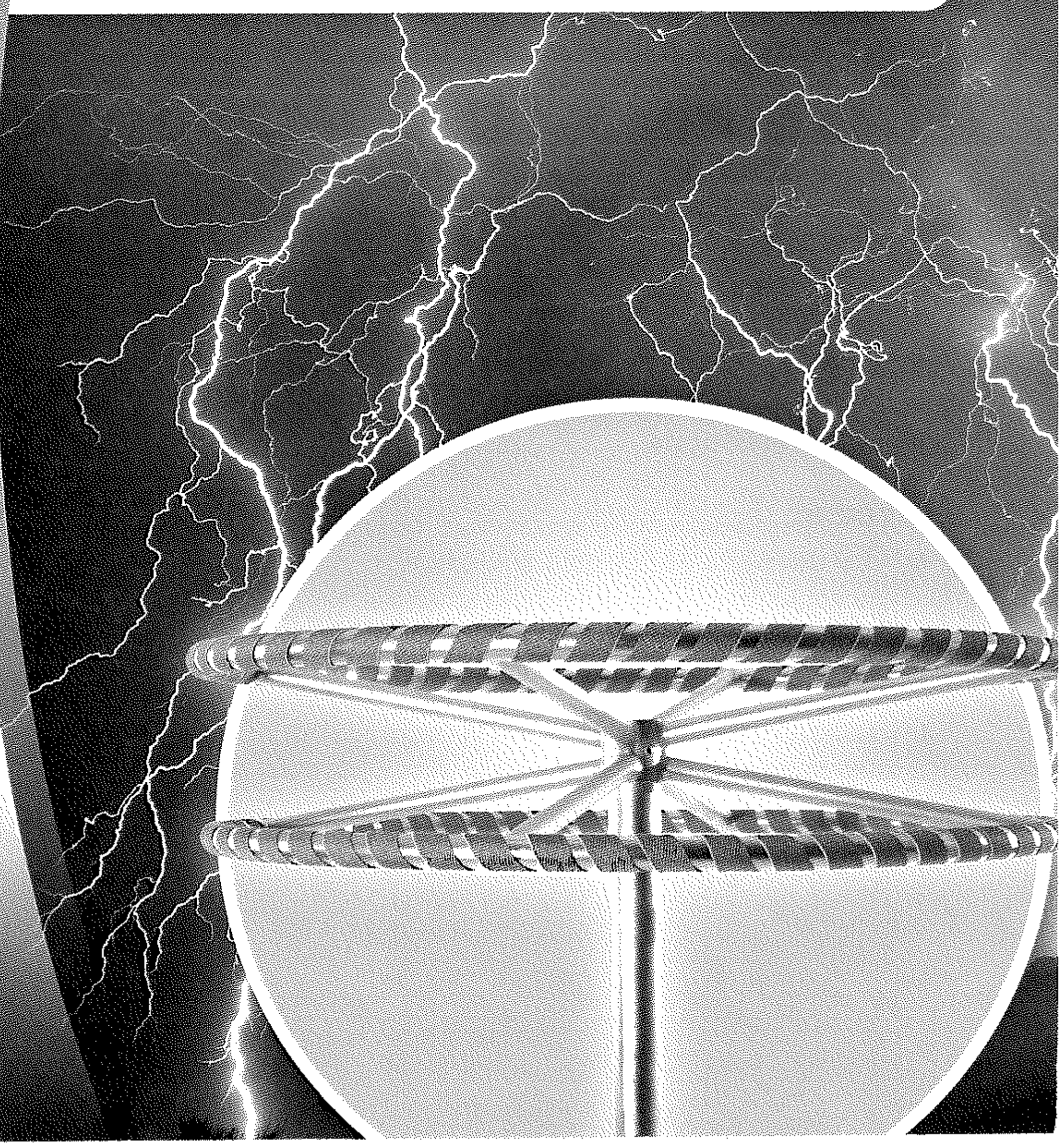
Key Concepts

- Electrons carry a negative charge, and protons carry a positive charge.
- Opposite charges attract each other, and like charges repel each other.

Curricular Competencies

- Use knowledge of scientific concepts to draw conclusions consistent with evidence.
- Consider changes in knowledge over time as tools and technologies have developed.
- Generate and introduce new or refined ideas when problem solving.
- Seek and analyze patterns, trends, and connections in data, including describing relationships between variables and identifying inconsistencies.

Lightning carries a large amount of electrical energy. It is beautiful to observe, but it is also extremely dangerous. For over 100 years, people have used lightning rods to reduce this danger. Lightning rods are designed to direct lightning strikes away from buildings and prevent damage and fires. However, they do not always succeed. To improve their success rate, scientists have studied the way that electrical charges build up around objects on the ground and interact with electrical charges in the clouds. This has led them to design new lightning rods like the one shown in the inset. These rods, designed by Canadian scientist Farouk Rizk, generate regions of electrical charges that cause lightning to strike in places where it will do no harm.



Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

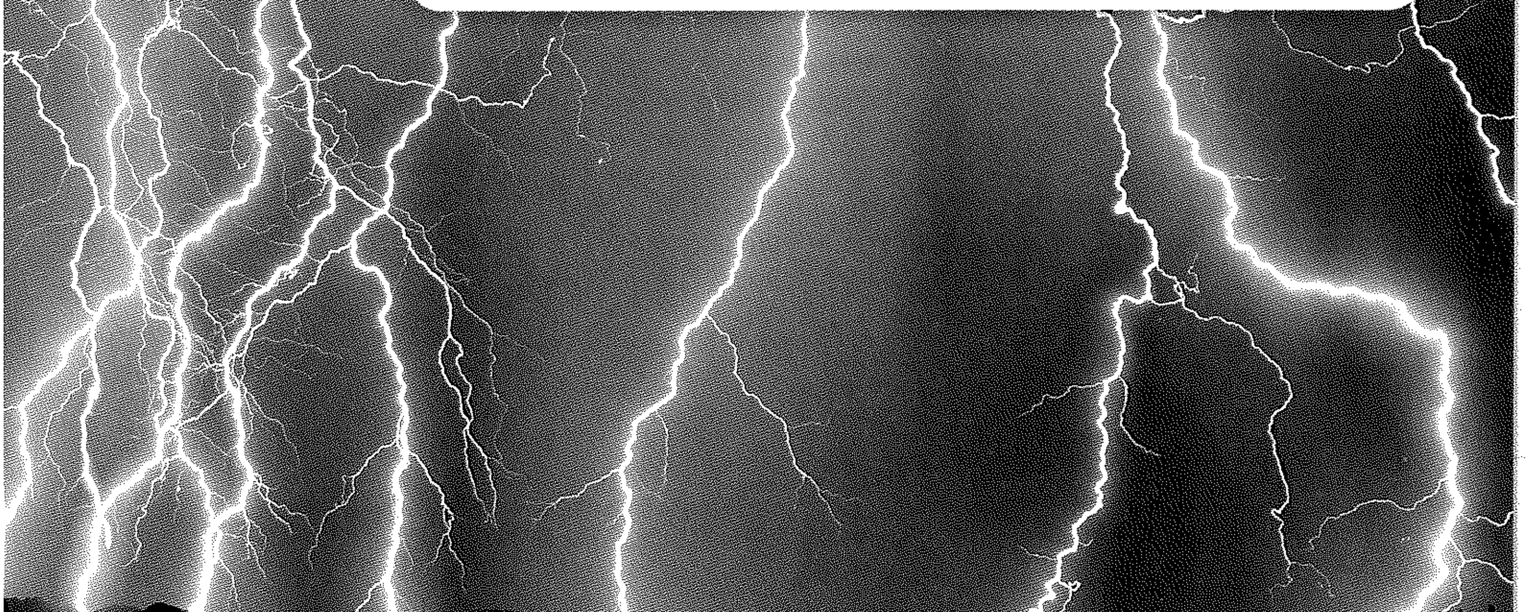
1. **Identifying Preconceptions** The word "charge" can have many meanings. Discuss your understanding of this word. What does "charge" mean when it is used in connection with electrical energy?
2. **Applying** You have probably received a small shock from touching a door knob, another person, or a pet. What were the conditions like when this happened? What were you wearing? What was the weather like? What determined whether you got a shock?
3. **Applying First Peoples Perspectives** Investigate the role of lightning in First Peoples cultures. Are there traditional stories connected with its power? What do the stories teach? If possible, learn the word for lightning in the language of the local First Peoples in or near the place where you live.

Key Terms

There are three key terms that are highlighted in bold type in this Topic:

- negative charges
- law of electric charge
- positive charges

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meanings. Add other terms that you think are important and want to remember.



CONCEPT 1

Electrons carry a negative charge, and protons carry a positive charge.

Activity

Recalling Atoms and Charge

Sketch an atom. Add labels to show protons and electrons. Write a caption to describe their properties.

negative charges the charges of electrons

positive charges the charges of protons

Rub two different materials together. Depending on the materials you use, something may come off one and transfer to the other, and the two materials will attract each other. About 250 years ago, American scientist Benjamin Franklin used the term **negative charges** to describe the "somethings" rubbed off a material. He said that an excess of **positive charges** were left behind.

Today we know the negative charges are the charges of electrons, and the positive charges are the charges of protons. Protons are part of the nucleus of atoms and are held firmly in place, so they cannot be rubbed off materials. Electrons can be rubbed off, because they surround the nucleus and some are not tightly bound to it.

When electrons are rubbed off a material, it becomes positively charged. The material that gains electrons becomes negatively charged. Charging a material by rubbing is called *charging by friction*. Figure 3.9 shows an example. Whether a material gains or loses electrons depends on the combination of materials.

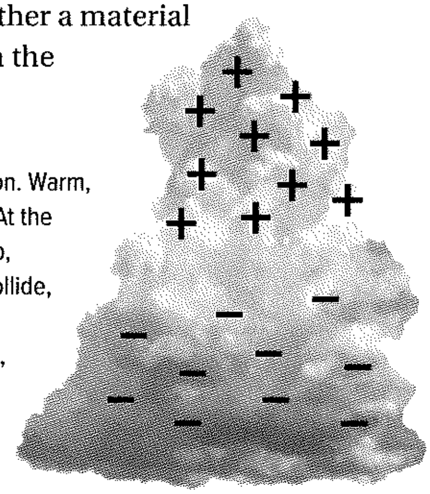


Figure 3.9 Clouds may be charged by friction in a thunderstorm. **How do you think lightning forms?**

Clouds in storms can become charged by friction. Warm, moist air causes strong updrafts in the clouds. At the same time, hail and ice crystals fall from the top, causing downdrafts. As droplets and crystals collide, electrons are stripped from upward-moving particles and are carried downward. As a result, clouds are negatively charged at the bottom and positively charged at the top.

Extending the Connections

Lightning Rock of the Sumas First Nation

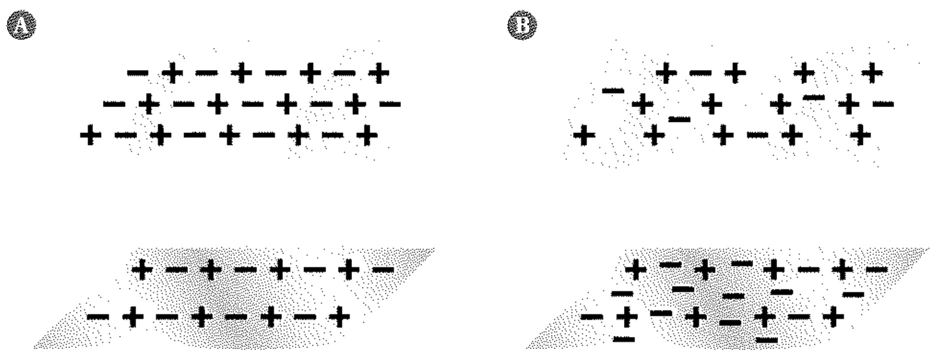
Find out the story of the "transformer rock" that challenged Thunderbird and how a culturally important site stopped a developer's plans.

Electrically Neutral and Electrically Charged Materials

The following is true of uncharged and charged materials or objects:

- **Uncharged Materials:** Before two materials are rubbed together, they have equal numbers of positively charged protons and negatively charged electrons. Because the equal numbers of positive and negative charges cancel each other out, the materials are *electrically neutral.*
- **Charged Materials:** If electrons are rubbed off one material, the protons stay behind and the material becomes *electrically charged.* So does the material that gains the electrons. A material or object that is electrically charged has an unequal number of positive and negative charges.

Figure 3.10 shows two materials before and after they were rubbed together. Observe the number of charges in each material.



This diagram shows a paper towel (top) and an acetate strip (bottom) before they are rubbed together. Therefore, each one has an equal number of positive and negative charges. These cancel each other out so each material is electrically neutral.

This diagram shows the two materials after they are rubbed together. Electrons are rubbed off the paper towel and transferred to the acetate strip. The paper towel now has fewer negative charges, and the acetate strip has more negative charges. The paper towel is positively charged, and the acetate strip is negatively charged.

Figure 3.10 Two materials before and after being rubbed together

Before you leave this page . . .

1. Explain the relationship among negative charges, positive charges, electrons, and protons.
2. Describe what sometimes happens in terms of charges when you rub two different types of materials together.

CONCEPT 2

Opposite charges attract each other, and like charges repel each other.

Activity

Charge the Tape

1. Cut cellophane tape into two 10 cm pieces. Fold over about 5 mm at the end of each piece to make handles.
2. Stick the two pieces of tape on your desk.
3. Hold the pieces of tape by their handles and quickly pull the tape off the desk.
4. Slowly bring the pieces of tape near to each other.
5. Describe what happens as the pieces of tape approach each other. Suggest a possible explanation.

law of electric charge the law stating that opposite charges attract each other, and like charges repel each other

Long before scientists knew what positive charges and negative charges were, they knew how charges interacted with each other. Two important properties of charges are summarized in the **law of electric charge**, which is stated in the box below.

The Law of Electric Charge

1. Opposite charges attract each other.
2. Like charges repel each other.

Connect to Investigation 3-B on page 210

The law of electric charge applies to all individual charges. This means that a negative charge does not just attract another positive charge. Instead, every negative charge attracts every positive charge. In the same way, every negative charge repels every other negative charge, and every positive charge repels every other positive charge. When you bring together objects that have an excess of either positive charges or negative charges, you see the overall result of all these different attractions and repulsions.

Extending the Connections

Applying Properties of Electrical Charges

People who work in jobs where they are exposed to nuclear energy carry a small device that measures exposure to radiation. This device makes use of electrical charges. What other types of technologies depend on the properties of electrical charges?

Attraction Between Charged Objects and Neutral Objects

The law of electric charge explains why charged objects attract neutral objects (Figure 3.11). All neutral objects have an equal number of protons and electrons. Therefore, they have an equal number of positive and negative charges. When you bring a charged object near a neutral object, the electrons in the neutral object do not come off. Instead, the positive and negative charges in the molecules of the object stretch apart from each other. Figure 3.12 shows what happens to a neutral wall when a charged balloon comes close to it.

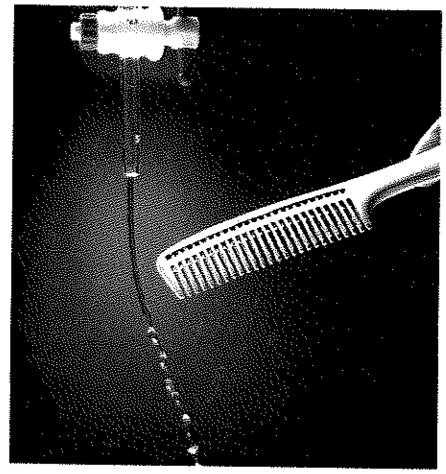


Figure 3.11 In this photo, the comb is charged, and the water is neutral.

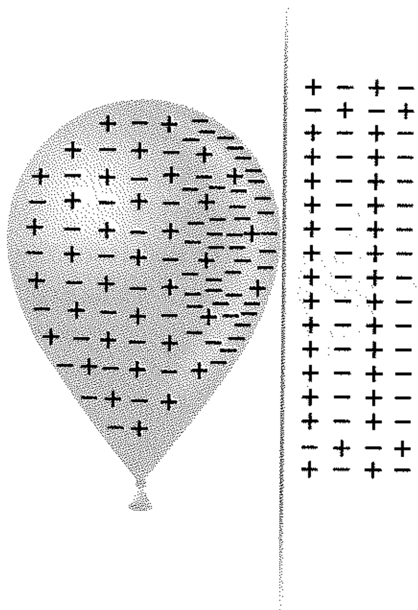


Figure 3.12 This diagram shows why a charged balloon sticks to an electrically neutral wall.

The negative charges in the wall are pushed away from the surface by the negative charges on the balloon. Then the positive ends of the molecules in the wall are attracted to the negative charges on the balloon. These forces of attraction are strong enough to hold the balloon to the wall.

Activity

Repulsion Between Two Charged Objects

Draw a diagram like the one in Figure 3.12 to explain what happens when two negatively charged objects come close to each other.

Before you leave this page . . .

1. State the law of electric charge.
2. Refer to Figures 3.11 and 3.12. Make a labelled sketch, including charges, to explain why a stream of neutral water bends toward a positively charged comb.

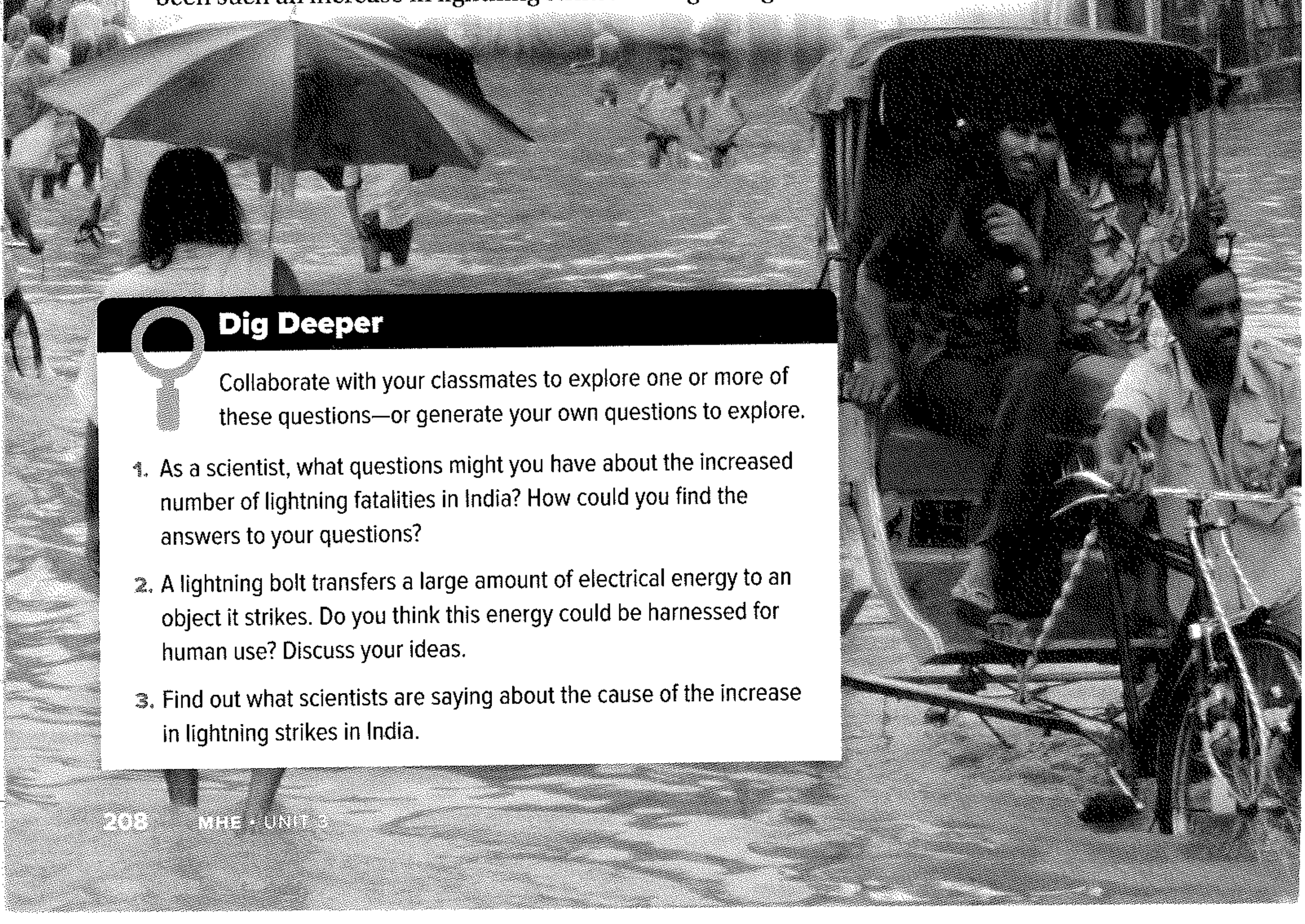
AT ISSUE Lightning Fatalities on the Rise in India

What's the Issue?

June 2016

Monsoons brought more than heavy rain to several states in India this summer. Lightning strikes associated with the storms killed nearly 100 people over just a two-day period. Lightning strikes are typical in monsoon season, but this level of lightning activity is unusual. Worst hit was the eastern state of Bihar, with 59 fatalities. Most of the victims were farmers and workers working in the fields. As one injured person told news agencies, "When it was raining we immediately took shelter. It [the lightning bolt] hit us there, and then we fell unconscious. We could not understand what had happened. Then in the middle, when I regained consciousness, I realised that I had been hit by something."

Thousands of lightning-related fatalities occur each year in India, and this number is on the rise. Nearly 25 000 people were killed by lightning in India over the last 10 years. This number is up nearly 50% from the previous 10 years. The Indian government has called on scientists to try to explain why there has been such an increase in lightning strikes and lightning-related fatalities.



Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. As a scientist, what questions might you have about the increased number of lightning fatalities in India? How could you find the answers to your questions?
2. A lightning bolt transfers a large amount of electrical energy to an object it strikes. Do you think this energy could be harnessed for human use? Discuss your ideas.
3. Find out what scientists are saying about the cause of the increase in lightning strikes in India.

Check Your Understanding of Topic 3.2

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. You have three objects. One is positively charged. One is neutral. And one is negatively charged. Use sentences and sketches to compare the numbers of positive and negative charges in each of these objects. PA C

2. Two items of clothing are made of different materials. They are tumbled together in a clothes dryer. The items stick together when they are removed from the dryer, as shown below.

   a) Name the process that has just taken place.

   b) Explain how this process could cause the clothing items to stick together. PA AI

3. Use the terms electrically charged and electrically neutral to explain how the comb in Figure 3.11 can attract the water stream without touching it. PA

4. You have four different materials labelled A, B, X, and Y. After you rub A and B together, they attract each other. After you rub X and Y together, they attract each other. Now you bring A near to X and observe that they attract each other. What would happen if you brought B near to Y? Explain your reasoning. PA

Connecting Ideas

5. You have been rubbing two materials together for several minutes, but neither seems to be charged. What questions do you have about this situation? What is one way you could begin to investigate a possible explanation? QP E

6. You are asked to explain the concepts of like charges repelling and unlike charges attracting each other to a grade 6 class. What could you use as an analogy to explain the concepts? Write presentation notes that use your example to explain the interaction between charges. PA C

Making New Connections

7. Consider the following set of facts.

   The first-known person to write about the charged behaviour of objects was a Greek thinker named Thales (THAY-leez), about 2500 years ago. He noticed that when he rubbed a material called amber against fur or wool fabric, he heard crackling sounds and saw small flashes of light. (Amber is a clear, yellow-orange solid that formed from the hardened sap of trees that lived millions of years ago.) Thales also noticed that rubbed amber picked up feathers, leaves, and other small, light objects. When the atom's negatively charged particle was discovered in 1897, it was given the name electron. This word comes directly from an ancient Greek word, *elektron*, which means amber.

   Write a brief paragraph of two or three sentences that describes how past and present are connected by this set of facts. AI C

INVESTIGATION
3-B
STRUCTURED INQUIRY

Skills and Strategies
- Planning and Conducting
- Applying and Innovating
- Communicating

Safety
- Use care when handling glass objects to avoid breaking them or being cut.
- Use care when handling any sharp objects.

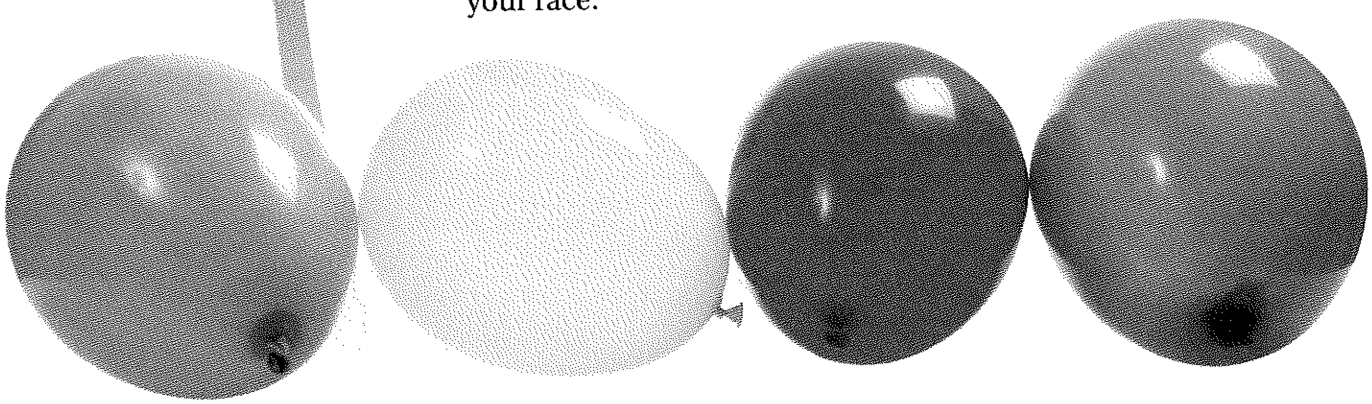
What You Need
- materials that can charge an object by friction
- objects that can be charged by friction and that will roll, float, or slide easily
- masking tape or other similar tape
- non-latex gloves

The Great Race

Your team will be moving an object along a race track using only attraction and repulsion. The team that gets its object over the finish line first wins.

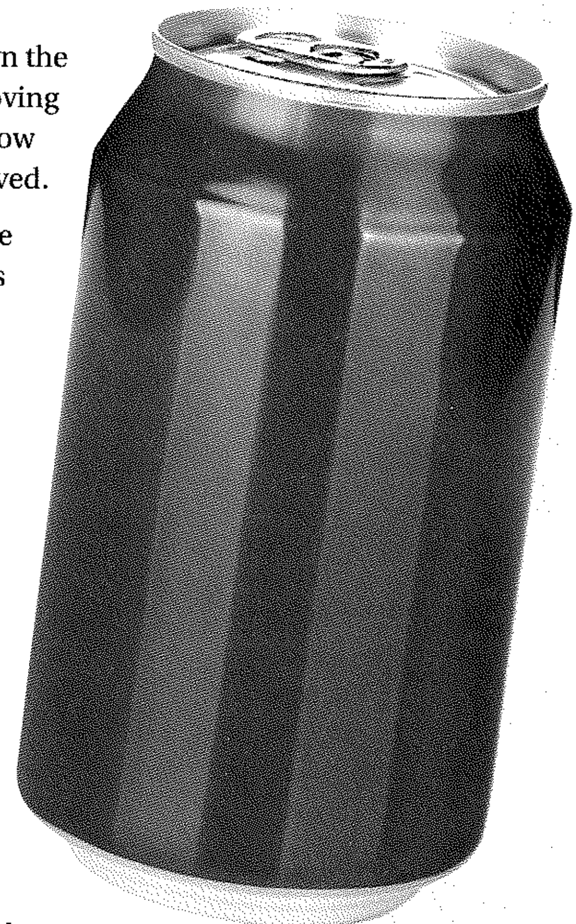
Question
How can you move an object using only attraction or repulsion?

Procedure
1. As a class, choose an area for a race track. Use tape to mark the starting line and the finishing line.
2. As a team, choose the object that you will be racing. You must be able to make the object roll, float, or slide without touching it or blowing on it, using only attraction and/or repulsion.
3. Select another object that you will use to attract or repel your object to make it move along the track.
4. Rub your objects with different materials to generate charges. Wearing gloves may improve your results. Observe how the charged objects behave when brought close together. Based on these tests, decide how you will charge your objects. Revise your choices as required.
5. When all of the teams have made their choices, carry out your race.



Process, Analyze, and Communicate

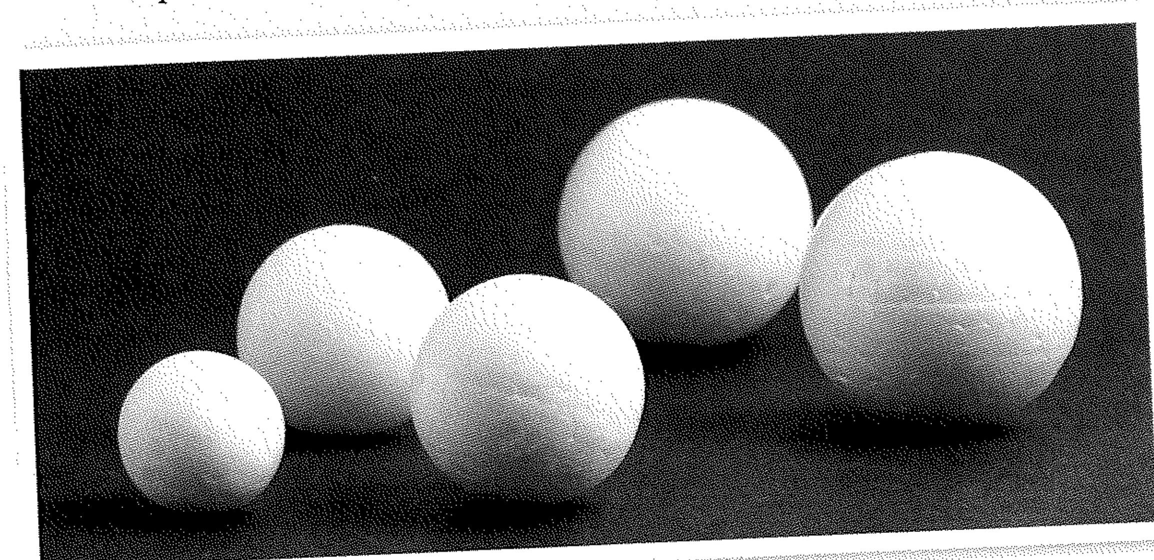
1. Make a sketch of the object that your team raced down the track, and the object that attracted or repelled the moving object. Add plus and minus signs to your sketch to show a possible explanation for why your racing object moved.
2. Write a paragraph that explains why you think that the winning team's object won the race. Use the concepts of the law of electric charge in your explanation.
3. What would you do differently if you were planning another race?



Apply and Innovate

4. As a team, design another type of "trick" based on the law of electric charge that you could perform. For example:
   - Could you make an object spin on a platform?
   - Could you design an obstacle course for a rolling, floating, or sliding object?
   - Could you set up a "Charged Circus" with different kinds of acts and feats?

   Choose your trick and design a procedure that will obtain your desired result. If there is time, practise and perform your trick.
5. Suggest one application that moving an object by attraction or repulsion might have in industry, in manufacturing, or in a consumer product.



TOPIC 3.3

How do charges flow through the components of a circuit?

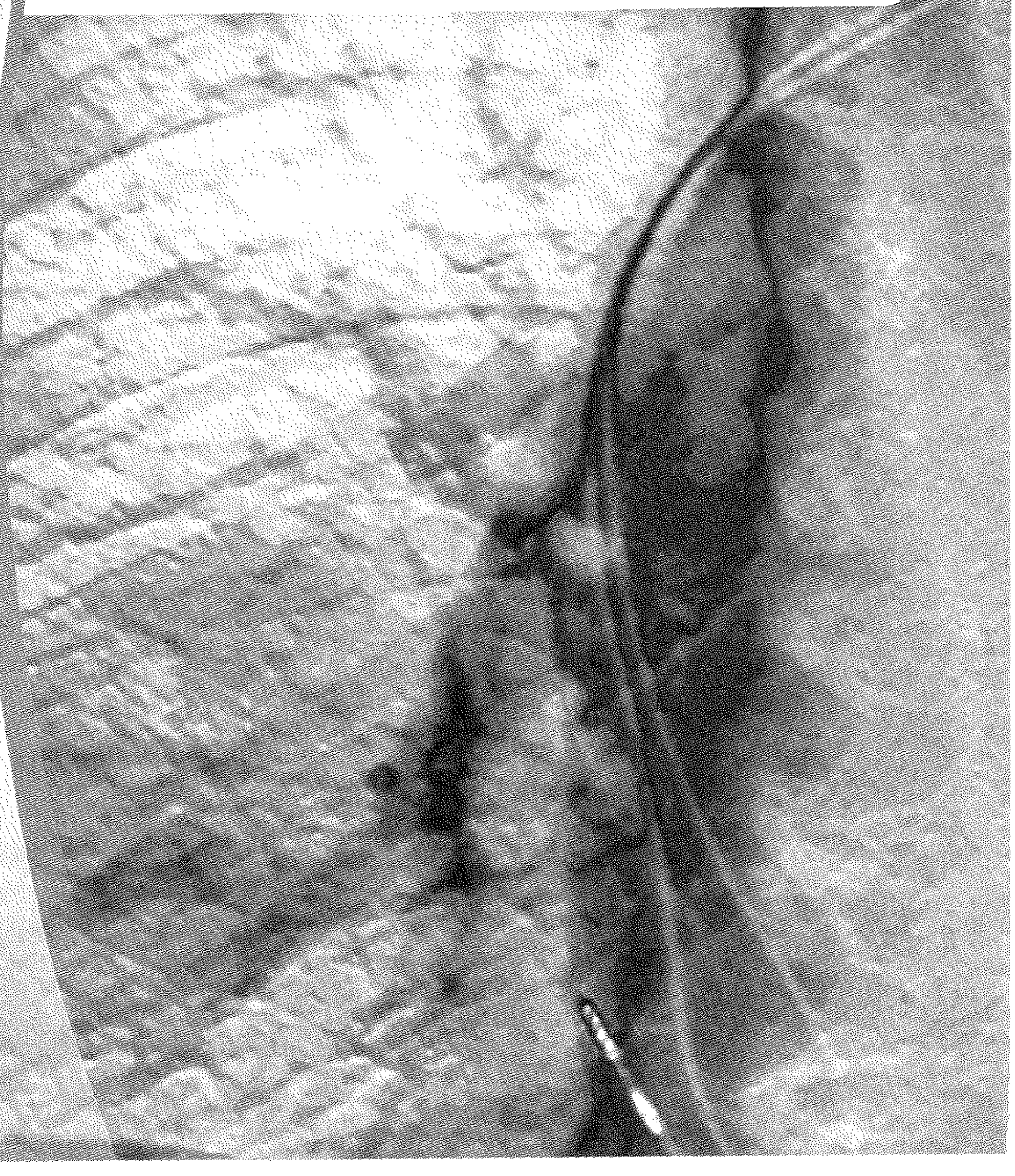
Key Concepts

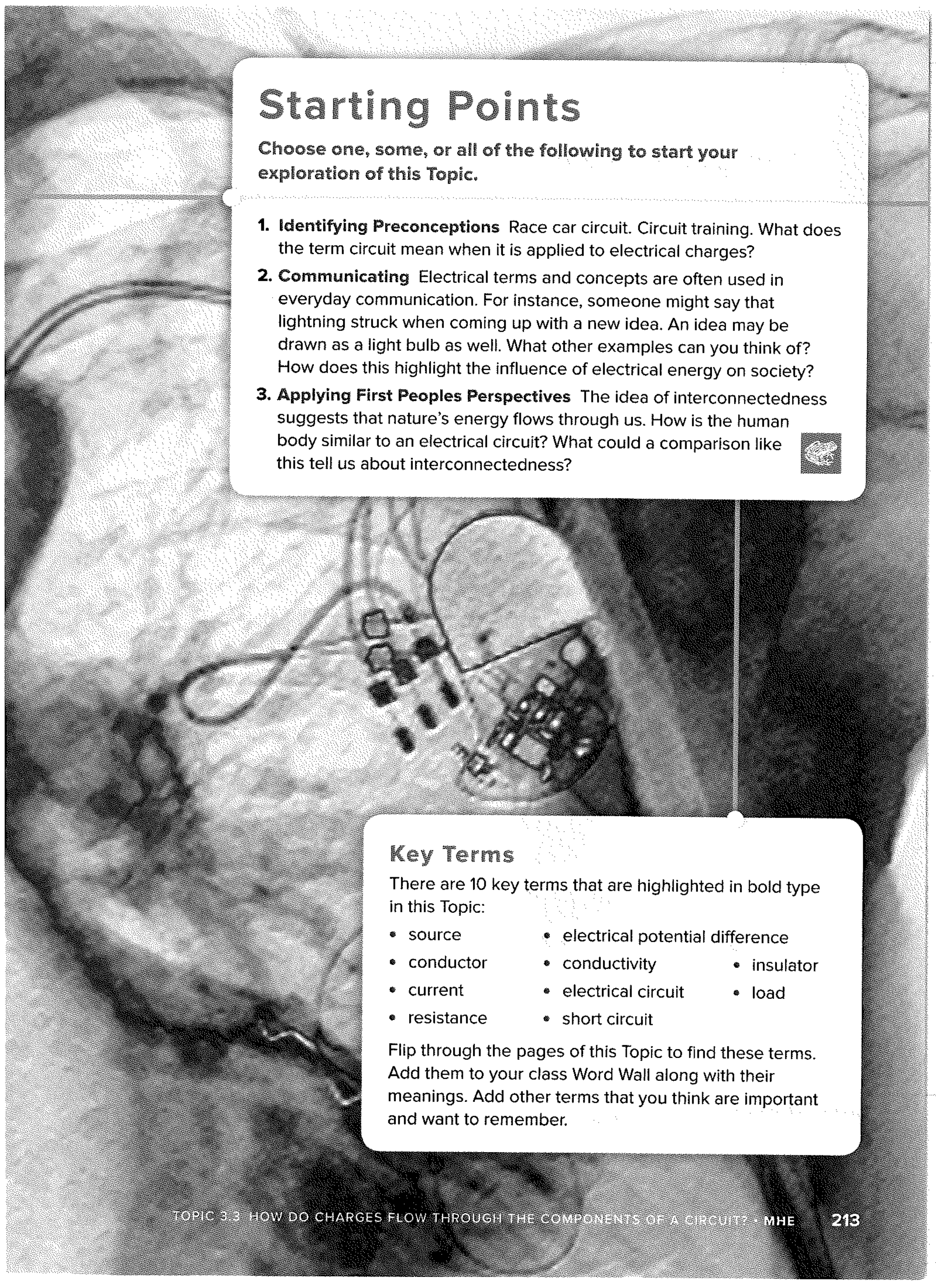
- Chemical energy separates electrical charges in cells.
- Charges can flow through conductors, but not insulators.
- Moving electrical charges form an electric current.
- A load resists the flow of current.
- Conductors must form a closed loop to allow current to flow.

Curricular Competencies

- Collaboratively and personally plan, select, and use appropriate investigation methods to collect reliable data.
- Select and use appropriate equipment to systematically and accurately collect and record data.
- Demonstrate a sustained intellectual curiosity about a scientific topic or problem of personal interest.

In 1950, Canadian Drs. Wilfred Bigelow and John Callaghan first used an external electrical device, developed by Dr. John Hopps, to pace the beating of a dog's heart. The device was the first pacemaker. Modern technology has brought the pacemaker a long way since those days. Pacemakers are used to help people with irregular heartbeats. As well, they are small enough to be surgically inserted under the skin on the chest. The electrical energy to run a pacemaker comes from a battery that lasts 10 years or longer. Electrical charges flow through the tiny electrical device, completing an electrical pathway called a circuit within the human body.





Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** Race car circuit. Circuit training. What does the term circuit mean when it is applied to electrical charges?
2. **Communicating** Electrical terms and concepts are often used in everyday communication. For instance, someone might say that lightning struck when coming up with a new idea. An idea may be drawn as a light bulb as well. What other examples can you think of? How does this highlight the influence of electrical energy on society?
3. **Applying First Peoples Perspectives** The idea of interconnectedness suggests that nature's energy flows through us. How is the human body similar to an electrical circuit? What could a comparison like this tell us about interconnectedness?

Key Terms

There are 10 key terms that are highlighted in bold type in this Topic:

- source
- conductor
- current
- resistance
- electrical potential difference
- conductivity
- electrical circuit
- short circuit
- insulator
- load

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meanings. Add other terms that you think are important and want to remember.

CONCEPT 1

Chemical energy separates electrical charges in cells.

Activity

Battle of the Batteries

Although most people buy batteries at the store, it is actually possible to make your own. Find out how online. Check your design with your teacher before building the battery. Then enter a class "battle of the batteries" to see who can get their battery to run a device your teacher specifies.

Connect to Investigation 3-C on page 228

An AA "battery" is an *electrochemical cell*. In a cell, chemical reactions of two different metals or metal compounds occur on the surface of *electrodes*. The electrodes are in a solution called an *electrolyte*. The reactions cause one electrode to become positively charged, and the other to become negatively charged. The electrodes are in contact with *terminals* in the cell. When terminals are connected to an electrical pathway, charges flow through it. Figure 3.13 shows two types of cells. A *dry cell* contains a moist paste as an electrolyte. In a *wet cell*, the electrodes sit in a liquid solution. Both transform chemical energy into electrical energy to run portable devices.

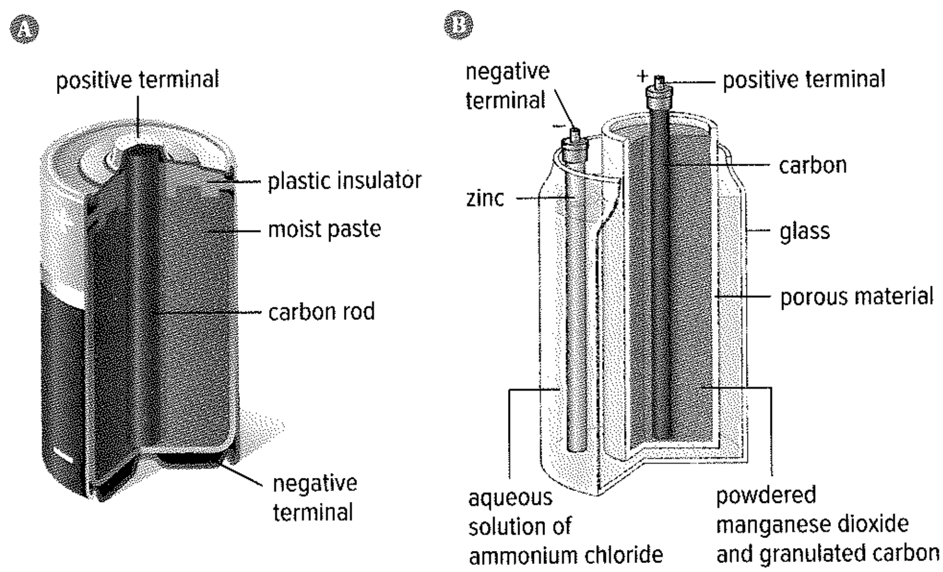


Figure 3.13 A dry cell A and a wet cell B.

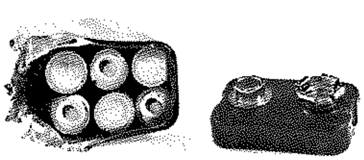


Figure 3.14 The battery shown here is made up of six individual cells.

source anything that supplies electrical energy

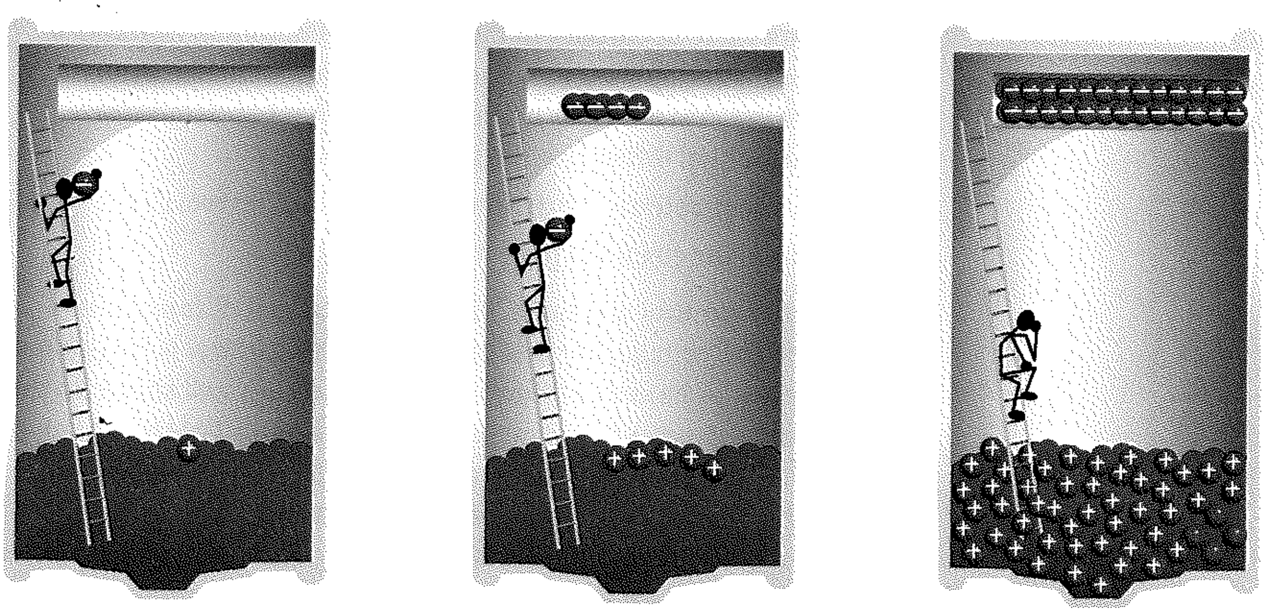
In comparison, a *battery* is a connection of two or more cells. You make a battery when you place AA cells together in an electrical device. Often, several cells are packaged together in a casing to make a battery (Figure 3.14). Cells and batteries are sources. A **source** is anything that supplies electrical energy. Electrical outlets are also sources.

Understanding How a Cell Works

Because opposite charges attract each other, it takes energy to separate positive and negative charges. The previous Topic explained how friction can provide this energy. In a cell, chemical reactions separate the positive and negative charges. In other words, chemical energy does the work of separating the charges. (Energy is the ability to do work. Work is done on an object when a force acts on it and makes it move through some distance.) Because work went into separating the charges, the electrons now have the energy to do other work, such as running a fan or a watch. The electrical energy now stored in the cell is a form of potential energy. It has the potential to do work because of the separation or position of the charges.

Figure 3.15 shows a model that explains how charges are separated and gain electrical potential energy as a cell becomes charged. A worker represents chemical energy released in chemical reactions.

Figure 3.15 The worker in this model represents chemical energy.



The worker carries electrons up a ladder and places them at the negative terminal. The worker leaves positively charged ions on the bottom at the positive terminal. The first electron is easy to carry up the ladder because only one pair of charges is being separated. The attraction is not very strong. Only a small amount of electrical energy is stored in the cell.

After a few charges have been separated, all of the positive charges of the positively charged ions at the positive terminal are attracting the negative charge of the electron that the worker is carrying. As well, the negative charges of the electrons at the negative terminal are repelling the negative charge of the electron that the worker is carrying. So it takes more energy to carry each additional electron up the ladder. The worker (chemical energy) has done a lot of work to separate the charges. This energy is now stored in the electrical potential energy of the separated charges.

Eventually, the repulsion of the electron by the negative charges and the attraction by the positive charges gets so strong that the worker cannot carry any more electrons up the ladder. No more chemical energy will be transformed into electrical energy.

Electrical Potential Difference

electrical potential difference a quantity that provides a measure of the electrical potential energy a unit of charge gains when passing through a source

A unit of charge, called a *coulomb*, gains electrical potential energy when it passes through a source, such as a battery. The quantity that provides a measure of the electrical potential energy that is gained by a unit of charge is called the **electrical potential difference**. It is called a difference because it measures the difference in electrical potential energy per unit of charge between the positive terminal and the negative terminal in a cell. Think of Figure 3.15. To charge a cell, a chemical reaction does work to separate electrons and positive ions. It takes more energy to carry each electron up the ladder. This is because the forces of attraction and repulsion acting on it get stronger and stronger. Separating the final charge requires the most energy of all. The electrical potential difference of the cell represents the amount of energy it took to carry the last unit of charge up the ladder.

The electrical potential difference of a cell is determined by the nature of the chemical reaction that takes place in the cell. Cells and batteries are rated according to their electrical potential difference between one terminal and the other. Other sources, like electrical outlets, are rated in a similar manner. The symbol and units for electrical potential difference are given below.

- The electrical potential difference is measured in volts (V).
- The symbol for electrical potential difference is *V*.

Because of its symbol and units, electrical potential difference is often called the voltage. For this reason the term *voltage* is frequently used on cells and batteries (Figure 3.16). In the 1.5 V cell shown in the figure, it took 1.5 units of energy to carry that last unit of charge up the ladder. Note that if two cells are linked together, as in a flashlight or radio, their voltages add up. For example, if two 1.5 V cells are placed in a radio, their voltage is 3 V. Similarly, if six cells are packaged together, they form a 9 V battery.

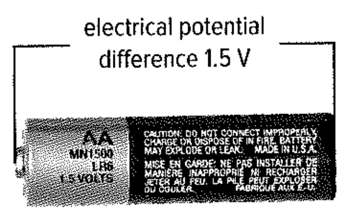


Figure 3.16 A typical AA or AAA cell provides an electrical potential difference of 1.5 V.

Before you leave this page . . .

1. Use an analogy other than a worker and a ladder to explain how chemical energy is transformed into electrical energy in a cell.
2. Why is the electrical potential difference of a source referred to as a difference?

CONCEPT 2

Charges can flow through conductors, but not insulators.

Activity

Charging Balloons

1. Wearing non-latex gloves, rub a rubber balloon with a wool cloth. Making sure the balloon does not touch anything, bring it near several tiny bits of paper.
2. Still wearing gloves, rub a metallic (mylar) balloon with a wool cloth. Bring the balloon near the bits of paper, being careful not to touch it to anything.
3. Repeat steps 1 and 2 without wearing the gloves.
4. Compare your observations. What differences do you observe among the four tests you completed? Suggest a reason for each difference you observed.

When two different solid materials are rubbed together, electrons can be transferred from one material to the other. The electrons will either stay on the surface of the new material or travel through it. Any material that electrical charges can move through is called a **conductor**. Electrons can move through almost all metals, but they move through some metals more easily than others. How easily the charges move through a material is referred to as its **conductivity**. A material through which charges cannot travel at all is an **insulator**.

Look at Figure 3.17. Most electrical wiring is made out of metals that conduct charges very well, such as copper. Most electrical cords and wires are covered with rubber or plastic. These materials are insulators. Most non-metals, such as glass and wood, are also insulators.

conductor a material charges can travel through

conductivity an indication of how easily charges travel through a material

insulator a material charges cannot travel through

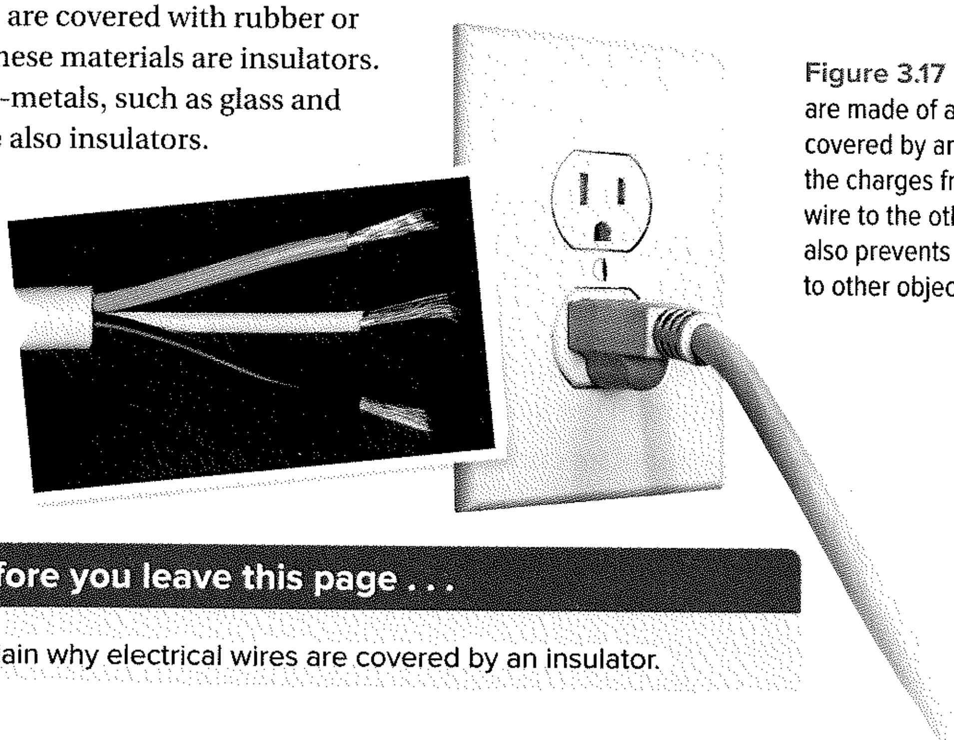


Figure 3.17 Electrical cords are made of a metal conductor covered by an insulator to prevent the charges from moving from one wire to the other. The insulator also prevents charges from moving to other objects, including you.

Before you leave this page . . .

1. Explain why electrical wires are covered by an insulator.

CONCEPT 3

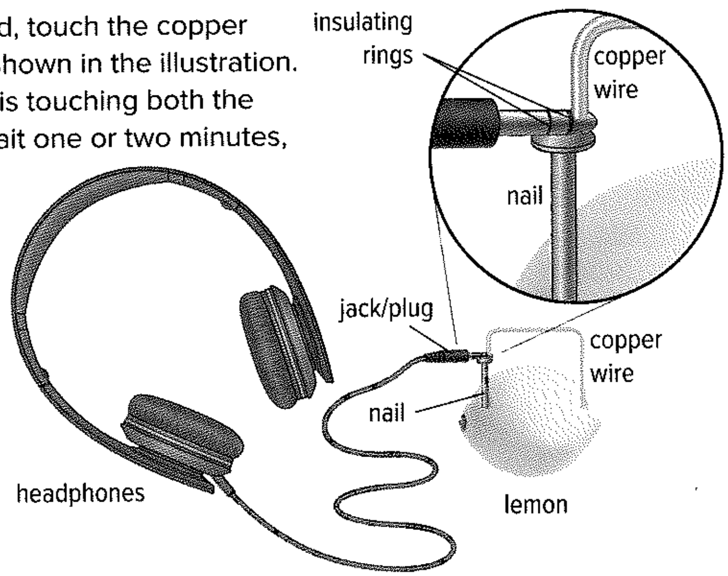
Moving electrical charges form an electric current.

Activity

Electric Lemon

Safety: Advise your teacher if you are allergic to citrus fruits.

1. Stick a copper wire into one end of the lemon and a non-galvanized nail into the other.
2. Bend the top of the copper wire so it nearly touches the nail.
3. Put on the headphones. Hold the plug of the headphones on top of the nail and listen.
4. With your other hand, touch the copper wire to the plug as shown in the illustration. Make sure the plug is touching both the nail and the wire. Wait one or two minutes, listening carefully.
5. Try to account for the differences you observed.



Charges can flow from a source through conducting materials to an appliance or an electrical device, such as a cellphone. Chemical energy from the source causes charges to move through the conductor, usually wires, carrying energy to the device. The moving charges are called an electric **current**. You need to remember the symbol and units for current because you will be using them in calculations in the next Topic.

current moving charges

Connect to Investigation 3-D on page 230

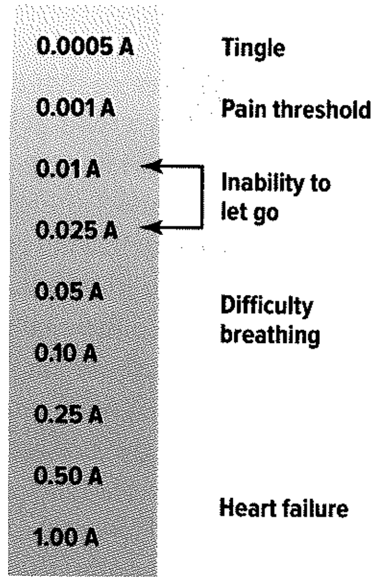
- The symbol for current is I.
- Current is measured in units called amperes. The symbol for amperes is A.

For example, the equation $I = 3$ A means that the current (I) is three amperes (3 A).
The smaller unit of electric current is the milliampere (1A = 1000 mA).

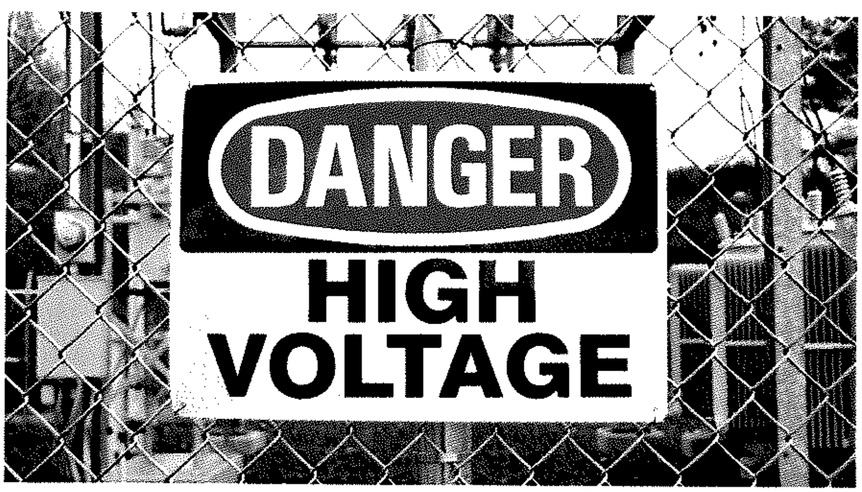
Activity

Effects of Voltage and Current on the Human Body

The scale on the right shows how the effects of current on the human body vary with the amount of current that flows through the body. The voltage is 120 V, the standard household voltage. Study the scale and then answer the questions that follow.



1. Find out what the electric current is in homes in B.C. What type of caution does the scale on the right suggest that you should take around household currents? Justify your response.
2. Electric current is used in some medical applications to treat health problems. Find out more about these applications and choose one that interests you. How does the treatment work? What kind of voltage and current is involved? What safety precautions, if any, are taken during the treatment?
3. Electrical hazard warning signs often say "Danger High Voltage." Considering the effects of current on the human body, do you think this warning should refer to current rather than voltage? Discuss your ideas as a class.



Before you leave this page . . .

1. Describe the relationship between moving charges and electric current.

Connect to Investigation 3-E on page 232

CONCEPT 4

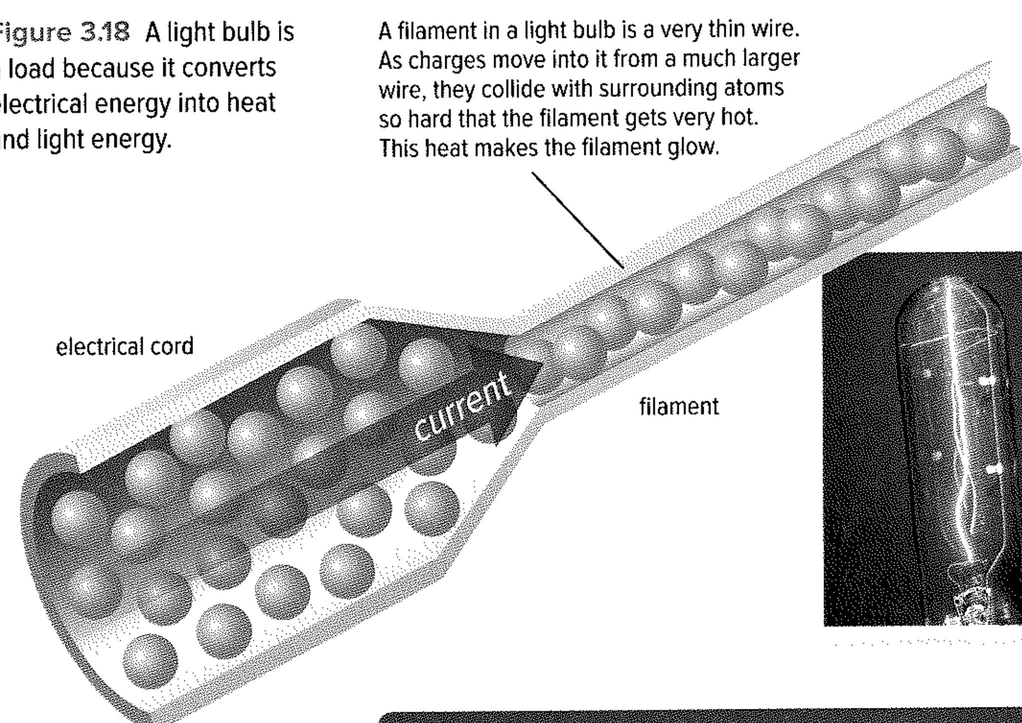
A load resists the flow of current.

load device that converts electrical energy into another form of energy

resistance describes the amount that current is hindered by a load

A device that converts electrical energy into another type of energy is a **load**. A light bulb is a load that transforms electrical energy into light energy. A radio is a load that transforms electrical energy into sound energy. As electrons pass through a load, they lose energy as electrical energy is converted into another type of energy.

A load resists, or hinders, the flow of current. This happens because the electrons in the current collide with the atoms that make up the load, or even with each other, as shown in Figure 3.18. The collisions interfere with the flow of the current. The degree to which the flow of current is hindered is referred to as **resistance**. The symbol for resistance is *R*. The unit used to measure resistance is the ohm. The symbol for an ohm is the Greek letter omega, Ω. You need to remember these symbols and units to complete calculations in Topic 3.4. The filament in a light bulb is a good example of resistance to the flow of charges. Figure 3.18 shows how resistance makes a filament-type light bulb light up.



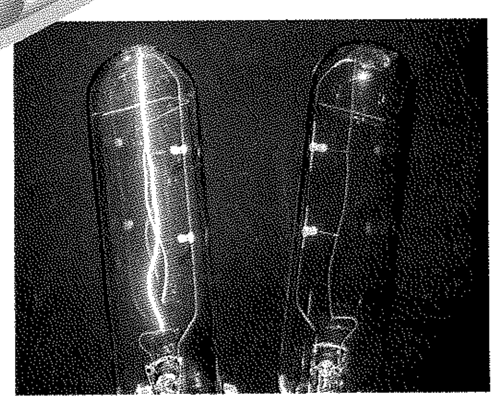


Figure 3.18 A light bulb is a load because it converts electrical energy into heat and light energy.

Before you leave this page . . .

1. Use the terms source, current, and load to describe how you think a flashlight works.

CONCEPT 5

Conductors must form a closed loop to allow current to flow.

Activity

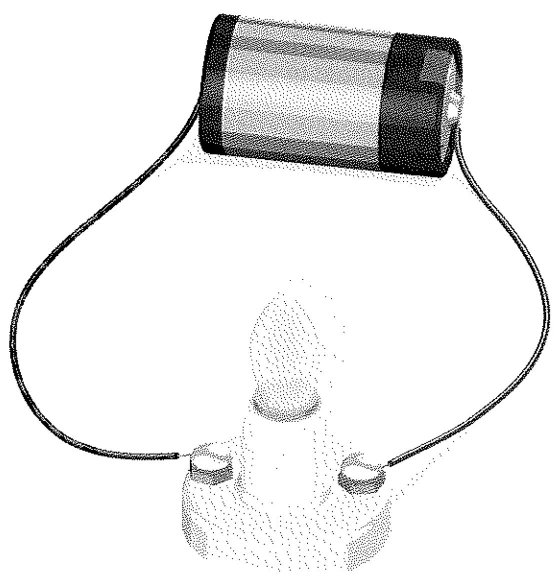
Take Apart a Flashlight

1. Carefully take apart the flashlight provided. Draw a diagram of how the components fit together inside. Label the components.
2. Using a coloured pencil or marker, draw arrows to indicate the direction in which you think the charges flow through the components of the flashlight.
3. Compare your diagram to those drawn by others. Make any changes you think will improve your diagram.
4. Which components are essential to the function of the flashlight? What are the roles of the other components?
5. Use the materials provided by your teacher to light a flashlight bulb. Did the light go on? If not, explain why you think it did not. Try again until you are successful.

When a source, load, and conductor are connected in a way that allows current to flow, it is called an **electrical circuit**. In order for current to flow, a circuit must form a closed loop. Figure 3.19 shows the simplest possible circuit having only a source and a load.

electrical circuit at a minimum, a source, a load, and wires in a closed loop that allow current to flow

Without a load to resist the flow of current, the current would be so large that the conductor would quickly get very hot and start a fire. This would be called a **short circuit**. Short circuits are fire hazards if they occur within a building's wiring.



short circuit a circuit with a resistance that is too low, making the current so high that it is dangerous

Figure 3.19 A closed loop allows current to flow and light the bulb. **Short circuits can be dangerous if they occur in the wiring of a building. Suggest how a short circuit might form in a building.**

Modelling the Flow of Current

Figure 3.20 shows how current flows through a simple, closed circuit.

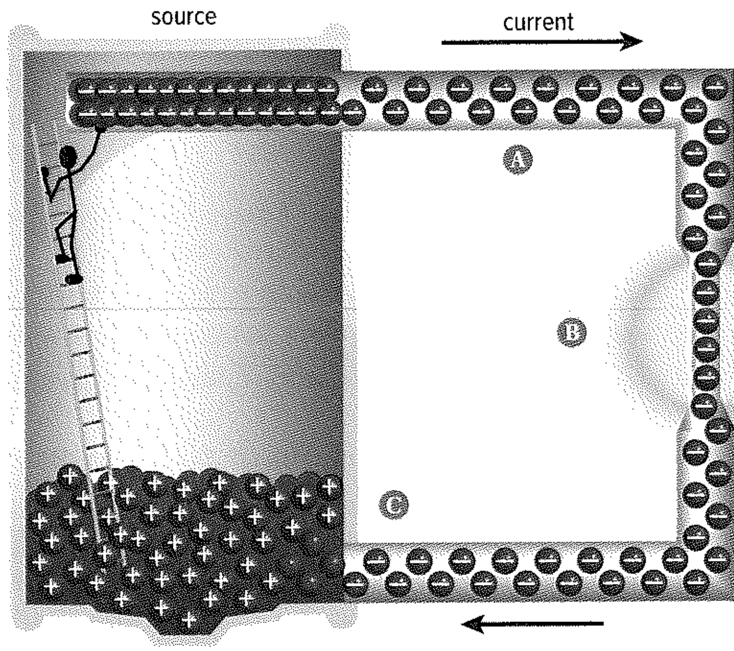


Figure 3.20 How current flows through a circuit

A The conductors already have electrons in them. The negative terminal repels the negative charges in the conductor; the positive terminal attracts them. As a result, electrons move along the conducting wires, and electrons from the cell move into the conductor.

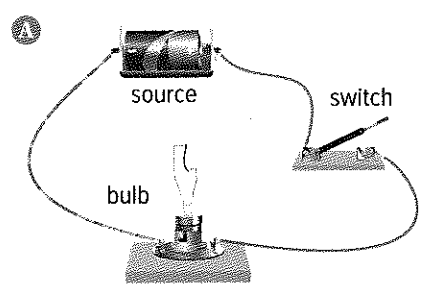
B As the electrons pass through the load, they transfer some of their energy to the load. They then leave the load and return to the cell.

C Electrons enter the cell and combine with positive ions to become neutral. Over time, there are fewer electrons at the negative terminal and fewer positive ions at the positive terminal. The worker can carry more electrons up the ladder, keeping the number of separated charges equal at all times.

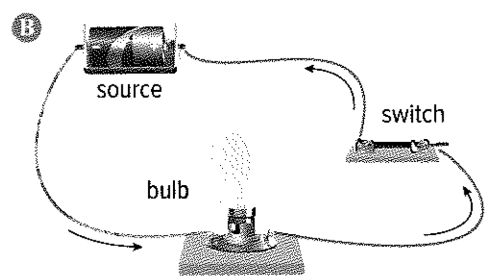
Controlling the Flow of Current

The light bulb in Figure 3.19 would always be on. In a typical circuit, a switch lets you turn the light on and off (Figure 3.21).

Figure 3.21 How a switch controls current in a circuit



The switch is open. There is no closed path so the current cannot flow. The circuit is open.

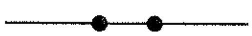


The switch is closed, allowing current to flow and the light to be on. The circuit is referred to as closed.

Using Circuit Diagrams

Simple symbols are used to make it easier to draw circuits. Table 3.1 lists the symbols for the basic parts of a circuit. The quantities used to describe the components and their units of measurement are also included. Figure 3.22 shows how the symbols are used to draw a circuit with a cell or a battery, conducting wires, a load, and a switch.

Table 3.1 **Symbols for Circuit Diagrams**

Component		Symbol	Quantity	Unit of Measurement
Source	Cell		Electrical Potential Difference (*V*)	Volt (V)
	Battery			
Conducting Wire			Current (*I*)	Ampere (A)
Load			Resistance (*R*)	Ohm (Ω)
Switch	Open			
	Closed			

Note: The long line in the symbols for cells or batteries represents the positive terminal and the short line represents the negative terminal.

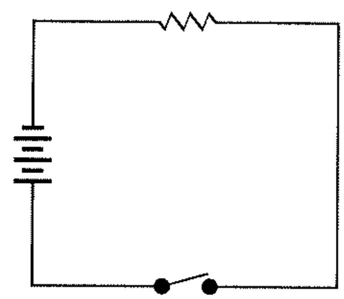


Figure 3.22 This circuit diagram describes the same circuit that is shown in Figure 3.21A. **Identify the source, the load, and the switch in the circuit diagram.**

Activity

Drawing Circuit Diagrams

Appendix A on page 394 provides more guidance on how to draw circuit diagrams. Use this appendix to draw circuit diagrams for the following circuits.

1. A circuit with a cell that runs a buzzer without a switch.
2. A circuit with a battery in which an open switch has turned off two light bulbs.
3. A circuit with a battery, a closed switch, two light bulbs, and a clock.

Putting It All Together

To gain a better understanding of how the components of an electrical circuit work together, compare the electrical circuit with the water circuit in Figure 3.23.

Water Circuit

In the water circuit, the pump lifts the water to a higher level against the pull of gravity. A valve at the top of the pipe controls whether the water flows down. When the water runs down, it turns a water wheel.

Electrical Circuit

In the electrical circuit, the cell or battery is similar to the pump. It raises charges to a higher level of electrical potential energy. The switch is like the valve. It determines whether the electrons are allowed to flow through the circuit. When the electrons are allowed to flow, the current runs through the load and lights the light bulb.

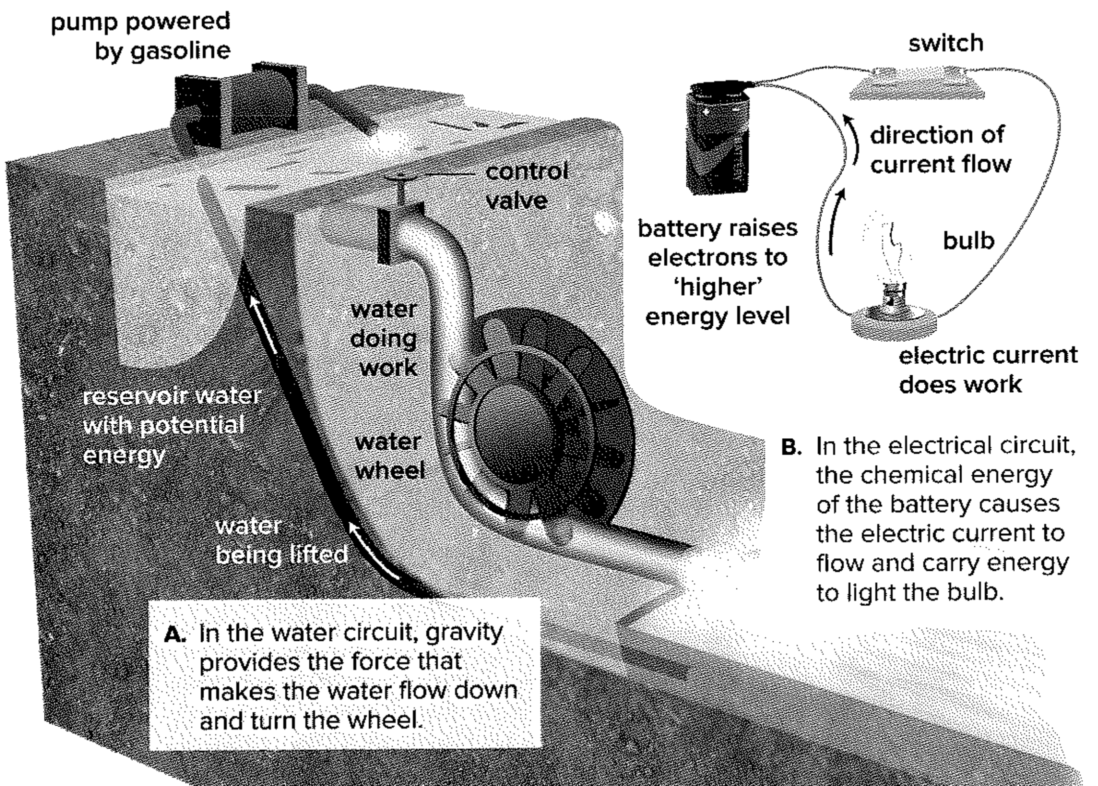


Figure 3.23
A comparison of a water circuit and an electrical circuit

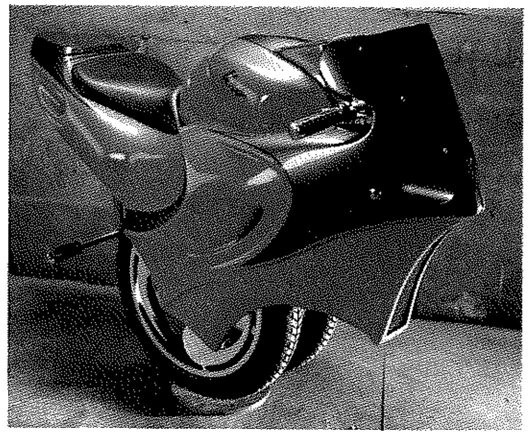
Before you leave this page . . .

1. Explain what "short circuit" means.
2. Describe the role of a switch in an electrical circuit.
3. Draw a circuit diagram for the circuit shown in Figure 3.21B.

AT ISSUE Electric transportation and accessories hit the road

What's the Issue?

The world of electric vehicles is expanding at high speed. Electric cars, motorcycles, and scooters are already a common sight in many B.C. cities, but more unusual types of electric transportation are on the horizon. Electric airplanes, skateboards, and even paragliders are just a few ways to get around that rely on batteries. And the trend toward electric transportation doesn't just stop at vehicles. How about a motorcycle helmet with an electronic heads-up display that allows you to see your speed on your visor? Even a jacket wired to blink when you make a turn could be coming soon to a closet near you.



Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. Ben Gulak is the inventor of the motorcycle shown on this page. His invention began as a school science project. What questions do you have about electric vehicles in Canada? Choose the one that interests you most and explore it further.
2. The B.C. government has made it legal for electric vehicles to drive in HOV (high occupancy vehicle) lanes without meeting occupancy requirements. Discuss whether you agree or disagree with this legislation.
3. Electrical clothing isn't just for transportation fashions. Some are practical, like a hoodie wired for sound or a winter coat with a built in heater. Others are just fun and attractive, like a dress that lights up in full colour. What do you think of electric fashion? Is it a waste of electrical energy and one more way to add batteries to the landfill? Or is it a cool and practical trend you would follow?

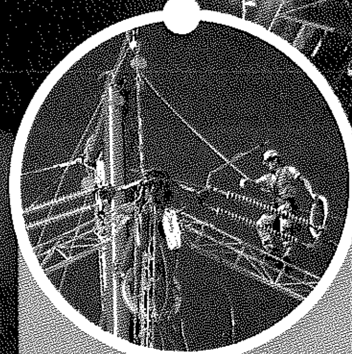
Focus on Physics

What kinds of jobs involve electrical energy?

- Power Station Operator
- Construction Inspector
- Powerline Technician
- Electronic Service Technician
- Robotics Engineer

Electrical Engineer

Want to be involved in leading-edge research to build better generating systems, improve telecommunications technology, and enhance computer systems? If so, electrical engineering may be the career for you.



Electrician

Whether wiring residential homes or the tallest skyscrapers, it's an electrician's job to keep current flowing reliably and safely.

Meteorologist

Understanding electrical energy and how charges behave helps meteorologists predict where lightning will strike, and when.

Questions

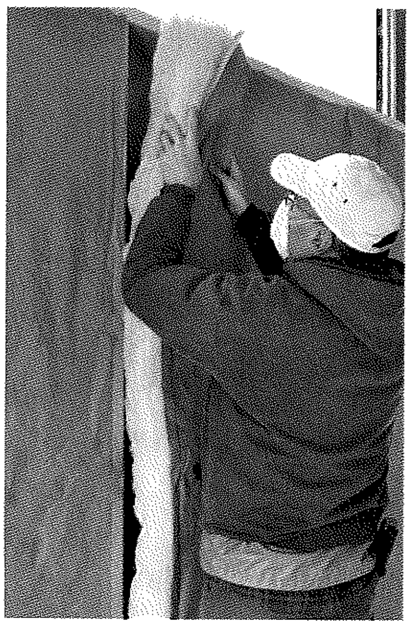
1. What other jobs and careers do you know or can you think of that involve electrical energy?
2. Research a job or career related to Unit 3 that interests you. What attracts you to it? What kinds of things do you have to know, do, and understand for this job or career?

Check Your Understanding of Topic 3.3

QP Questioning and Predicting   PC Planning and Conducting   PA Processing and Analyzing   E Evaluating
AI Applying and Innovating   C Communicating

Understanding Key Ideas

1. a) How is energy stored in a cell or in a battery?
   b) What kind of energy was used to generate the electrical energy that is stored in a cell? PA
2. Compare the insulation in the building below to an insulator as it relates to the movement of electrons through a material. PA E AI



3. a) Define the term *load* as it applies to an electrical circuit.
   b) Give three examples of loads that you would find in an electrical circuit. PA
4. What is the relationship between a load and resistance in an electrical circuit? PA
5. Draw a circuit diagram for the following:
   a) an open circuit with one source, two loads, and one switch
   b) a closed circuit with one source, two loads, and one switch PA C
6. For each of the following pairs of terms, explain the relationship between the terms. PA
   a) conductor; conductivity
   b) closed circuit; short circuit
   c) source; electrical potential difference
7. a) Explain the difference between a cell and a battery.
   b) Identify a portable electrical device you use regularly. Do you think it uses a cell or a battery? Explain your reasoning. PA E AI
8. Your lab partner tells you that the circuit that you are testing has an electrical potential difference of 2 A. What is wrong with the statement? Write the statement correctly. PA

Connecting Ideas

9. A classmate is working with a source that is labelled 18 V. The classmate refers to the source as a cell. Why might you think that the term cell is incorrect? How is the source most likely related to a cell? PA E AI

Making New Connections

10. You head out in a car for a picnic at a local park. Just as you finish your picnic, a thunderstorm rolls in. A moment later, lightning streaks across the sky. One friend urges you to take shelter under a nearby tree. Another suggests you return to the car, which is farther away. With which friend do you agree and why? Refer to insulators and conductors in your response. PA E AI

INVESTIGATION

3-C

STRUCTURED AND GUIDED INQUIRY

Skills and Strategies

- Processing and Analyzing
- Evaluating

What You Need

- access to information resources (for example: online, in-print, interviews)

Investigating Cells and Batteries

PART A: MAKE A CELL-ECTION—STRUCTURED INQUIRY

Question

What properties do you consider important in selecting a cell or battery for a specific application?

Procedure

1. Design a table with four headings: Application, Properties of Cells That Could Be Used, Recommended Cell, and Reasons for Recommendation. Give your table an appropriate title.
2. Research the meanings of these properties: storage, capacity, recharge life, primary cell, secondary cell.
3. Use the information in the Table of Cells and Batteries in Common Use on the next page, and other sources of your choice as information resources. For each application that follows, use your research to fill in a row in the table you created in step 1.
   - key holder with a light
   - travel alarm clock
   - child's singing teddy bear
   - pacemaker
   - scuba diver's light
   - cellphone
   - portable drill
   - wheel chair
   - snow blower
   - road-hazard warning light

   Consider the properties you listed in Procedure step 2, as well as cost and environmental impact.

Process and Analyze

1. Which cells that you recommended have the least impact on the environment? Explain your reasoning.
2. Did you recommend primary cells or secondary cells more often? Explain your choices.
3. Think about the portable devices you use and the cells or batteries that provide them with electrical energy. Would you change the type of cell or battery you use for any of these devices? Explain.

PART B: THE LIFE OF A CELL OR BATTERY—GUIDED INQUIRY

Question

What can you learn about the impacts of a cell or battery throughout its life?

Procedure

1. Choose a type of cell or battery from the Table of Cells and Batteries in Common Use.
2. What questions do you have about the impacts of the cell or battery from its production through to its disposal? Record your questions and then do research to find the answers.
3. Share your answers with the class using a medium of your choice.

Table of Cells and Batteries in Common Use

Name	Primary/ Secondary	Typical Uses	Pros	Cons
Zinc-carbon	Primary	Flashlights, small radios, music players	Is inexpensive	Gives poor performance at low temperature
Alkaline	Primary	Flashlights, small radios, music players	Lasts longer than zinc-carbon cells	Is more expensive than zinc-carbon cells
Silver-oxide	Primary	Calculators, watches, hearing aids, pagers	Is small and long lasting	Is relatively expensive
Zinc-air	Primary	Hearing aids, pagers	Has a long shelf life if sealed	Requires oxygen from the air
Nickel-cadmium	Secondary	Portable power tools, laptop computers, shavers, toothbrushes	Can be recharged 500 to 700 times	Is an environmental hazard because of the cadmium
Nickel-metal hydride	Secondary	Portable power tools, laptop computers, shavers, toothbrushes	Can be recharged 300 to 400 times; is good for high-demand applications, such as cameras and power tools	Is relatively expensive
Lithium-ion	Secondary	Cellphones, laptop computers	Can be recharged 300 to 400 times; has an excellent shelf life; is good at high and low temperatures	Is relatively expensive

INVESTIGATION

3-D

GUIDED INQUIRY

Skills and Strategies

- Questioning and Predicting
- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Communicating

Safety

- Do not hold the photovoltaic cell by the wires.
- If you use any water, do not let wires get wet.
- Handle the electrical equipment carefully.

What You Need

- multimeter
- wires with alligator clips
- photovoltaic cell
- other materials depending on your design

Testing a Photovoltaic Cell

Question

How much current and electrical potential difference can a photovoltaic cell generate? What factors affect the ability of a photovoltaic cell to generate these quantities?

Procedure

1. As a class, brainstorm some factors that might affect the current and electrical potential difference generated by a photovoltaic cell.
2. Review Appendix A on page 395 on how to use a multimeter to measure current and electrical potential difference. If you are still not sure how to connect the meter to your photovoltaic cell, do research to find out how to make these connections.
3. Draw and label a circuit diagram that shows how you will connect the multimeter to the photovoltaic cell.
4. Assemble your circuit. Measure and record the current generated by the photovoltaic cell and the electrical potential difference across the cell.
5. Within your group, choose one of the factors that might affect the ability of your photovoltaic cell to generate a current or electrical potential difference.
6. Decide how you will test the factor you chose in step 5 and measure any differences in current or electrical potential difference. Make a sketch of the arrangement of your apparatus. Be sure to keep all of the other factors constant while you change the factor that you are testing. Write a hypothesis and a procedure for your test. Check your experimental design with your teacher before you test it.
7. Carry out your procedure for testing the factor of your choice. Record your results.

Process and Analyze

1. Why is it important to keep all other factors the same while you are making changes in your chosen factor?
2. Describe any problems you had in assembling your apparatus and making measurements. Identify possible sources of error.
3. Share your results with the class. As a class, make a table of the amount of current and electrical potential difference that each group recorded for their photovoltaic cell in step 4. Then make a table of all of the factors that were tested by all of the groups in step 7 and include the results.
4. How similar were the currents and electrical potential differences that different groups recorded in their original measurements in step 4? Suggest some possible causes for any differences in these measurements.
5. As a class, discuss possible reasons that the factors tested in step 7 affected current or electrical potential difference.

Apply

6. Based on the findings of the class, make recommendations about designing an array of solar cells that will provide electrical energy for a home. Include as many different factors as you can.

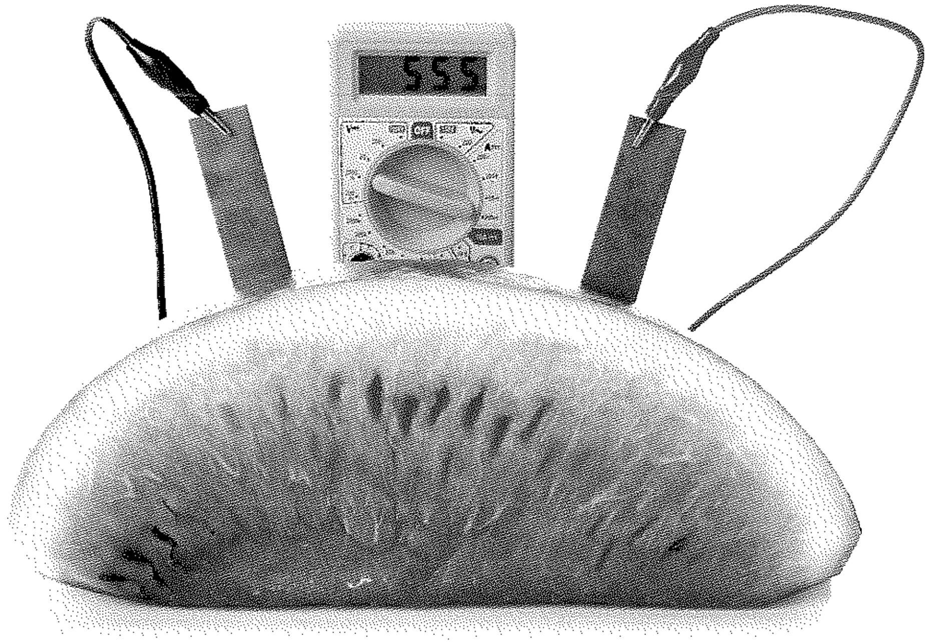
INVESTIGATION

3-E

GUIDED INQUIRY

The Fruit Cell Challenge

In this investigation, you will create a wet cell from a fruit. If you connect the cell to a multimeter as shown below, you will be able to see that a current is flowing.



Skills and Strategies

- Questioning and Predicting
- Planning and Conducting
- Processing and Analyzing
- Evaluating

Safety

- Be careful handling sharp pieces of metal.
- Handle the multimeter with care.
- Advise your teacher if you are allergic to any type of fruit.

What You Need

- several types of fruit
- multimeter
- various types of metal strips or nails such as copper, zinc, iron, aluminum
- small electrical devices such as bulbs or motors
- wires with alligator clips

Question

What properties of a piece of fruit make it act like an electrochemical cell?

Procedure

1. As a class, decide on some type of challenge that teams will participate in with the fruit cells. For example, can a fruit cell light a small light bulb, or run a toy motor in a car? How long can a fruit cell run a device?
2. As a team, brainstorm a list of possible characteristics of a fruit cell that might contribute to its function as an electrochemical cell.
3. As a team, select two or three types of fruit and metal strips/nails to test for their ability to act together as a cell.
4. As a team, write a procedure for how you will assemble and test your fruit cells. Create a table to record your results.
5. Carry out your procedure.

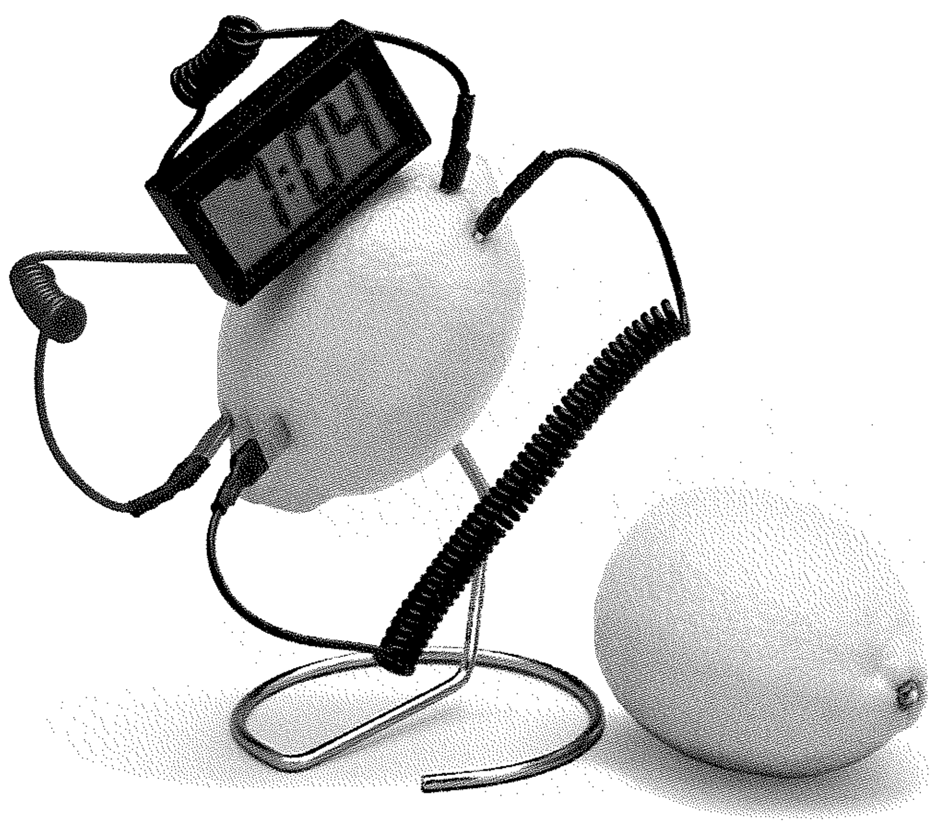
6. Compare your results. Then choose the best fruit cell to use in the challenge.
7. Write a procedure for carrying out the challenge that the class chose.
8. Carry out the challenge.

Process and Analyze

1. Describe the cell that won the challenge. Suggest reasons why it worked best.
2. What did you conclude about the properties of fruit that allow it to act as an electrochemical cell?
3. Why do you think that fruit cells are not commonly used to run electrical devices?

Evaluate and Innovate

4. What could you do to improve your design for this investigation? For example, could you use more than one piece of the fruit that you chose? What difference might more than one piece of fruit make? Would it have made a difference if you had softened the piece of fruit by rolling it with pressure? Write a paragraph explaining your ideas.



TOPIC
3.4

How are circuits used in practical applications?

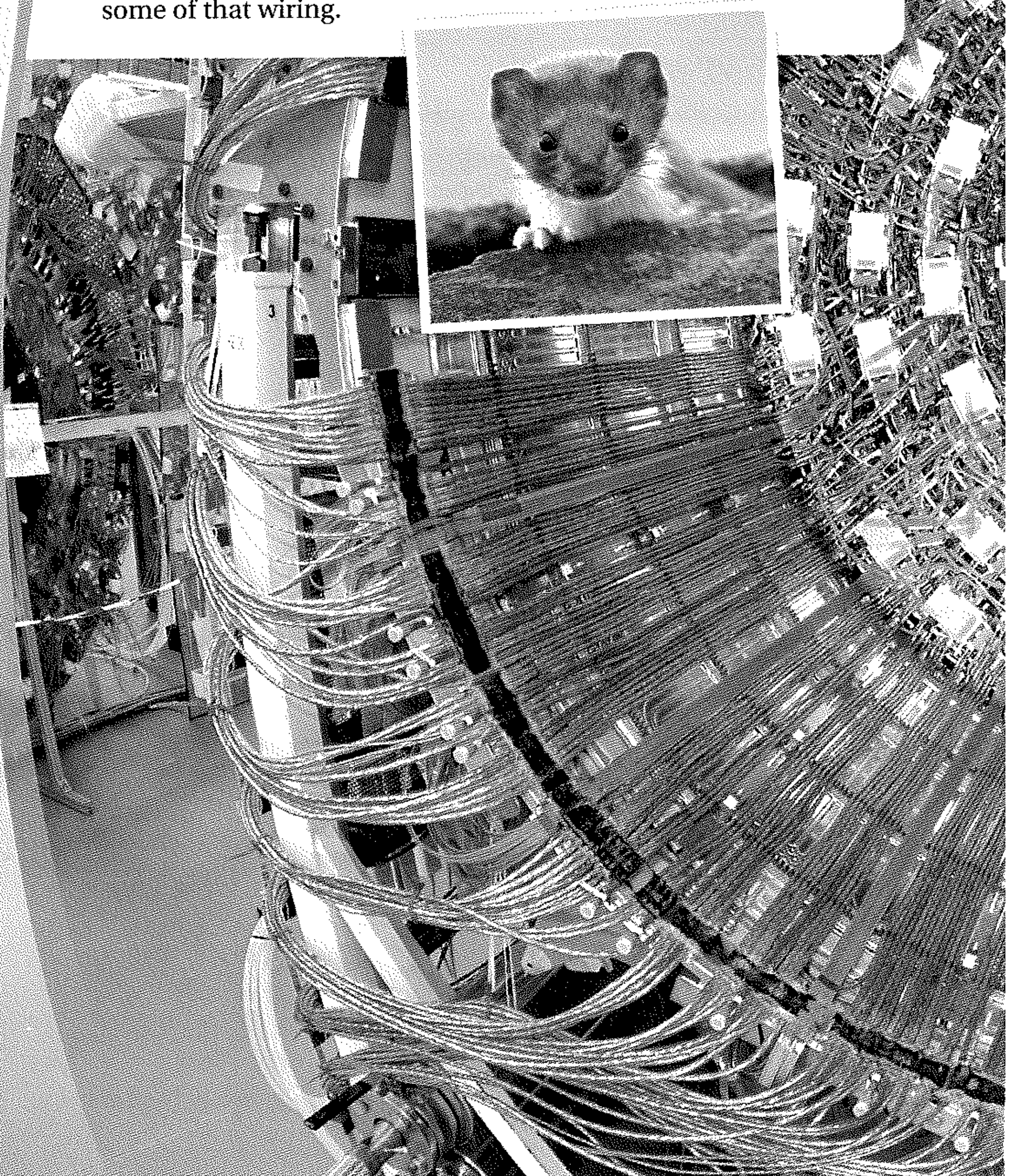
Key Concepts

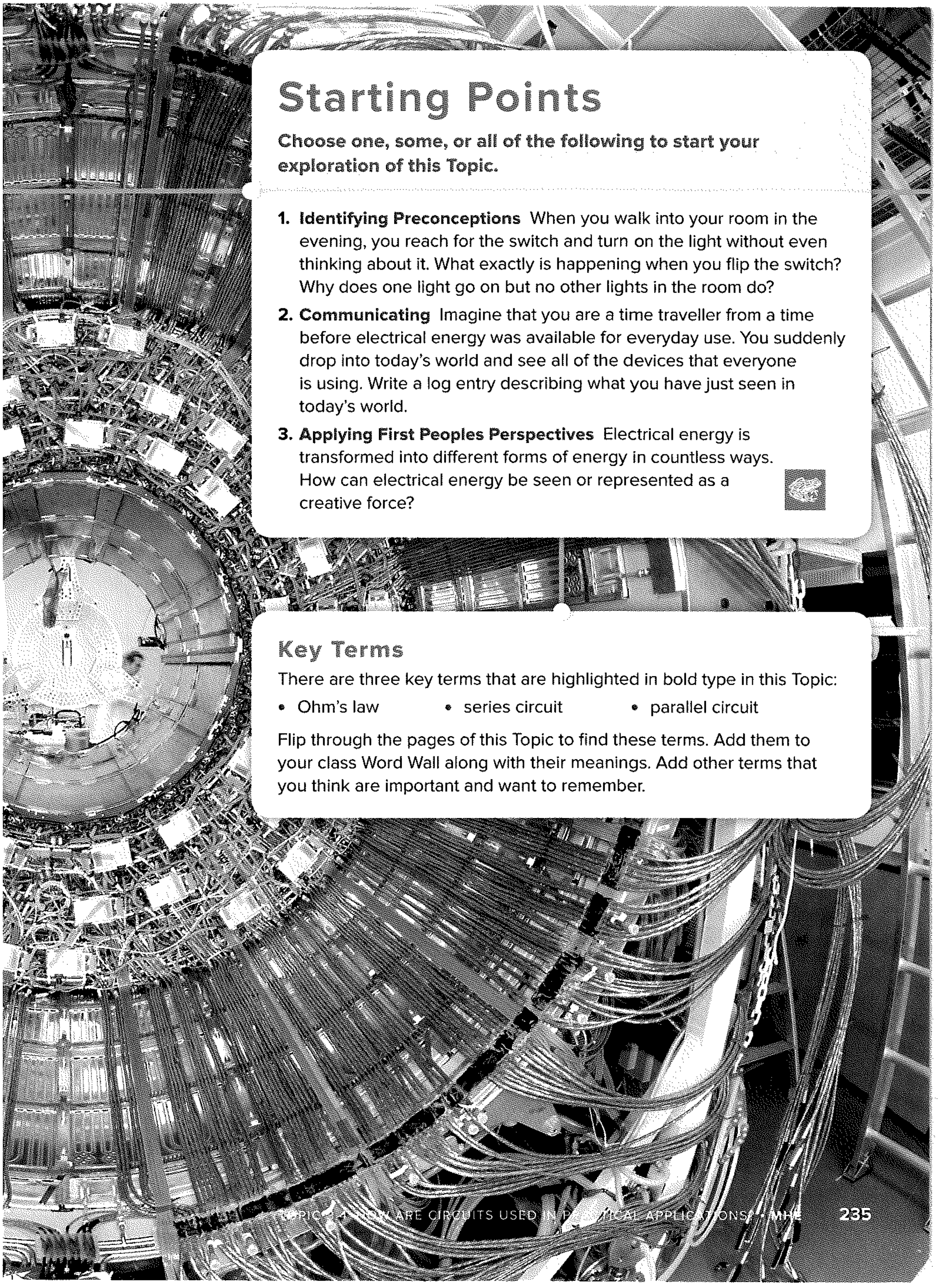
- Voltage, current, and resistance in a circuit are related by Ohm's law.
- Loads can be connected in series or in parallel in a circuit.
- Parallel loads are practical for circuits in the home.

Curricular Competencies

- Construct, analyze and interpret graphs, models, and/or diagrams.
- Evaluate the validity and limitations of a model in relation to the phenomenon modelled.
- Evaluate methods and experimental conditions, including identifying sources of error or uncertainty, confounding variables, and possible alternative explanations and conclusions.

In 2016, headlines around the world announced that the world's largest and most costly scientific instrument, the Large Hadron Collider (LHC), had been shut down for several days. The cause was a small and uninvited guest in the electrical building. A weasel had chewed on a single electrical cable. High tech, it seems, was no match for a lowly weasel. Even after fixing the damaged cable, scientists had to test many electrical circuits in the facility. Each connection and each wire in the thousands of kilometres of electrical wires in the LHC is designed to carry out a specific function. This photo shows just some of that wiring.





Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** When you walk into your room in the evening, you reach for the switch and turn on the light without even thinking about it. What exactly is happening when you flip the switch? Why does one light go on but no other lights in the room do?
2. **Communicating** Imagine that you are a time traveller from a time before electrical energy was available for everyday use. You suddenly drop into today's world and see all of the devices that everyone is using. Write a log entry describing what you have just seen in today's world.
3. **Applying First Peoples Perspectives** Electrical energy is transformed into different forms of energy in countless ways. How can electrical energy be seen or represented as a creative force?

Key Terms

There are three key terms that are highlighted in bold type in this Topic:

- Ohm's law
- series circuit
- parallel circuit

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meanings. Add other terms that you think are important and want to remember.

CONCEPT 1

Voltage, current, and resistance in a circuit are related by Ohm's law.

Activity

Comparing Current and Resistance

The table shown here lists the resistance of some common home appliances. The last column shows the current that passes through each appliance when connected to a 120 V source (standard household voltage). Draw a graph of resistance versus current for these items. Put resistance on the *x*-axis and current on the *y*-axis. Study your graph. How is current related to resistance? For example, when the resistance increases, what happens to the current?

Appliance	Resistance (Ω)	Current (A)
Lamp	150	0.8
Laptop computer	60	2.0
Toaster	20	6.0

Connect to Investigation 3-F on page 244

It is critical that too much current does not flow through the conductors in a circuit. If the current is too high, the wires can get extremely hot and start a fire. Fortunately, it is possible to predict what the current will be in a circuit.

Ohm's Law

German physicist Georg Ohm studied the relationship among electrical potential difference, current, and resistance in electrical circuits. He discovered that when he raised the electrical potential difference, the current increased for a given resistance in a conductor. He developed the relationship now known as **Ohm's law**, shown in the box below.

Ohm's Law law stating that the electrical potential difference between two points in a circuit is equal to the current times the resistance between those two points

Ohm's Law

The electrical potential difference between two points in a circuit is equal to the current times the resistance between those two points.

$$V = IR$$

V is the symbol for electrical potential difference, I is the symbol for current, and R is the symbol for resistance.

By rearranging the variables in Ohm's law, it is possible to calculate any of the variables if the value of the other two is known.

Activity

Using Ohm's Law

Study the following sample problem to learn how to use Ohm's law. Then solve the following problems. More sample problems are provided in Appendix A on page 397.

Sample Problem

Imagine that you are testing an electrical toy. You are going to plug it into your home outlet, which provides an electrical potential difference of 120 V. The wires are small and you do not want the current to go above 1.5 A. How high must the resistance of the electrical toy be?

Solution

Because you want to determine a resistance, you will need to rearrange the formula $V = IR$ into the formula $R = \frac{V}{I}$.

Substitute the values into the formula.

$$R = \frac{V}{I}$$
$$= \frac{120\ \text{V}}{1.5\ \text{A}}$$
$$= 80\ \Omega$$

The electrical toy must have a resistance of at least 80 Ω to ensure that the current does not go above 1.5 A.

1. A television that is plugged into a wall socket has an electrical potential difference of 120 V. If a current of 1.25 A is flowing through the television, what is its resistance?
2. The filament of a flashlight bulb has a resistance of 40 Ω. If a 6.0 V battery is used in the circuit, what is the current?
3. A circuit board has a resistance of 12 Ω and requires a current of 0.25 A. What electrical potential difference is required to operate the circuit board?

Before you leave this page . . .

1. List the three symbols used in Ohm's law. Explain what each symbol represents and give the units for each of the variables.

CONCEPT 2

Loads can be connected in series or in parallel in a circuit.

Activity

Circuit Challenge

1. You will be given a battery, two switches, two light bulbs, alligator clips, and several conducting wires. Your challenge is to build three different circuits.

   Circuit #1: One switch must control both light bulbs. When you close the switch, both light bulbs go on. If either bulb is removed (to simulate burning out), the other bulb goes off.

   Circuit #2: One switch must control both light bulbs. When you close the switch, both light bulbs go on. When either bulb is removed, the other bulb remains on.

   Circuit #3: Each light bulb is controlled by its own switch. When one switch is closed, one light bulb goes on. When the other switch is closed, the other light bulb goes on. Neither bulb is affected by the other one.

2. Discuss how these circuits might be applied in a home or classroom.

All of the circuits that you have studied so far have a single loop. In such a circuit, current flows along one pathway. Most circuits, however, are much more complex, and current may flow along more than one pathway.

One Pathway

When current can flow along just one path in a circuit, the circuit is called a **series circuit**. The circuit components are connected in series. Figure 3.24 shows three light bulbs connected in series. Trace the path of the current. Notice how there is only one path in which it can flow through the battery, switch, and loads.

series circuit a circuit in which current can only flow along one path

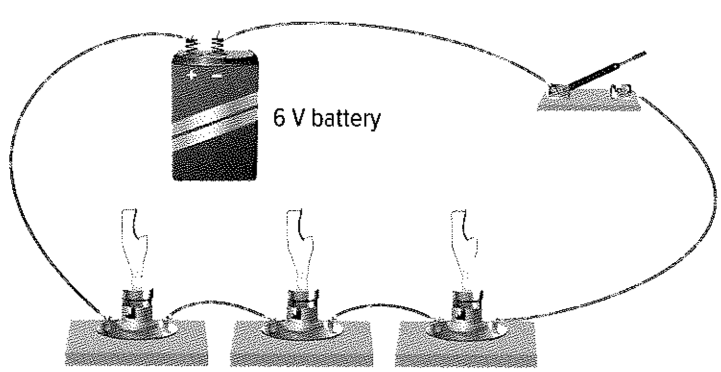


Figure 3.24 All of the components in this circuit are connected in series.

Multiple Pathways

When a circuit has at least one branch point where the current splits into two or more pathways, it is a **parallel circuit.** The components in these pathways are connected in parallel. Figure 3.25 shows a circuit that has all of the same components as the circuit in Figure 3.24. However, the bulbs are connected in parallel. Trace the path of the current. Notice where it branches and the current splits into two pathways.

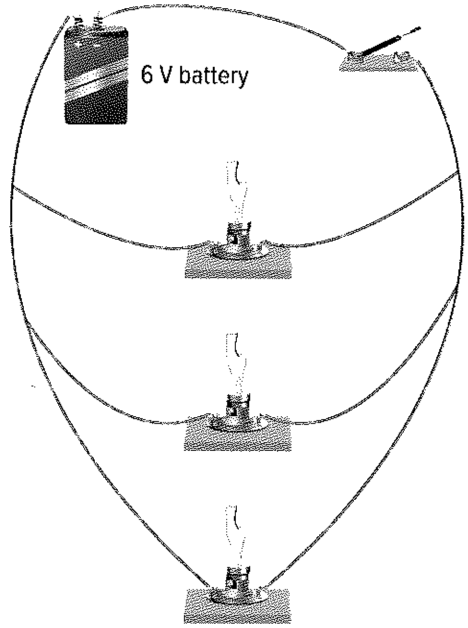


Figure 3.25 The three bulbs are connected in parallel. The battery and switch are in series.

Connect to Investigation 3-G on page 245

parallel circuit a circuit that has at least one branch point where the current splits into two or more pathways

At a branch point, the current splits so the sum of the currents in the branches is the same as the current in the single conductor before the branches. Figure 3.26 compares a series and a parallel circuit. In the parallel circuit, the current is reduced in each branch.

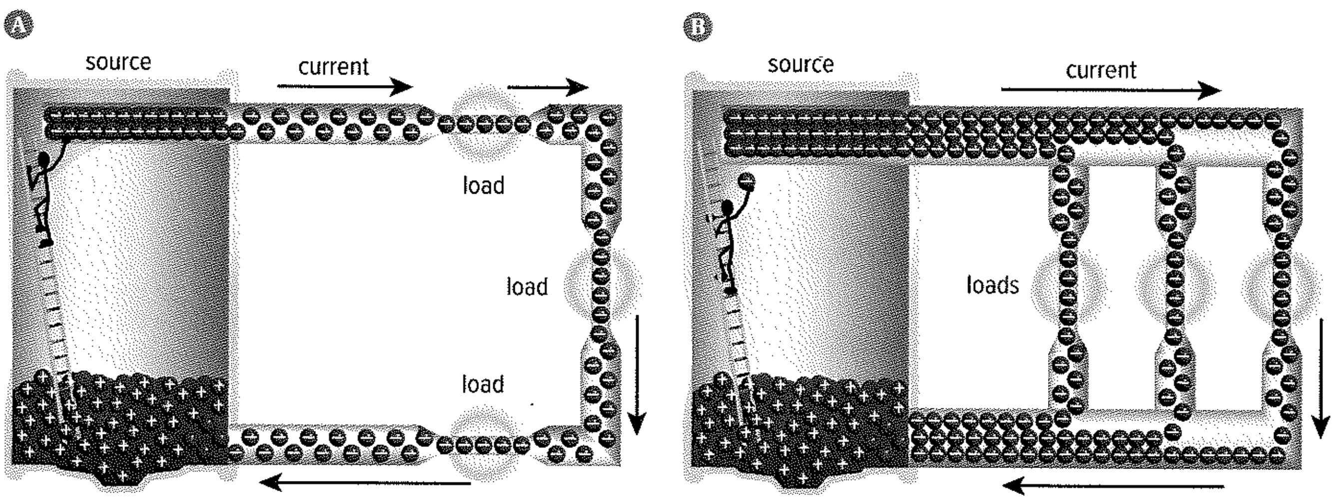


Figure 3.26 Ⓐ In this series circuit, there is just one path through which the current can flow. The current is equal in all parts of the circuit. Ⓑ In this parallel circuit, the current splits into three paths. In each path, the current is reduced.

Before you leave this page . . .

1. Use the analogy of two different roads or rivers to compare a series and parallel circuit.

CONCEPT 3

Parallel loads are practical for circuits in the home.

If one load in a series circuit burns out, the circuit will be open, charges will stop moving, and no loads in that circuit will work. This makes series circuits impractical in homes, where many loads are needed. Think of a kitchen. Each load must work independently of all others. Otherwise a burned out ceiling lamp would cause a toaster, microwave, and radio on the same circuit to stop working. Likewise, if you turned off the radio, all the other appliances would stop as well.

In Figure 3.27, all the devices are connected in parallel. Each can be controlled by its own switch without shutting off the others. The pathways in the diagram represent conductors, and the coloured lines represent current flowing to a specific device. The arrow in part A shows that, when all appliances are on, a large amount of current is passing through the conductor near the source. When large amounts of current flow through a wire, it can get very hot and it becomes a safety hazard.

Connect to Investigation 3-H on page 246

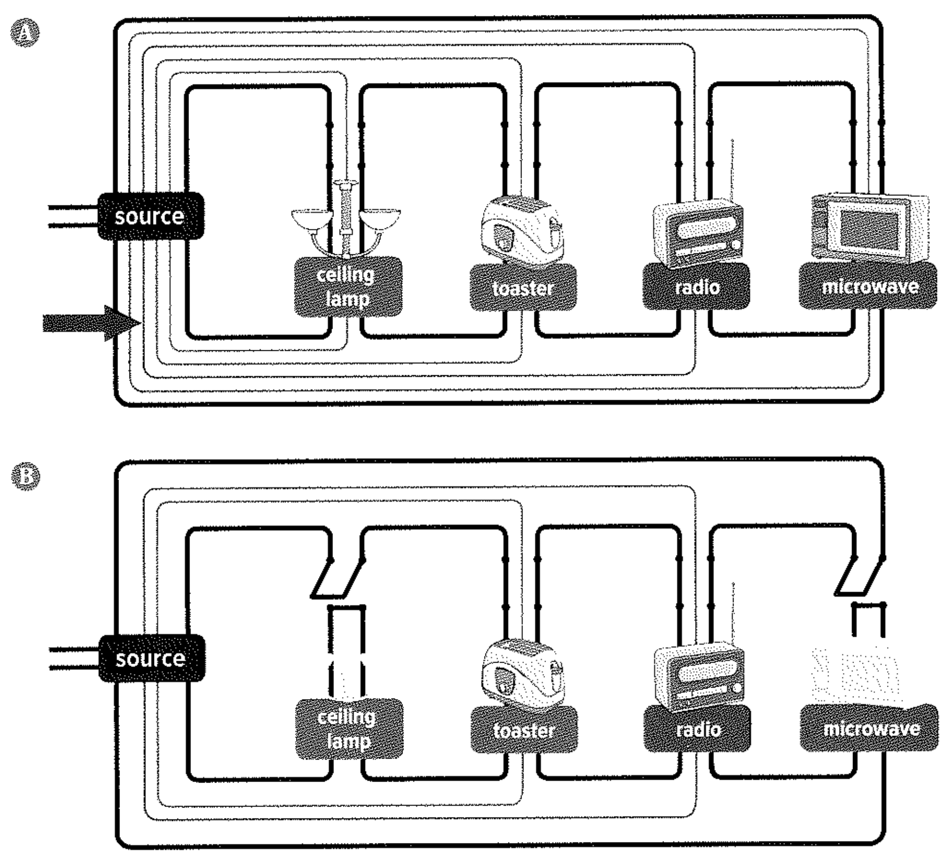


Figure 3.27 Parallel circuits are practical because each appliance is controlled by its own switch.

Ⓐ All of the appliances are running.

Ⓑ When the microwave and lamp are turned off, the toaster and radio still run.

Multiple Circuits Within a Building

While parallel circuits are convenient in one room, imagine if all the electrical devices in an entire home were connected to the same parallel circuit. The current flowing to each device also would be flowing through the wire conductors connected to the source. This large amount of current would make the wires extremely hot, possibly causing a fire.

Because of this safety concern, many separate parallel circuits are installed in buildings, as shown in Figure 3.28. Each colour represents a single parallel circuit. A very large electrical cable carries electrical energy from a power company to a building. This large cable branches out and is connected to each of the parallel circuits inside a circuit panel. The cables for all circuits leave this circuit panel and carry electrical energy throughout the building.

Connect to Investigation 3-I on page 249

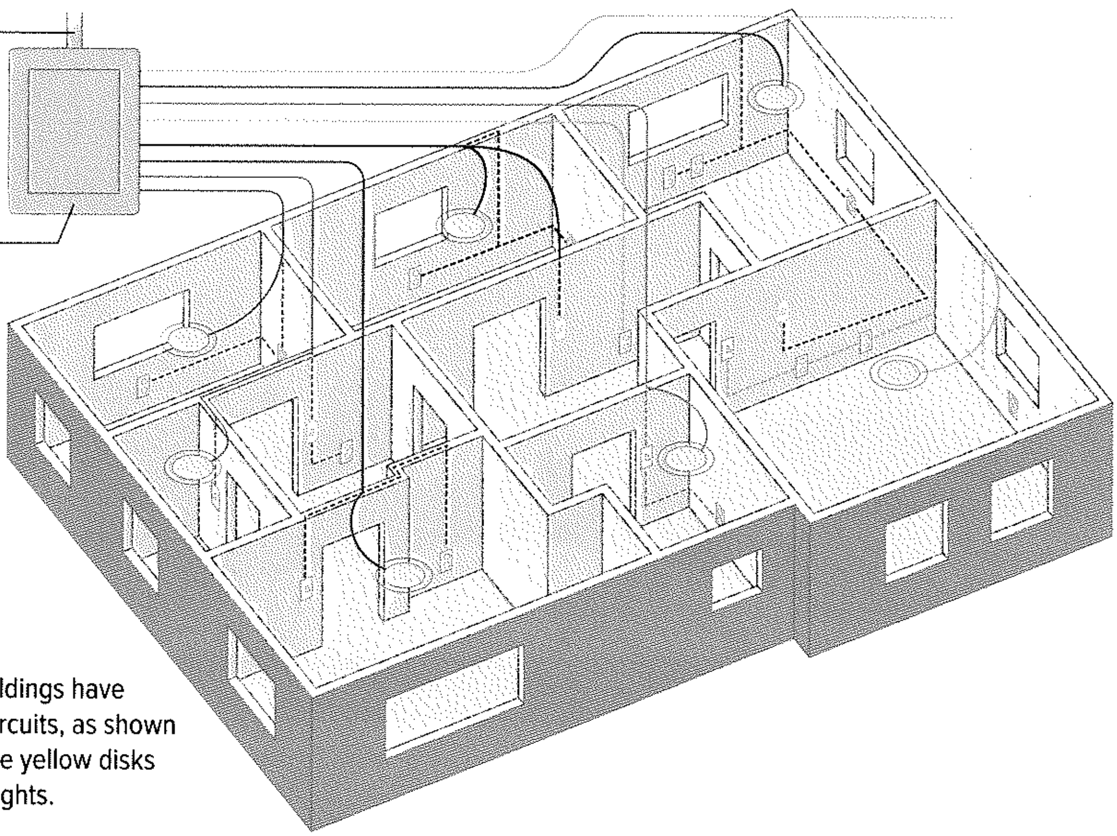


Figure 3.28 Buildings have multiple parallel circuits, as shown in this diagram. The yellow disks represent ceiling lights.

Before you leave this page . . .

1. Explain why it would be impractical to wire a home with a circuit in which all loads were connected in series.
2. Explain why a parallel circuit with too many electrical devices connected to it is not safe.

AT ISSUE What was the AC/DC war about?

What's the Issue?

More than 100 years ago, an epic battle took place between two of history's greatest inventors. Nikola Tesla and Thomas Edison were involved in the dispute about whether to use direct current (DC) or alternating current (AC) to supply commercial electrical energy to customers. Tesla was in favour of using AC. Edison preferred DC. Let the battle begin!

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. AC/DC: It's not just the name of a rock band. What questions do you have about these two different types of currents and how can you find the answers?
2. Imagine you lived at the time of Edison and Tesla. Find out why they had the opinions they did. Would you have been on Team Edison or Team Tesla? Explain your position.
3. Tesla's behaviour was very eccentric (considered to be unusual or odd), especially in his later years. How could the personality of a scientist affect the public's acceptance of his or her work?

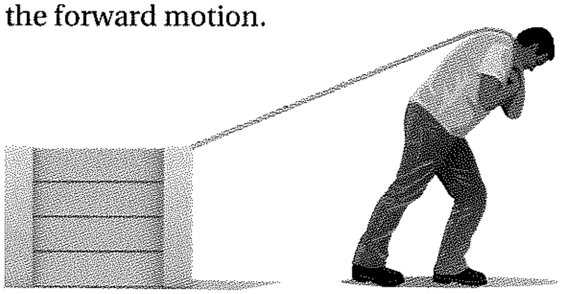
Check Your Understanding of Topic 3.4

QP Questioning and Predicting   PC Planning and Conducting   PA Processing and Analyzing   E Evaluating
AI Applying and Innovating   C Communicating

Understanding Key Ideas

1. You have a circuit that has a battery, a switch, and a buzzer. You are asked to find the resistance of the buzzer. PA
   a) What two pieces of information would you need in order to calculate the resistance of the buzzer?
   b) Write the formula you would use to carry out the calculation.

2. The person in the figure below is pulling a heavy load. However, the load is resisting the forward motion.



   The figure can act as a model for what happens in electrical conductors, cells and batteries, and electrical devices in a circuit.
   a) Write a paragraph that explains what you think each circuit component would represent in the model, and why.
   b) How does the figure model resistance in a circuit? PA E AI C

3. Two identical light bulbs are connected in a closed circuit. The wiring of the circuit is not visible. Suggest a way that you can determine if the bulbs are wired in series or in parallel. PC PA

4. Draw a circuit diagram of a kitchen that has a toaster, blender, and bread machine that can each be turned off while the other appliances keep running. PA AI C

Connecting Ideas

5. A dimmer switch includes a variable resistor. When you adjust the dimmer, you increase or decrease the resistance in the circuit. The electrical potential difference supplied to the circuit remains the same.
   a) What happens to the current in the circuit when you change the resistance? Refer to Ohm's law in your response.
   b) Why do you think that this brightens and dims the light? PA AI

Making New Connections

6. Read the quote below and answer the questions that follow. PA E AI

   "Like many of our trees the cedar is in danger. There are very few old growth trees left and many young trees are cut down to use as hydro and telephone poles. When you drive down the highway these poles are standing along the road, holding hydro and telephone wires. So you all still receive help from the cedar tree."

   Chief Frank Malloway
   Yakweakwioose First Nation,
   Chilliwack

   In B.C., many cedar poles hold up wires that carry electrical energy to buildings.
   a) Describe the path that electrical energy takes from these poles into the different rooms in your home.
   b) The wires held up by the poles are much larger than the ones in your home. Why is this the case?
   c) The cedar is very important in First Peoples culture in parts of B.C. Suggest another way electrical energy could be transported.

INVESTIGATION

3-F

GUIDED INQUIRY

Skills and Strategies

- Questioning and Predicting
- Planning and Conducting
- Evaluating
- Applying and Innovating
- Communicating

Safety

- Do not turn on the power supply without your teacher's approval.
- Use care in handling sharp pieces of metal.
- Do not cause short circuits.

What You Need

- Play-Doh® of several colours
- power supply
- wires with alligator clips
- ammeter and voltmeter or two multimeters
- ruler
- Play-Doh® extruder
- nails or pieces of metal

Resistance of Play-Doh®

Question

What factors affect the resistance of a conductor such as Play-Doh®?

Procedure

1. Brainstorm factors that affect the resistance of a conductor. Choose at least three factors to investigate. For each factor you decide to investigate, write a hypothesis to predict which possible outcome you think will occur.
2. Decide on the dimensions and characteristics of the Play-Doh® you will test.
3. Use the extruder to prepare the pieces of Play-Doh® that you are going to test. Knead the Play-Doh® before extruding.
4. Draw a circuit diagram of your apparatus which shows how you will measure current and electrical potential difference.
5. Decide on how to connect the pieces of Play-Doh® to the parts of the circuit. For example, you might insert small nails or pieces of metal into ends of the Play-Doh® to connect to the wires with alligator clips.
6. Assemble your apparatus and have your teacher check it. Measure the current and electrical potential difference of each piece of Play-Doh® you made. Start at very low power and turn it up slowly. Record your measurements.

Process and Analyze

1. Use Ohm's law to calculate the resistance of each piece of Play-Doh®.
2. Use data for two tests that differ only by one variable. Compare the resistances of those two samples. Did that variable cause the resistances to differ? If so, how?
3. Write a paragraph that summarizes the factors that affect the resistance of Play-Doh®.

Evaluate

4. Describe possible sources of error in your measurements. Discuss how errors could be reduced if you repeat your investigation.

INVESTIGATION

3-G

GUIDED INQUIRY

Circuit City

Skills and Strategies

- Questioning and Predicting
- Planning and Conducting
- Evaluating
- Applying and Innovating
- Communicating

Safety

- Be careful not to make short circuits. Heat could cause the paper to burn.

What You Need

- conducting paint, ink, or tape
- sturdy paper, such as photo paper
- pencil
- LED light bulbs
- battery
- alligator clips
- masking tape
- small copper wires
- information resources

Question

How can you design a model of an electrical system for a city neighbourhood?

Procedure

1. What questions do you have about how to model the electrical system of a city neighbourhood? Write them down and find the answers.
2. Decide what tests you want to perform or questions you want to answer. For example, what will happen to the rest of the neighbourhood if a tree strikes a power line?
3. On a large piece of paper, sketch your streets and buildings. The buildings should be simple and large enough to put bulbs in them.
4. Before using conducting material, lightly sketch the paths of all electrical conductors and locations of the light bulbs.
5. Add your conducting material. Note that conducting paint or ink must dry before it will conduct an electric current.
6. Add the light bulbs to your circuit. Connect the battery with the small copper wires.
7. When your circuit city is working, perform the tests that you designed in step 2.

Evaluate

1. What problems did you have with your design? How were you able to fix them?
2. What type(s) of circuits did you include? Explain why you chose the type(s) you did.
3. What was the biggest challenge that you had to overcome?
4. Evaluate the limitations of using a model to demonstrate the electrical system of a city neighbourhood.

INVESTIGATION

3-H

STRUCTURED INQUIRY

Electrical Wiring in a Building

Skills and Strategies

- Questioning and Predicting
- Planning and Conducting
- Evaluating
- Applying and Innovating
- Communicating

Safety

- You must have an adult with you at all times when conducting your safety check.

What You Need

- pencil
- ruler
- paper
- graph paper

PART A: ELECTRICAL SAFETY CHECK

Just like you have regular health and dental checkups, the electrical system in your home or school should have regular checkups to keep it safe.

Question

Does your home or school pass an electrical safety check?

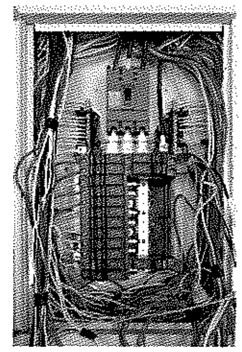
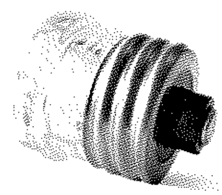
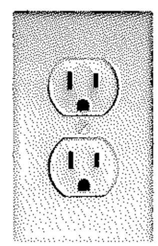
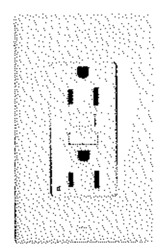
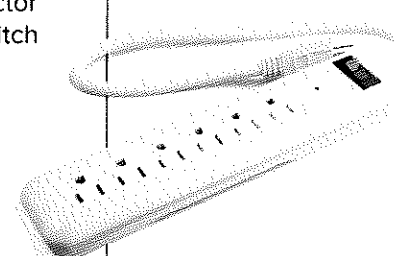
Procedure

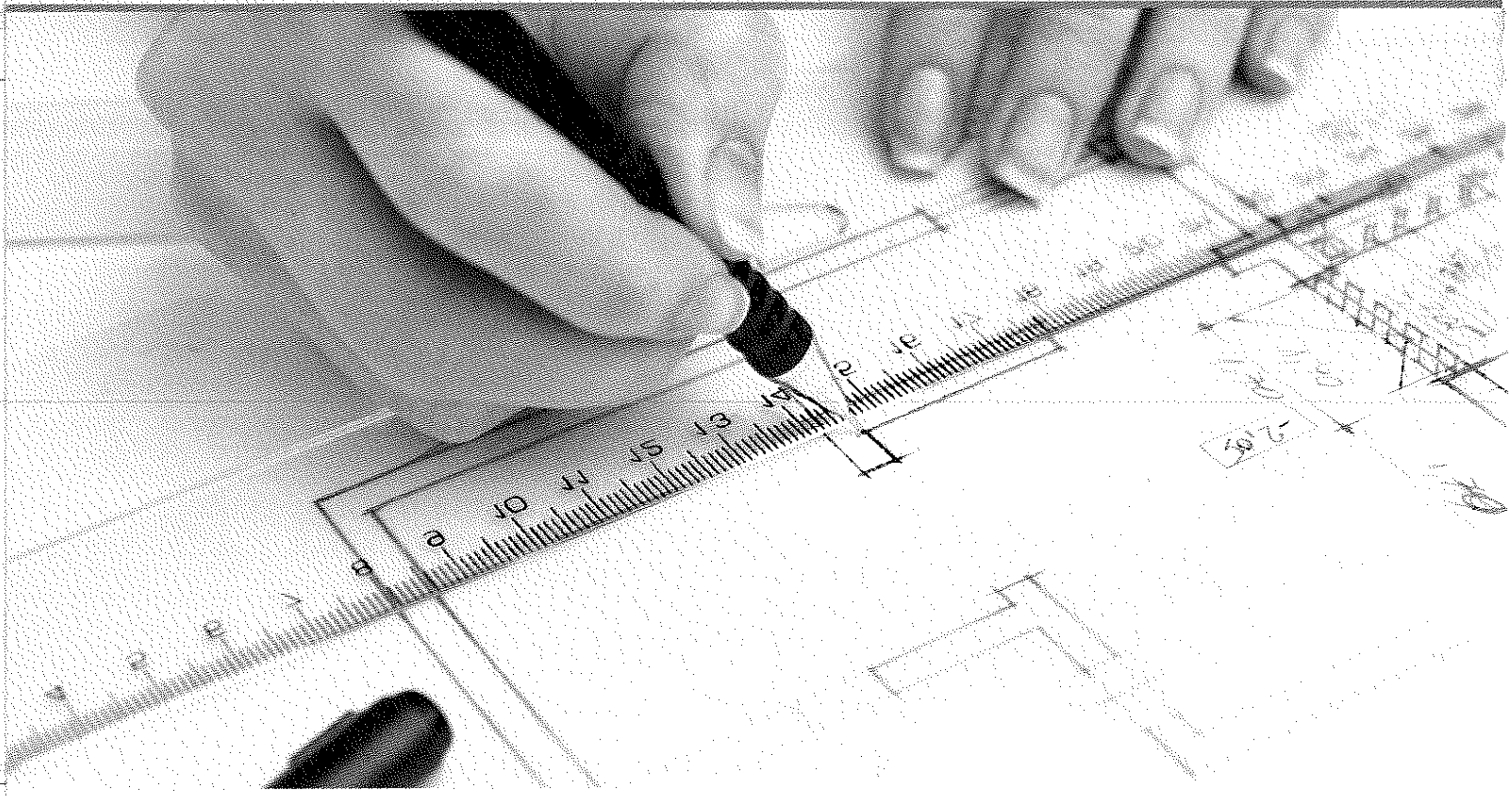
1. Review the Table of Electrical Safety Equipment in Buildings on the next page so you understand the function of each device and how it works.
2. Review the electrical safety points below for ideas that can help with a safety check.
   a) Are switches and outlets:
      - warm to the touch
      - making a sound
      - discoloured
      - loose
   b) Are appliance cords:
      - frayed
      - nailed in place
      - warm to the touch
      - pinched
      - under carpets
      - near hot surfaces
   c) In the circuit panel:
      - are the circuit breaker switches labelled?
      - do any of the breaker switches trip frequently?
      - if there are fuses, are they the right current rating?
3. Use the above information to write a checklist for giving your home or school an electrical safety check.
4. Carry out your safety check. You must have an adult with you at all times.

Analyze and Evaluate

1. Make a list of all observations that indicated to you that there might be a hazard.

Table Electrical Safety Equipment in Buildings

Device	Safety Purpose	How It Works	Example
Circuit breaker	Limits the amount of current to a set value; prevents overheating in wires and possible resulting fires	When a current is too large, a part of the circuit breaker is heated, and then bends and breaks contact with another part, opening the circuit; the circuit breaker must be manually reset	
Fuse	Limits the amount of current to a set value; prevents overheating in wires and possible resulting fires	Contains a metal conductor that melts at a temperature corresponding to a set amount of current, which creates an open circuit and stops the current; must be replaced	
Three-hole outlet and plug	Prevents shock resulting from faulty appliances	Outlet contains three slots, including a round one that is grounded; plug's round prong is electrically connected to appliance's metal frame; if a loose wire is connected to the frame, it sets up a large current that trips a circuit breaker connected to the outlet	
Ground fault circuit interrupter	Replaces wall outlet when it is within 1.5 m of water source, prevents shock	Contains a circuit breaker that trips extremely quickly if there is any difference in current between the right slot and the left slot; saves lives because it trips more rapidly that a regular circuit breaker in a building	
Power bar with surge protector	The power bar allows all appliances connected to it to be turned off with one switch. The surge protector prevents damage to circuits in electronic devices during power surges.	Each outlet on the surge protector is connected in parallel; the switch is in series with the wall outlet. Current above a pre-set maximum causes resistance of part of the surge protector to drop rapidly, diverting the current to ground.	



PART B: ELECTRICAL PLAN OF YOUR ROOM

To ensure the electrical safety of your own room, it would be helpful to know the electrical details of your room.

Question

How is your room electrically wired?

Procedure

1. Measure your bedroom and draw an accurate scale diagram of the floor plan that includes doors, windows, wall switches, electrical outlets, and permanent light fixtures.
2. Add any electrical components to your drawing using standard circuit diagram symbols for lights and switches, and a circle with an "X" inside for wall outlets.
3. Try to determine which electric components of your room are connected together. The light switch, for example, probably does not control the wall outlets. On your plan draw a possible wiring diagram for your room.
4. Label any current electrical safety features on your diagram. Would you add any others? Which would you add, and where would you use them? Explain. Label these safety features on your diagram as well.

Analyze and Evaluate

1. Describe at least two things an electrician must consider when wiring a bedroom.

Apply and Innovate

2. Imagine that you wanted to add an additional light to your room, controlled by the existing light switch. On your diagram, show the additional electric components and possible wiring in a different colour. Justify your choices.

INVESTIGATION

3-1

GUIDED INQUIRY

Build a Staircase Circuit

Skills and Strategies

- Planning and Conducting
- Evaluating
- Applying and Innovating
- Communicating

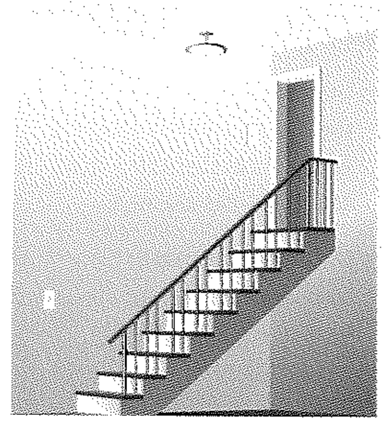
Safety

- Use caution when handling electrical supplies.

What You Need

- battery (6 V)
- connecting wires
- flashlight bulb in holder
- 2 three-connection switches

Many staircase lights can be turned on or off by operating either of two switches placed at the top and bottom of the staircase, like the one shown here.

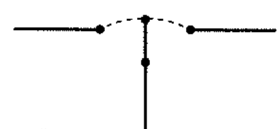


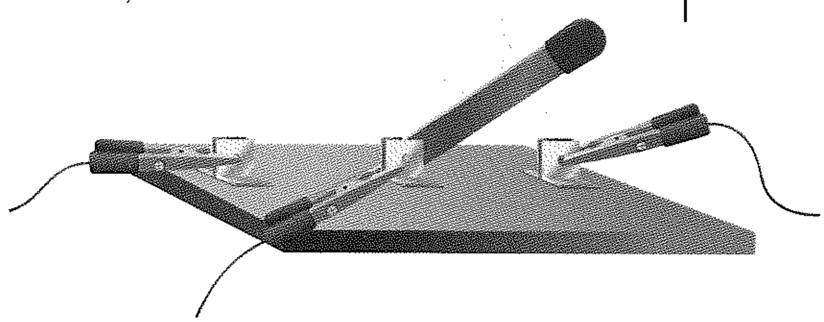
Question

How do you design a circuit in which two switches control one light for a hallway or staircase?

Procedure

1. Design a circuit that will allow you to control one light with either of two switches. If the light is off, either switch must turn it on. If the light is on, either switch must turn it off. The switches that you will use are three-connection switches, as shown here.





2. Have your teacher approve your design. Then connect and test your circuit.
3. If your circuit does not operate properly, check the connections and your circuit diagram. If necessary, modify your circuit diagram and rebuild your circuit.

Evaluate

1. Did your first circuit work properly? If not, explain why not.
2. What precaution would you expect an electrician to take before wiring switches in a building?

TOPIC 3.5

How can electrical energy be generated and used sustainably?

Key Concepts

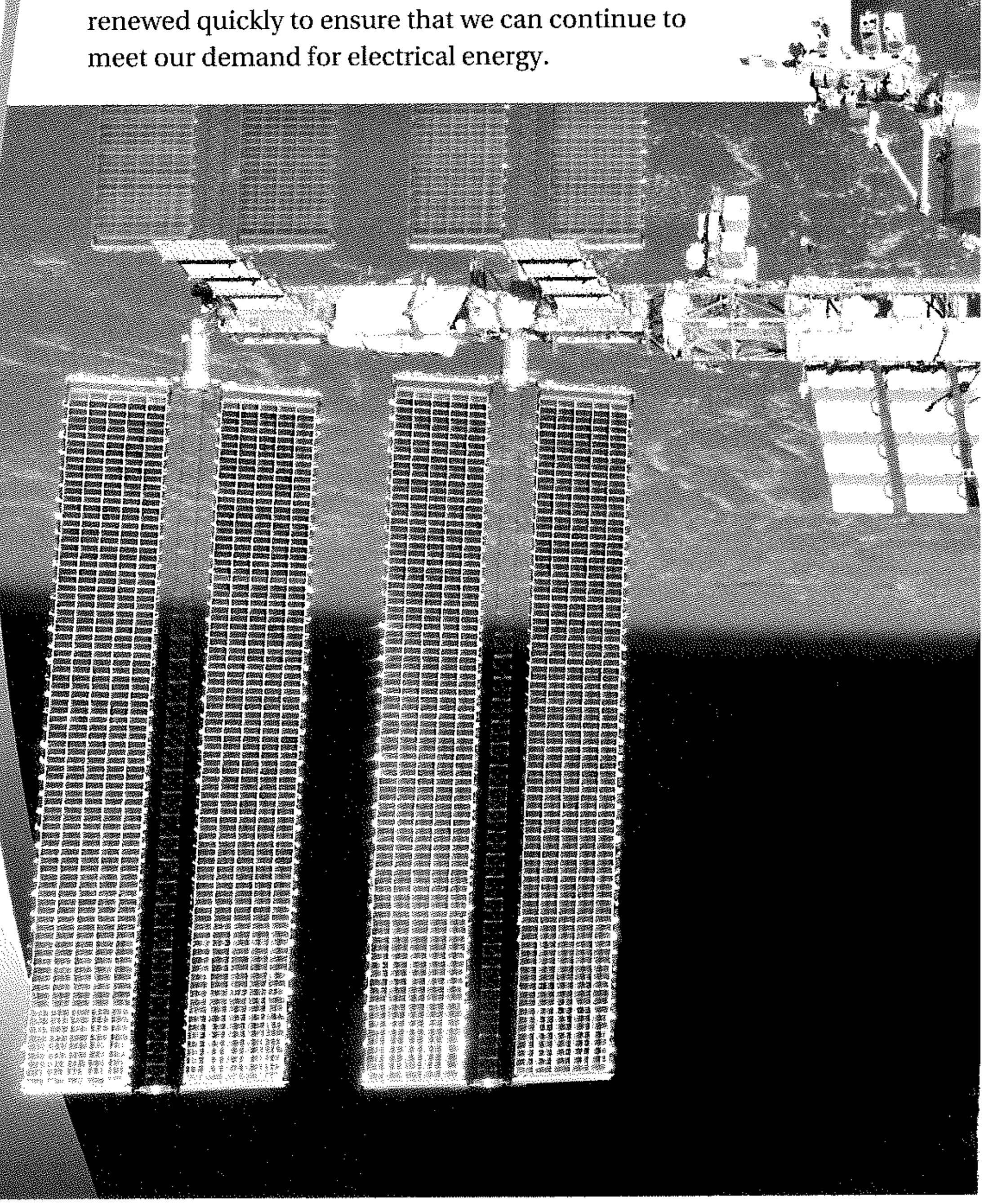
- Sustainable use of electrical energy begins with understanding how its use is measured.
- Making informed choices helps you use electrical energy sustainably.
- Renewable energy sources provide sustainable options for generating electrical energy.

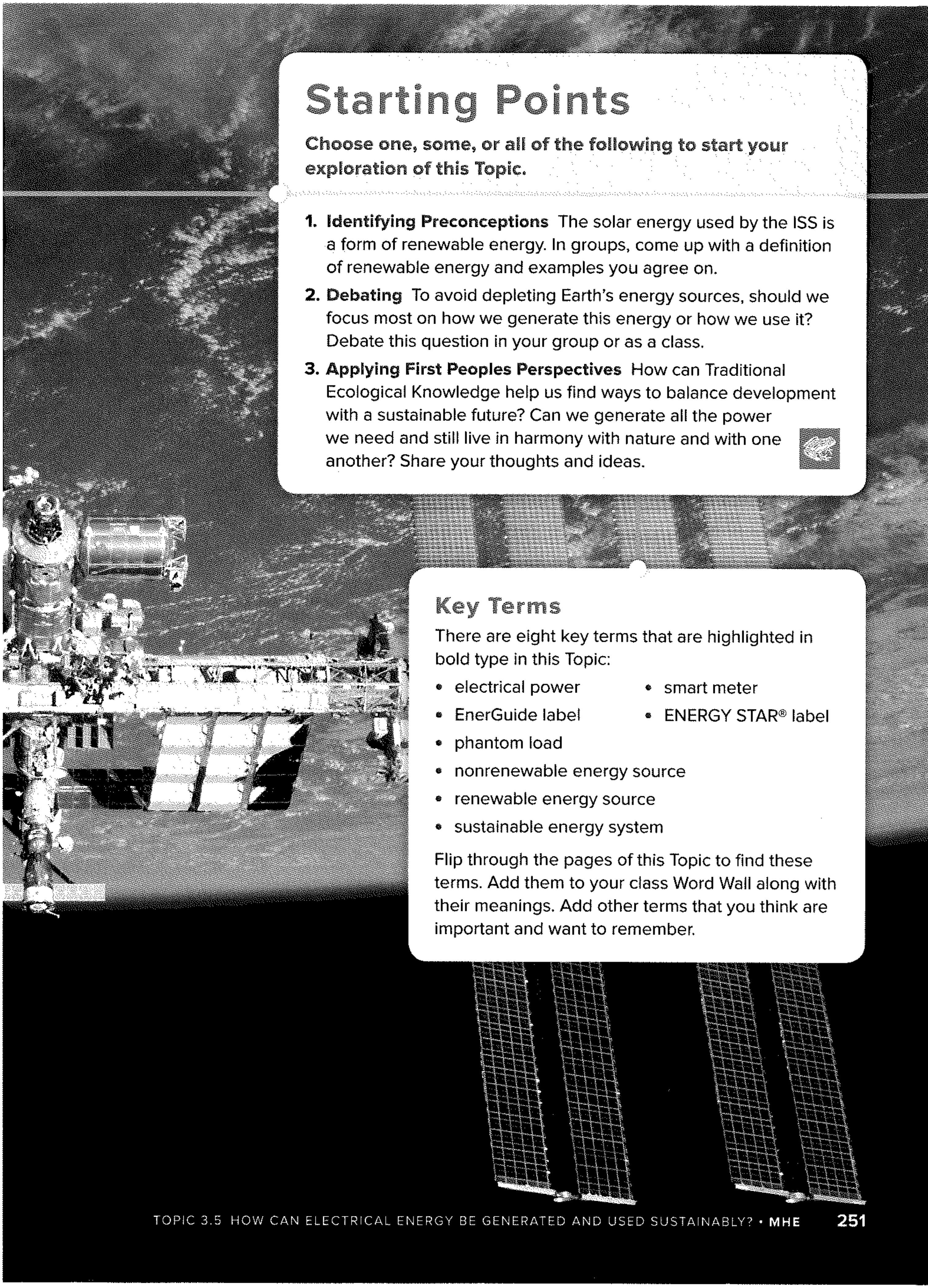
Curricular Competencies

- Express and reflect on a variety of experiences, perspectives, and worldviews of place.
- Experience and interpret the local environment.
- Contribute to finding solutions to problems at a local and/or global level through inquiry.
- Co-operatively design projects with local and/or global connections and applications.

The International Space Station (ISS) orbits high above Earth. The ISS has limited resources available to it. To generate the electrical energy it requires, the Station uses a series of photovoltaic cells that transform solar energy into electrical energy.

Earth also has limited resources and has even been referred to as Spaceship Earth. As a planet, we still rely on finite supplies of fossil fuels such as coal and natural gas to generate electrical energy. As a result, much of the world is already turning to other energy sources that can be renewed quickly to ensure that we can continue to meet our demand for electrical energy.





Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** The solar energy used by the ISS is a form of renewable energy. In groups, come up with a definition of renewable energy and examples you agree on.
2. **Debating** To avoid depleting Earth's energy sources, should we focus most on how we generate this energy or how we use it? Debate this question in your group or as a class.
3. **Applying First Peoples Perspectives** How can Traditional Ecological Knowledge help us find ways to balance development with a sustainable future? Can we generate all the power we need and still live in harmony with nature and with one another? Share your thoughts and ideas.

Key Terms

There are eight key terms that are highlighted in bold type in this Topic:

- electrical power
- EnerGuide label
- phantom load
- nonrenewable energy source
- renewable energy source
- sustainable energy system
- smart meter
- ENERGY STAR® label

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meanings. Add other terms that you think are important and want to remember.

CONCEPT 1

Sustainable use of electrical energy begins with understanding how its use is measured.

Activity

Toaster Versus Washing Machine

Several pairs of appliances are given below.

- a toaster and a washing machine
- a portable vacuum cleaner and a freezer
- a clothes dryer and a dishwasher
- a coffee maker and a computer

1. In a group, try to agree on which appliance in each pair uses electrical energy at a faster rate than the other. For example, if you run each appliance for one hour, which one uses more electrical energy?
2. Read the page of text below. Then use Table 3.2 to assess your choices.

Use of electrical energy is measured in two main ways. These ways are explained below.

Watts and Kilowatts

electrical power the rate at which electrical energy is used by a load

Electrical power is the rate at which electrical energy is used by a load. The load is typically an appliance, such as a washing machine or a television. Electrical power is measured in watts (W) or kilowatts (kW). 1 kW equals 1000 watts.

Most home appliances are labelled with their *power rating* (the rate they use energy) in watts. For example, a light bulb may be rated at 100 W. An iron may be rated at 1000 W or 1 kW. This tells you that if an iron and light bulb are on for the same length of time, the iron uses energy 10 times faster than the light bulb. The iron uses 10 times more energy. Table 3.2 lists the typical power ratings of several appliances.

Kilowatt-Hours

The electrical energy used by an appliance over time is measured in kilowatt-hours (kWh). Note that kWh combines the units for power and time. If you use an appliance rated at 1000 W or 1 kW for one hour, you will have used 1 kWh of electrical energy. You would need to use a 0.5 kW washing machine for 2 hours or a 2 kW dishwasher for half an hour to use the same amount of electrical energy.

Table 3.2 **Typical Power Ratings of Appliances**

Appliance	Typical Power Rating (kW)
Clock	0.0050
Clothes dryer	5.0
Washing machine	0.50
Coffee maker	1.0
Computer	0.20
Dishwasher	1.8
Freezer	0.34
Microwave oven	1.5
Toaster	1.1
Vacuum (portable)	1.6

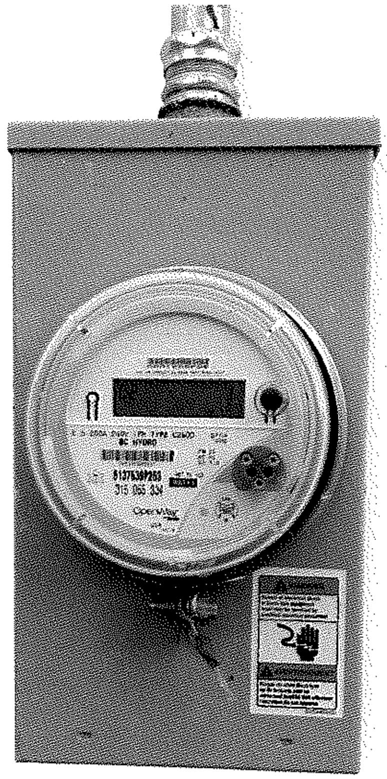


Figure 3.29 Smart meters measure electrical energy use as it changes over the course of the day.

Measuring Electrical Energy Use in Homes and Businesses

In most homes and businesses in B.C., use of electrical energy is measured by smart meters (Figure 3.29). **Smart meters** measure how electrical energy use changes in a building over the course of the day. The data are sent to the utility company automatically by wireless signals like those used by phones and other wireless devices. The meters can encourage "smart" behaviour on the part of consumers by giving people a means to track how and when they use electrical energy each day.

smart meter an electrical energy meter that measures how energy use changes in a building over the course of the day

Activity

Personal Use of Electrical Energy

1. Predict how your use of electrical energy at home varies on an average day.
2. Then predict how your use of electrical energy in summer would be different compared with winter. Sketch bar graphs to show your predictions.
3. Compare your graphs with those of other students. How are they similar? How are they different?
4. Do you think these data could help change the way your family uses energy? Explain.

Before you leave this page . . .

1. What is electrical power and how is it measured?
2. Describe one benefit of smart meters.

CONCEPT 2

Making informed choices helps you use electrical energy sustainably.

In a typical home, some appliances use more electrical energy than others. For example, a stove and a clothes dryer use more energy than a TV and a radio. However, some appliances of the same type are more energy-efficient than others. How can you tell the difference? Just check the label.

EnerGuide label a label that gives details about the amount of energy that an appliance uses in one year of normal use

Understanding EnerGuide and ENERGY STAR® Labels

The Government of Canada requires companies to label new electrical appliances to show how much energy they use in a typical year. This **EnerGuide label** is shown in Figure 3.30. Using more energy-efficient appliances helps you use electrical energy more sustainably. It also helps you save on the cost of electrical energy.

Activity

Reading EnerGuide Labels

Your teacher will give you several EnerGuide labels for the same type of appliance.

1. **a)** Of the samples provided, how much electrical energy does the least efficient appliance use per year, on average?
   b) How does this compare with the least efficient appliance available, as indicated on the bar of the EnerGuide label?
2. **a)** Of the samples provided, how much electrical energy does the most efficient appliance use per year, on average?
   b) How does this compare with the most efficient appliance available, as indicated on the bar of the EnerGuide label?
3. What other information might a consumer want to know about each appliance before choosing to buy one?
4. **a)** On a scale of 1 to 10, how important would the electrical energy efficiency stated on an EnerGuide label be to you when making a decision to purchase this type of appliance? Explain your choice. In your explanation, describe any other factors you would consider when buying this type of appliance.
   b) How much do you think EnerGuide labels influence purchasing decisions made by the general public? Explain your reasoning.

Figure 3.30 How to interpret an EnerGuide label

The large number shows how much energy the appliance uses in one year of normal use.

The shaded bar below the large number shows how the appliance compares with similar ones on the market.

The numbers on the bar give a range of efficiency for yearly energy use. The left end is the lowest (most efficient). The right end is the highest (least efficient).

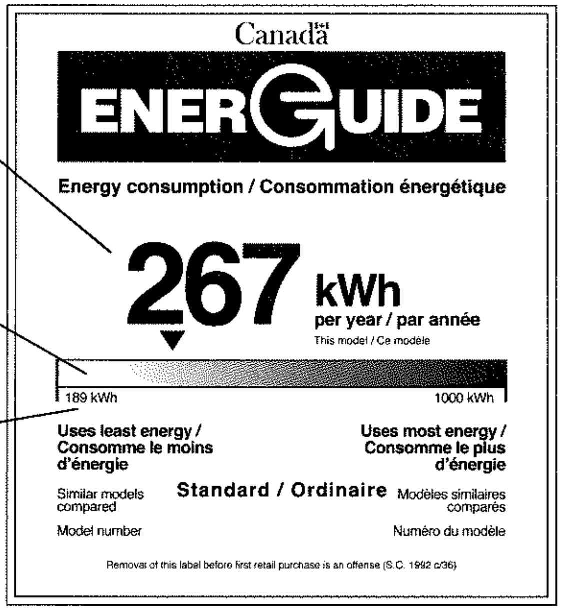


Figure 3.31 Appliances and equipment with the ENERGY STAR label use 10 to 50 percent less energy compared with a standard product in the same category.

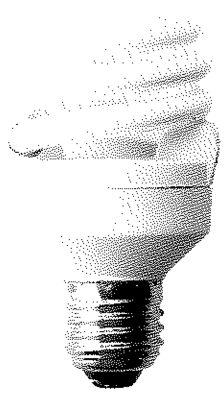
Another tool that can help you use electrical energy more sustainably is the **ENERGY STAR® label** shown in Figure 3.31. Appliances and equipment with this label have met minimum efficiency standards set by the Canadian government.

ENERGY STAR® label identifies a product as meeting or exceeding certain standards for energy efficiency

Activity

Comparing Lighting Options

Some light bulbs claim to use less electrical energy than others but have the same light intensity. How could you test this claim?



Design an experimental procedure to compare the energy consumption of several types of light bulbs. For instance, you might compare halogen, compact fluorescent, and/or LED bulbs.

The following tip will help you get started:

- The intensity of light is measured in units called *lumens*. Make sure that each light bulb in your experimental procedure emits the same number of lumens.

Connect to Investigation 3-J on page 264

phantom load electrical energy a device uses when it is turned off

Phantom Loads

Are you aware that many electrical devices are on even when you think they are switched off? They are in stand-by mode. For instance, to turn on a television with a remote control, the television must be on to sense the signal. The electrical energy a device uses when it is turned off is called a **phantom load**. In addition to remote-controlled devices, many other appliances, such as computers, washing machines, and microwave ovens, also have phantom loads. Figure 3.32 shows some common appliances with phantom loads in a typical home. The term phantom load sounds ominous, and in a way it is. Studies have shown that phantom loads account for about 900 kWh of electrical energy use each year in the average home.

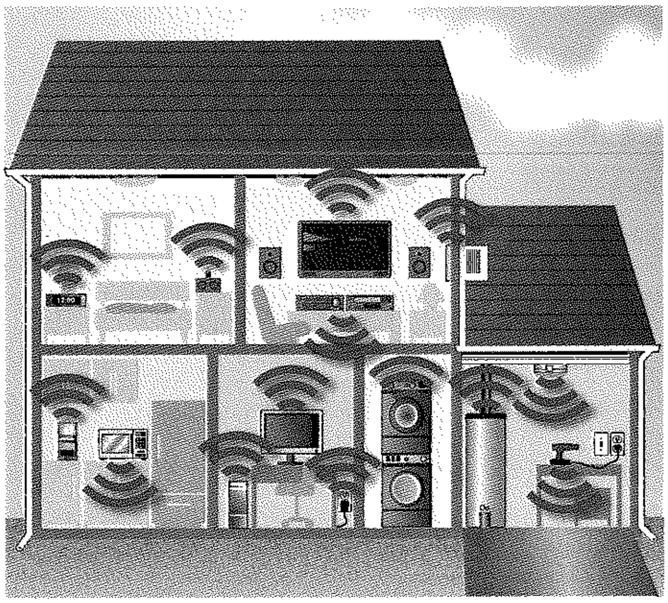


Figure 3.32 Devices with phantom loads are common in a typical home. **Identify the devices with phantom loads in this figure. For each device, explain why you think it has a phantom load.**

Activity

Fight the Phantom!

1. Create an inventory of possible phantom loads in your home or school. Use a table or other graphic organizer to organize your inventory. Your inventory should include the following information for each device.
   - type of device
   - location of device
   - number of devices in home or school
2. When you have completed your inventory, compare results with the class.
3. Do you think phantom loads are a significant waster of electrical energy in your home or school? Explain your reasoning.
4. How could you decrease the overall phantom load for the building you used for your inventory? Discuss your ideas with the class.

Before you leave this page . . .

1. Compare the information on an EnerGuide label with the information on an ENERGY STAR® label.
2. If a family goes away on vacation, why might electrical energy still be consumed in their home?

CONCEPT 3

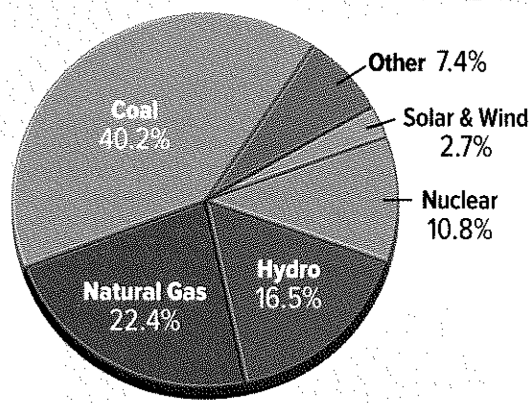
Renewable energy sources provide sustainable options for generating electrical energy.

Activity

Comparing Energy Sources

The graph on the right compares the percentage of different energy sources used worldwide. Use the graph to answer the questions that follow.

1. Identify the percentage of the world's electrical energy that is generated by the following energy sources.
   a) hydro **b)** nuclear **c)** fossil fuels **d)** wind and solar
2. What might the "other" sources on this graph refer to?
3. How do you think this graph would change if it showed energy sources used in **a)** Canada **b)** B.C. Provide your answers in the form of a graph.



Sources Used for World Electrical Energy Production

Electrical energy is always generated from another source of energy. The energy sources you learned about in Topic 3.1 are classified based on whether they are renewable or nonrenewable.

- **Nonrenewable energy sources** are not replaceable in a human lifetime. Fossil fuels are a nonrenewable energy source. Coal or natural gas is used to generate electrical energy in most provinces in Canada. The other nonrenewable energy resource is uranium (nuclear reactions), which is used to generate electricity in nuclear power plants. Since a human lifetime is so short in comparison, once these resources are used up, they are gone for good. As a result, nonrenewable energy sources are not a sustainable way to generate electrical energy.
- **Renewable energy sources** are produced on a continual basis or can be replenished fairly quickly. They are not at risk of being used up over the course of a human lifetime. Renewable energy sources include sunlight, wind, river flow, tides and waves, geothermal sources, and biomass. They provide sustainable options for generating electrical energy.

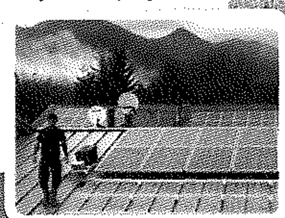
nonrenewable energy source an energy source that is non-replaceable in a human lifetime

renewable energy source an energy source that is available on a continuous basis

Connect to Investigation 3-K on page 266

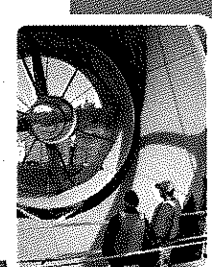
WAC Bennett Dam (2730 MW)

Located on the Peace River, this massive 183 m high, large-scale hydroelectric dam provides most of B.C.'s electrical energy. However, several controversies surrounded the building of the dam. These included concern over negative environmental impacts when 350 000 acres of forested land was flooded, creating Williston Lake. The flooding also displaced residents of the area, including members of the Tsay Keh Dene First Nation.



The Klemtu Small-scale Hydro (1.7 MW) and Solar Project (0.023 MW)

A small-scale hydro generating station off Baron Lake and photovoltaic cells on the roof of the Kitasoo Community School in Klemtu help the entire Kitasoo/Xai'xais community. Electrical energy generated by these projects reduces the isolated community's reliance on diesel generators.



Williams Lake Biomass Plant (68 MW)

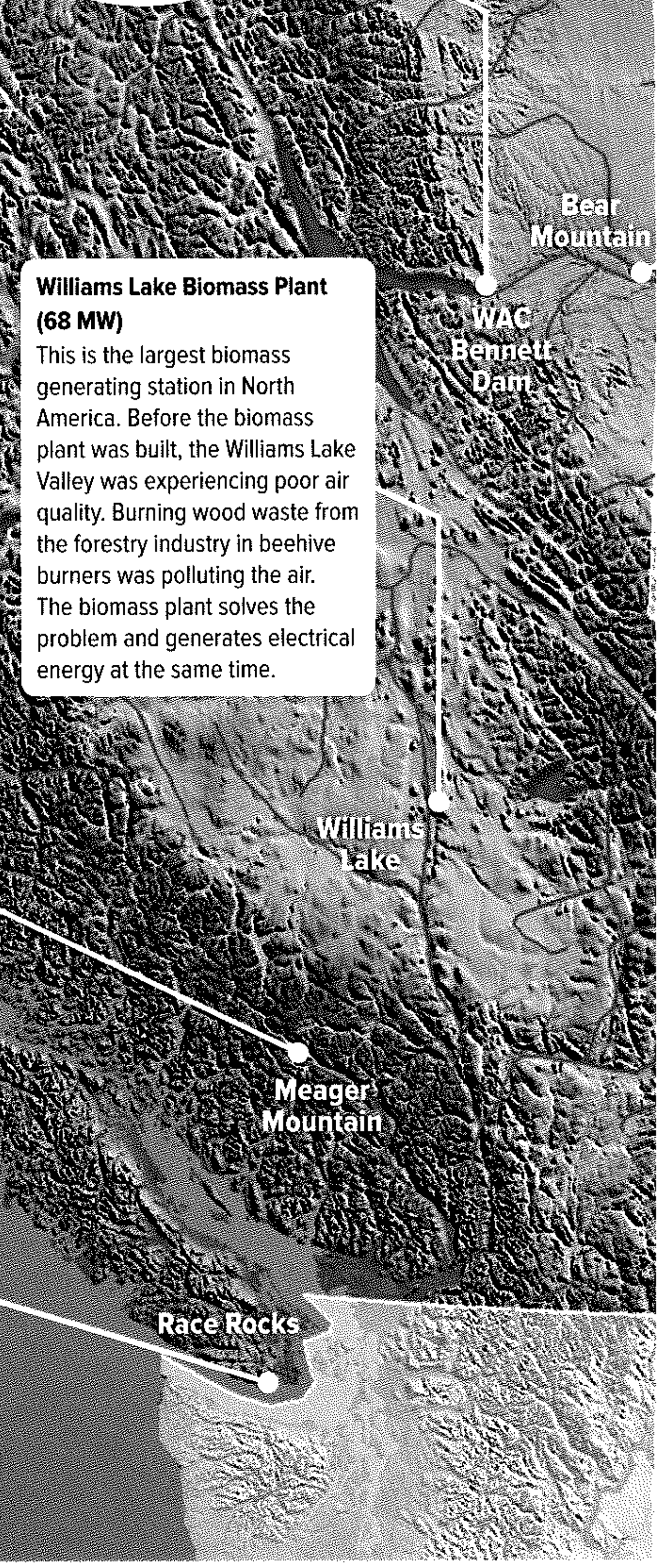
This is the largest biomass generating station in North America. Before the biomass plant was built, the Williams Lake Valley was experiencing poor air quality. Burning wood waste from the forestry industry in beehive burners was polluting the air. The biomass plant solves the problem and generates electrical energy at the same time.

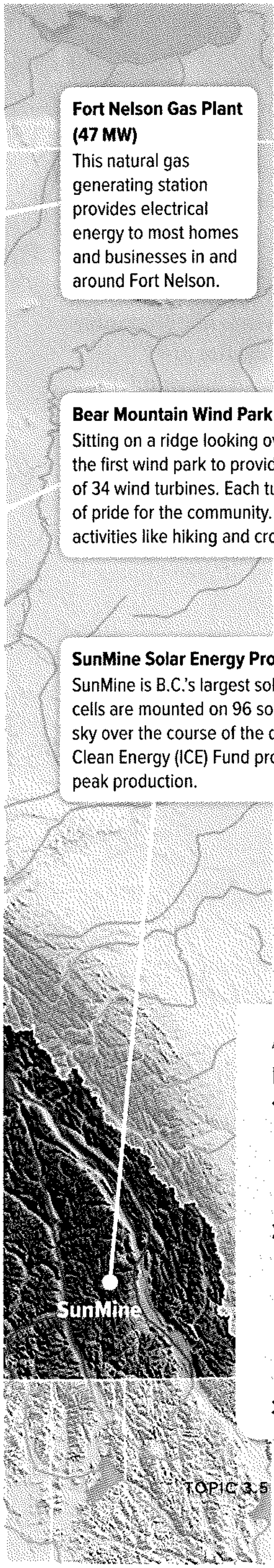
Meager Mountain Geothermal Potential (200 MW)

Molten rock rises to just a few kilometres below B.C.'s Coast Mountain range. At average temperatures of 200-300°C, the molten rock holds great potential to heat water, producing steam to turn turbines to generate electrical energy. In fact, the Coast Mountains have the greatest geothermal potential in all of Canada. Meager Mountain in Upper Lillooet Provincial Park has the potential to generate electrical energy for over 90 000 homes annually.

Race Rocks Tidal Energy Project (0.65 MW)

The Race Rocks Tidal Energy Project is located southwest of Victoria in the Race Rocks Ecological Reserve. This small-scale demonstration project was installed in 2006. It is the first operating tidal current turbine in Canada. The turbine transforms the kinetic energy of tidal currents into electrical energy. The project also acts as a testing ground for further research into tidal technology.





Fort Nelson Gas Plant (47 MW)
This natural gas generating station provides electrical energy to most homes and businesses in and around Fort Nelson.

Renewable and Nonrenewable Energy Sources in British Columbia

The map in Figure 3.33 shows a few ways that renewable and nonrenewable energy sources are used to generate electrical energy in B.C. on a large and small scale.

Bear Mountain Wind Park (144 MW)
Sitting on a ridge looking over Dawson Creek, Bear Mountain Wind Park is the first wind park to provide electrical energy commercially in B.C. It consists of 34 wind turbines. Each turbine is 78 m high. The local initiative is a source of pride for the community. The wind park site is also used for recreational activities like hiking and cross-country skiing, as well as cattle grazing.

SunMine Solar Energy Project (1 MW)
SunMine is B.C.'s largest solar project. Located just outside of Kimberley, over 4000 photovoltaic cells are mounted on 96 solar trackers. These trackers follow the Sun's movement through the sky over the course of the day. The project received much of its funding from B.C.'s Innovative Clean Energy (ICE) Fund program. It can generate electrical energy for about 250 homes at peak production.

Figure 3.33 This map shows several renewable and nonrenewable energy projects in B.C. Note that 1 MW (megawatt) is equal to a million watts. **Which initiatives on this map make use of renewable energy sources? Which ones use nonrenewable energy sources?**

Activity

Map It!

1. Choose a renewable or nonrenewable energy source that interests you. Research the source to find out where it is currently being used to generate electrical energy in B.C. If it is not being used, choose another source.
2. Research the source further to answer the following questions.
   - **a)** Is the source renewable or nonrenewable?
   - **b)** What are the pros and cons of using it to generate electrical energy?
   - **c)** Where and how is the source being used in B.C.?
   - **d)** One other question you have about the source.
3. Record your answers and add them to a map of the province as directed.

Connect to Investigation 3-L on page 268

Moving Toward a Sustainable Future

Although we have tended to use electrical energy unsustainably in the past, our behaviour is beginning to change. A shift is occurring in how electrical energy is being generated, used, and even thought about. This is part of a larger movement that is pushing for sustainable use of all energy sources. People's growing concern about the environment has been driving this change. So has the realization that nonrenewable energy sources will one day run out. This awareness is not just occurring in British Columbia and Canada, but all over the world.

As a result of this greater awareness, individuals and governments have begun to see the need for a sustainable energy system. A **sustainable energy system** is a sustainable way of perceiving, producing, and using energy, including electrical energy. The system has the following characteristics:

sustainable energy system a sustainable way of perceiving, producing, and using energy

- the extraction, production, and use of energy have limited impact on environmental and human health
- there is less reliance on decreasing nonrenewable sources
- it ensures the availability of renewable and reliable energy sources for current and future generations
- it provides access to affordable energy for Earth's entire population

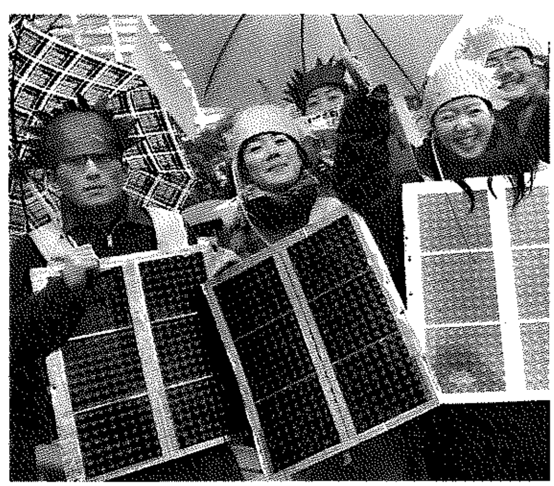
Activity

Voicing Your Concerns

Create a plan to raise awareness about the need for a sustainable energy system. For example, this could involve setting up an awareness group, creating a poster campaign, or raising awareness through social media. At a minimum, your plan should

- summarize how you will organize your campaign
- describe who your campaign will reach and how it will reach them
- discuss how your campaign will raise awareness about this issue
- explain how you will judge the success of your campaign once it is over

If there is time, present your plan using a medium of your choice.



First Peoples Ecosystem Based Management

Many of the characteristics of a sustainable energy system are in line with First Peoples Ecosystem Based Management (EBM). Some principles of EBM are given below.

Respect and Responsibility
Respect and responsibility go hand in hand. By making decisions that respect the natural world and the well being of all who call it home, First Peoples practise responsible use of resources. First Peoples consider themselves responsible for future generations, and respectful decision making helps them to be so.

Intergenerational Knowledge
Listening to Elders shares knowledge and decision making skills between generations. This way, decisions can be based on past experience. By sharing traditions and culture, the importance of place is also taught.

Balance and Interconnectedness
Balance keeps ecosystems healthy. It also makes sure that future generations are considered with each decision. Interconnectedness takes many relationships into consideration in decision making—not just between people, but also between other living things and their environment, and between ecosystems.

Giving and Receiving
Giving thanks for natural resources recognizes their value. It encourages shared responsibility for the natural world. Benefits of resources are shared between members of a community and with other communities.

Activity

Connecting with First Peoples Principles

T'sou-ke First Nation uses photovoltaic cells to generate electrical energy. It has started a project to use waves for this purpose as well. As a community, they are dedicated to using electrical energy sustainably. Their efforts have reduced their use of electrical energy by at least 75%.

1. Find out more about T'sou-ke First Nation's plan to use energy sustainably. In a group, discuss how First Peoples EBM applies to T'sou-ke First Nation. Research EBM principles further to gain a better understanding of how they reflect sustainability, environmental stewardship, resource management, and interconnectedness. If you are not sure what a term means, look it up.
2. How do you think the location of T'sou-ke First Nation influenced the type of renewable energy sources they chose to develop?
3. Consider where you live. How would your location and features of your region influence the choices you would make if you could choose the energy source used to generate electrical energy for your community? What other factors would it be important to consider?

Before you leave this page . . .

1. Explain why coal is a nonrenewable energy source and why moving water is a renewable energy source.
2. Identify the four main characteristics of **a)** a sustainable energy system and **b)** First Peoples Ecosystem Based Management.

TAKE a Stand

Make a Difference

Challenges of Changing to a Sustainable Energy System

To change to a sustainable energy system, everyone must learn to change how they act and how they think. The questions below highlight some of the challenges.

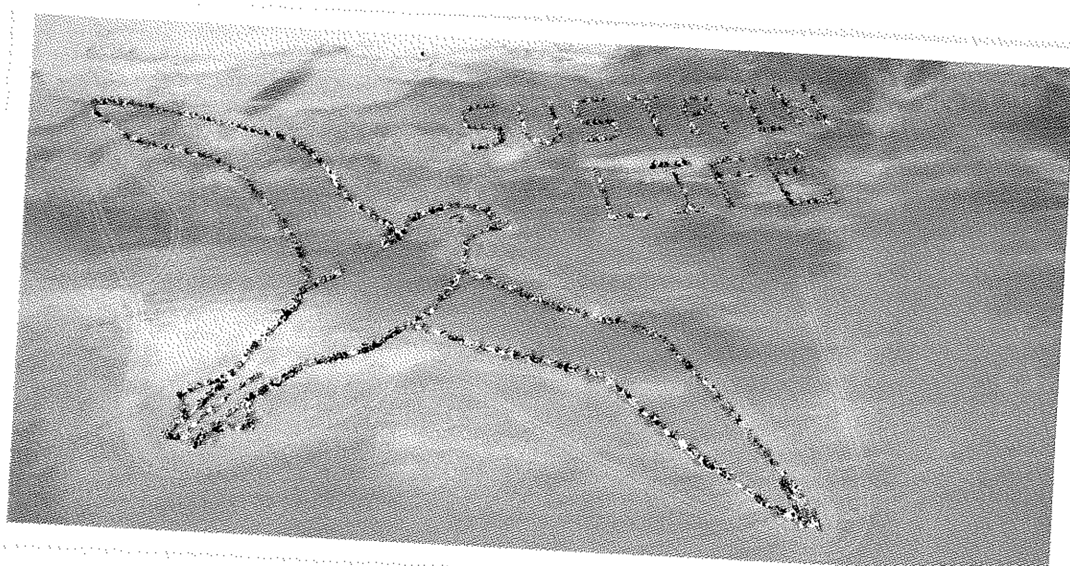
- Canada is a large and diverse country. Should a sustainable energy system be the same for all of Canada, or should it differ for different regions?
- What types of energy sources should be included? For instance, should only renewable resources be used?
- How can information about energy sources be obtained and presented in an unbiased way?
- How should we balance the needs of today with those of future generations?
- Developing renewable energy sources costs money. How much should we invest in these technologies? Who should pay?
- About 1.5 billion people on our planet have no access to electrical energy. How can individuals such as you help to reduce this number? How can a community help to reduce this number? How can society at large help?

Analyze and Evaluate

1. What is your opinion of the challenges listed in this feature? What other challenges are there? How easy do you think it will be to find and agree on solutions?

Communicate

2. Choose one issue that interests you in this feature. Research more information about it. Gather and evaluate sources that represent the many sides of the issue. Then take a stand on one side of the issue. Share your viewpoint with the public by writing a letter to the editor of a relevant newspaper or magazine, or commenting on a relevant web page.



Check Your Understanding of Topic 3.5

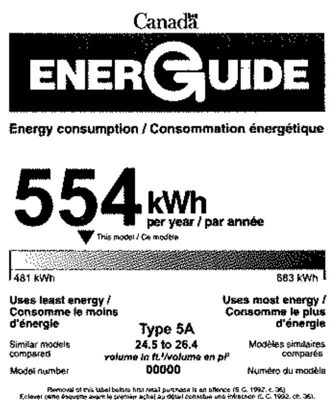
QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating AI Applying and Innovating C Communicating

Understanding Key Ideas

1. A light bulb is marked with 100 W. What does this mark tell a consumer about the light bulb? PA

2. Most B.C. homes and businesses have smart meters. PA
   a) How does a smart meter relay data to the utility company?
   b) What information does it relay?

3. Examine the label on the right. PA AI C



   a) Summarize, in your own words, the information provided on the label.
   b) Explain how you could use the information on the label when shopping for a new appliance.

4. You and your family have recently moved to a remote island on the B.C. coast. PA E AI
   a) Identify one nonrenewable energy source your family could use to generate electrical energy. Explain how it could be used to generate electrical energy.
   b) Identify one renewable energy source your family could use to generate electrical energy. Explain how it could be used to generate electrical energy.
   c) Explain which of the two sources you would recommend that your family uses. Justify your response.

5. Explain how electrical energy can be used by an electric toothbrush that is plugged in but is not running. PA AI

6. An environmental blog states that natural gas is renewable because it is generated from biomass. Do you agree? Explain. PA E

7. A letter to the editor of your local newspaper states that in a northern climate such as Canada's, sunlight can never be a reliable source of electrical energy. How would you explain, in a follow-up letter, that this is not the case? Refer to at least one example of how solar energy has been used to generate electrical energy in B.C. PA E AI C

Connecting Ideas

8. A source claims that phantom loads account for up to 5 percent of the electrical energy used in homes. Explain how you could collect and analyze data to test this claim. QP PA E AI

Making New Connections

9. During Earth Hour each year, for one hour, people all over the world are encouraged to use less electrical energy. E AI
   a) How might the organizers of future Earth Hours encourage more people to use less electrical energy for one hour on the day selected for Earth Hour?
   b) How might the organizers of future Earth Hours inspire people to make long-lasting lifestyle changes that will reduce their use of electrical energy?

INVESTIGATION

3-J

GUIDED INQUIRY

Skills and Strategies

- Questioning and Predicting
- Planning and Conducting
- Processing and Analyzing
- Evaluating
- Communicating

What You Need

- access to information resources (for example: online, in-print, interviews)

Create a Sustainable Energy Plan for Your School

Renewable energy sources, energy efficiency, and energy conservation each play an important role in a sustainable energy plan. In this investigation, you will apply these three components to create a plan to generate and use electrical energy more sustainably at your school.

Question

How can you create a sustainable energy plan for your school?

Procedure

1. Working in a group, you will prepare a presentation on the topic "A Sustainable Energy Plan for Our School." Your presentation format is up to you, but the presentation must meet the design criteria on the next page.
2. With your group, brainstorm how you will gather information. After you have collected your information, work together to organize it.
3. Design and create any images, models, or props that you will use.
4. Prepare your final presentation. Make your presentation as directed by your teacher.

Evaluate

1. Did you present enough data to convince your audience that your action plan was realistic? Explain.
2. What adjustments would you make to your plan for a new school being built in your community? Explain.

Design Criteria

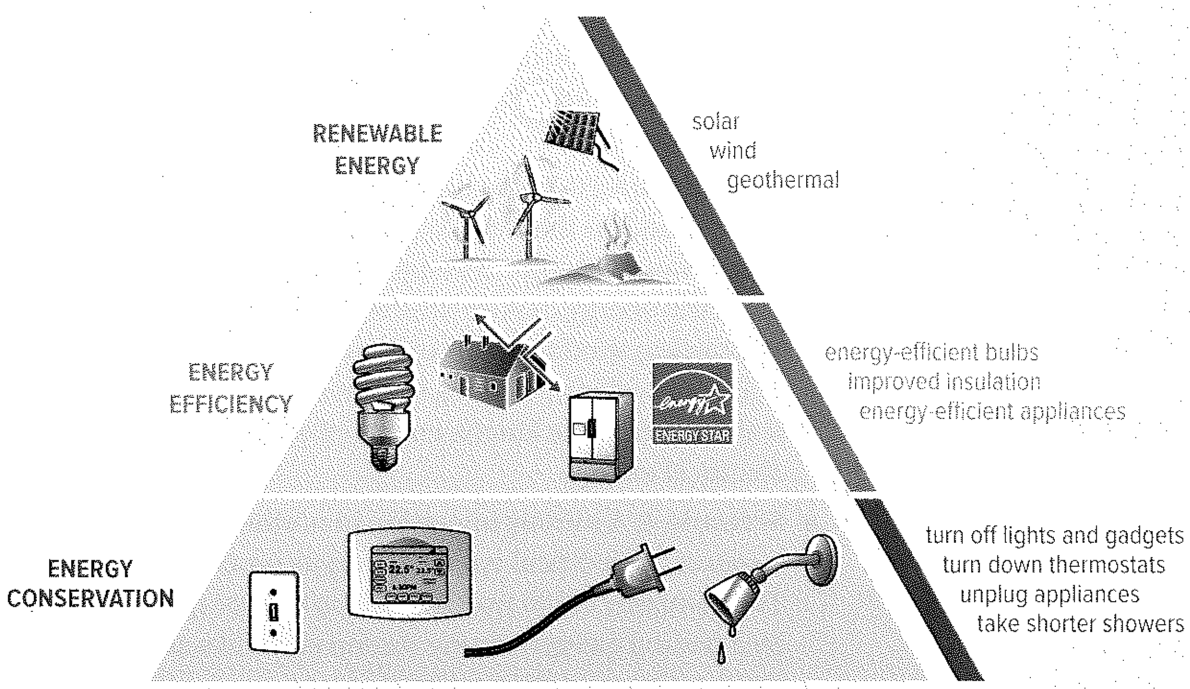
A. Your presentation should explain why it is important that your school generate and use electrical energy more sustainably.

B. Your presentation should answer the question "Can our school generate and use electrical energy more sustainably?" If your answer is "no," you must provide evidence and explain your reasoning. If your answer is "yes," include a step-by-step plan, focussing on how this change can be brought about.

C. Your presentation should include data on where and when electrical energy is currently used in the school, how much electrical energy is used, and what sources supply this energy.

D. Your presentation should assess the cost of implementing your plan. Consider the sustainable energy pyramid shown below.

- The top level consists of renewable energy sources. These resources tend to be expensive to produce. However, they are still important to a sustainable energy plan if affordable.
- The middle level addresses energy efficiency. This often involves buying newer, more efficient appliances and comes with a significant price tag.
- The base of the pyramid consists of energy conservation. It is the most cost-effective level and the one that the most people can participate in.



INVESTIGATION

3-K

STRUCTURED INQUIRY

Skills and Strategies

- Processing and Analyzing
- Evaluating
- Communicating

What You Need

- access to information resources (for example: online, in-print, interviews)

Energy Source Scenarios

Deciding on the best source of energy to generate electrical energy in a particular setting depends on many variables. Costs, environmental impacts, availability, reliability, and convenience are just a few of the many factors to consider.

Question

Which energy source is the best choice in a given situation?

Procedure

1. As a group, decide on a scenario in which you will compare two energy sources that can be used to generate electrical energy. Some scenarios you may choose from are below. You may also conduct research to create your own scenario.
   - **Scenario 1:** A ski hill on the south side of a mountain in southeastern B.C. is choosing between generating electrical energy with photovoltaic cells or buying electrical energy generated by a large commercial hydroelectric dam.
   - **Scenario 2:** A family wants to generate electrical energy for their isolated cabin in northwestern B.C. Their cabin is in a position to take advantage of a nearby geothermal energy source (hot springs) on a small scale. They are choosing between this option and a diesel-powered electric generator.
   - **Scenario 3:** A 20-home housing development is being constructed on the west coast of Vancouver Island. The owner would like the development to generate its own electrical energy. It is an area with strong steady winds, so building wind turbines on land is an option. The owner is also considering placing turbines in the ocean that will transform the kinetic energy of ocean waves into electrical energy.
   - **Scenario 4:** A mining operation in northeastern B.C. needs a source of electrical energy to run its processing facilities. The company could purchase electrical energy generated by a natural gas generating station or build a small run-of-river station on a river on its property.

2. Decide on factors you will consider and how you will rank and judge their importance. In a group, brainstorm answers to the following questions.
   - What key factors should be considered when choosing an energy source for a particular situation?
   - How can one factor be weighed against another?
3. Prepare a plan for comparing the two sources of energy in your group's scenario. Explain how you will assess the reliability of the sources you are using in your research. Have your teacher approve your plan before proceeding.
4. Make a list of the major advantages and disadvantages of each energy source.
5. Identify factors that might be particularly important in the scenario you chose.
6. Decide on which factors you think should be given the greatest weight, and rank them from most important to least important. Explain your reasoning.

Process and Analyze

1. Compare each energy source based on the factors you chose. Assign each energy source a score for each factor. For example, an energy source might receive a +2 for environmental impacts but a −1 for cost.
2. Some advantages and disadvantages are immediate (such as the initial cost of construction) while others are realized over a much longer period of time (such as gradual pollution of an ecosystem). Summarize how you weighed short-term versus long-term factors.

Evaluate and Communicate

3. Tally your results and reach a conclusion.
4. Prepare a recommendation that could be used to inform people involved in the situation you chose. Use a format of your choice, keeping your audience in mind.

INVESTIGATION

3-L

STRUCTURED INQUIRY

Skills and Strategies

- Questioning and Predicting
- Planning and Conducting
- Processing Information
- Evaluating
- Communicating

What You Need

- access to information resources (for example: online, in-print, interviews)

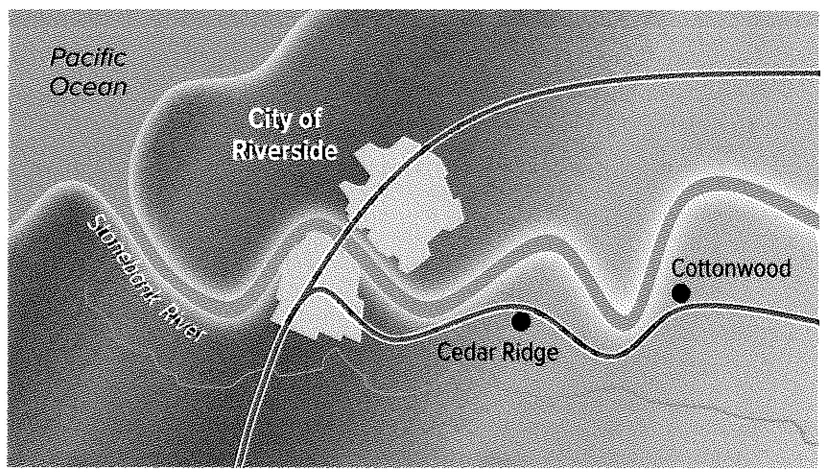
A Source of Electrical Energy for Riverside

The city of Riverside and its surrounding area (population: 10 000) is interested in establishing its own electrical energy generating station that utilizes a renewable energy source. The source must be able to supply 3 kW to every resident. Anything above this can be sold to neighbouring communities as surplus. Interested companies have been invited to present their proposals to the city council.

Question

What is the best renewable energy source to supply the city with reliable electrical energy year round?

This map shows the layout of the city, the shape of the valley, and two of the closest suburbs: Cedar Ridge and Cottonwood. The city is 20 km from an undeveloped coastline.



The Stonebank River winds through the valley and supplies water to the area. The city has a system of floodgates to cope with the spring floods that can affect the valley. The valley floor consists mainly of agricultural areas and neighbourhoods. The mountains around the valley are logged and used for recreation. A ski resort is located on a mountain just outside of the city. The mountain is a potential site of geothermal sources. The valley has an average wind speed of 14.3 km per hour. It has 288 sunny days per year on average.

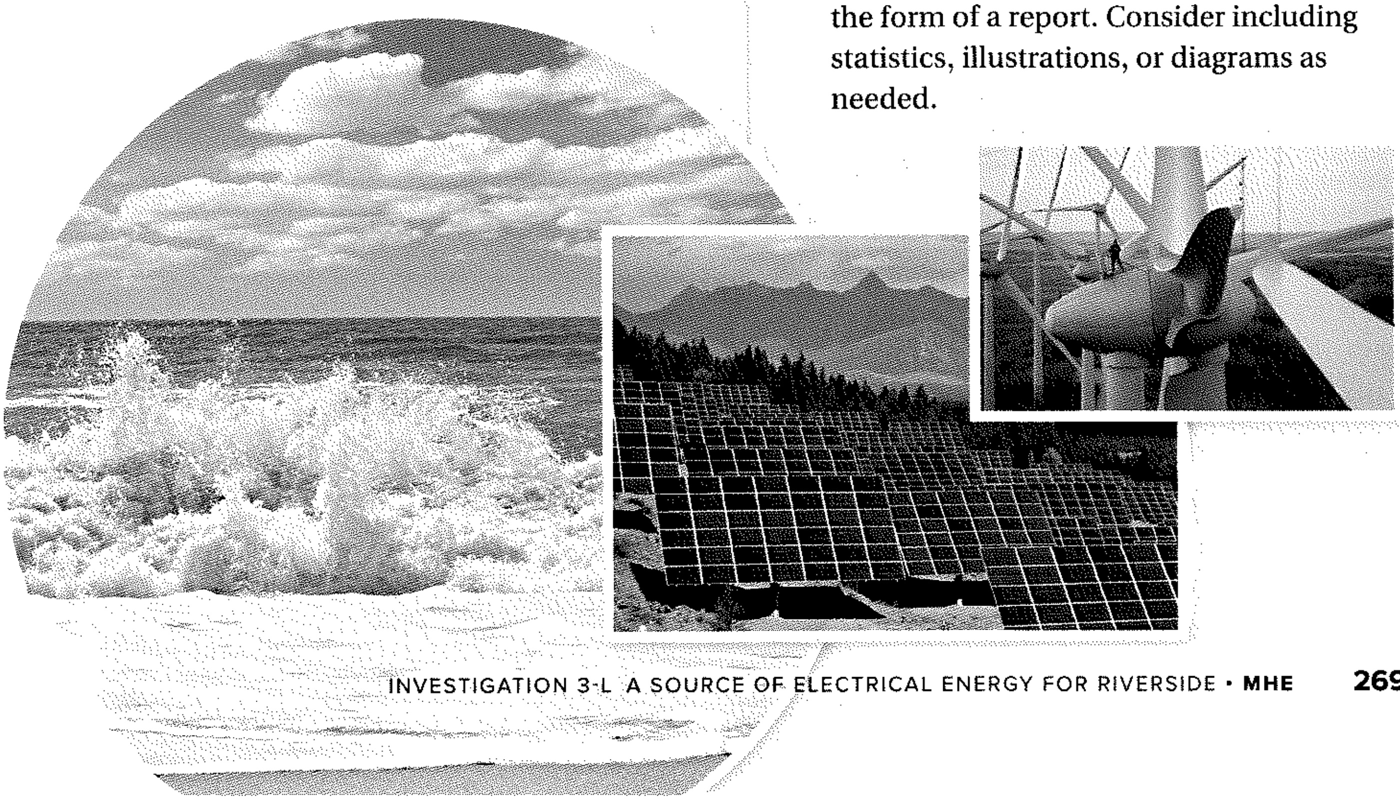
Procedure

1. Your teacher will assign your group the role of one of the following stakeholders or energy companies that will be attending the council meeting.
   - Sunny Skies Solar Energy
   - Eagle Mountain Wind Energy
   - From the Ground Down Geothermal
   - River Run Hydroelectric
   - Tsunami Wave and Tidal Energy
   - Woodland Biomass
   - Riverside Nature and Wildlife Association
   - local residents association
   - Riverside Valley Agricultural Cooperative
   - city council
   - local First Peoples

   If your group is an energy company, you will be preparing a proposal for the new electrical energy generating station. If your group is representing a local stakeholder, you will be preparing a presentation of your concerns regarding the generating station.
2. Use the information on this page, including the map, as well as Internet and library resources to conduct research as needed to learn more about your group's proposal, stance, or role.
3. Organize the results of your research to prepare your presentation for a mock town council meeting.
4. Your teacher will briefly explain each group's proposal, stance, or role. As you listen to each group's presentation, take notes to help yourself prepare questions to ask.
5. Make your presentation before the council. If you represent the city council, you will present your concerns to the other presenters last.

Evaluate and Communicate

1. What was the final decision of the council? What was their reasoning?
2. Do you agree with the decision? Why or why not?
3. Summarize the presentation you made in the form of a report. Consider including statistics, illustrations, or diagrams as needed.



UNIT 3

Summary

ESSENTIAL QUESTION

How do we apply our understanding of charges to generate and use electrical energy?

TOPIC 3.1:

How is electrical energy part of your world?

- Electrical energy has many applications.
- Many different types of energy can be transformed into electrical energy.
- Electrical energy is generated in different ways from different sources.

Key Terms

electrical energy
generator system

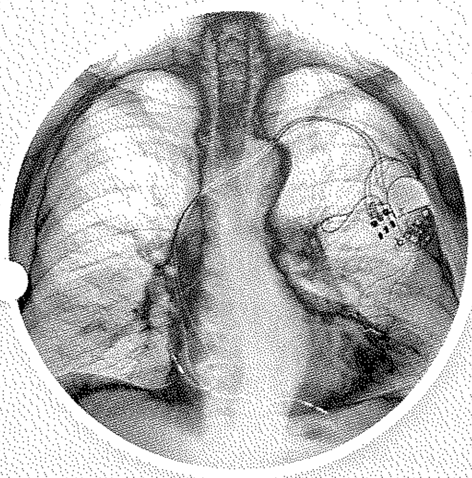
TOPIC 3.2:

How do electrical charges behave?

- Electrons carry a negative charge, and protons carry a positive charge.
- Opposite charges attract each other, and like charges repel each other.

Key Terms

negative charges
positive charges
law of electric charge



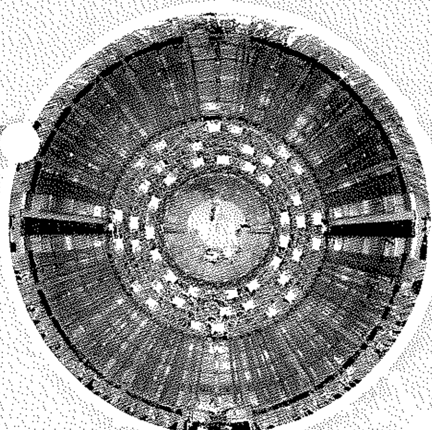
TOPIC 3.3:

How do charges flow through the components of a circuit?

- Chemical energy separates electrical charges in cells.
- Charges can flow through conductors, but not insulators.
- Moving electrical charges form an electric current.
- A load resists the flow of current.
- Conductors must form a closed loop to allow current to flow.

Key Terms

source	electrical potential difference		
conductor	conductivity	insulator	current
electrical circuit	load	resistance	short circuit



TOPIC 3.4:

How are circuits used in practical applications?

- Voltage, current, and resistance in a circuit are related by Ohm's law.
- Loads can be connected in series or in parallel in a circuit.
- Parallel loads are practical for circuits in the home.

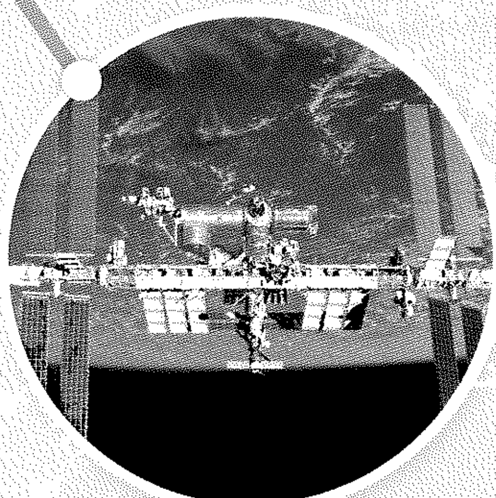
Key Terms

Ohm's law	series circuit	parallel circuit

TOPIC 3.5:

How can electrical energy be generated and used sustainably?

- Sustainable use of electrical energy begins with understanding how its use is measured.
- Making informed choices helps you use electrical energy sustainably.
- Renewable energy sources provide sustainable options for generating electrical energy.



Key Terms

electrical power	smart meter
EnerGuide label	ENERGY STAR® label
phantom load	nonrenewable energy source
renewable energy source	sustainable energy system

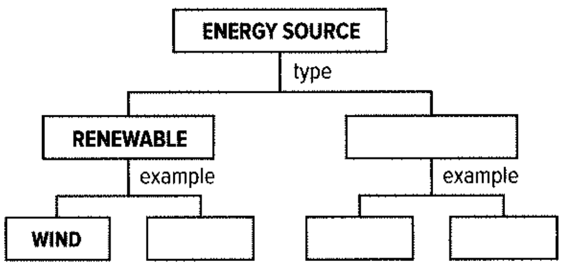
UNIT 3

Review

What Do You Know?
Connecting to Concepts

Visualizing Ideas

1. Copy and complete the concept map.

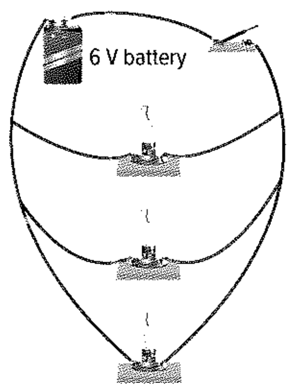


2. Design a graphic organizer to compare a water circuit with an electrical circuit.

Using Key Terms

3. Below are four sets of terms from this unit. For each set, write one or two sentences that use all the terms correctly.
   a) law of electric charge, negative charges, positive charges
   b) voltage, current, Ohm's law, resistance
   c) current, closed circuit, load
   d) electrical energy, EnerGuide label, smart meter

4. Examine the diagram.
   a) Identify the load(s), source, switch, and direction of current flow.
   b) Identify the type of circuit.



Communicating Concepts

5. How does each of the following use electrical energy to perform a function?
   a) a maglev train to travel
   b) a tablet to carry out a command from your finger
   c) a neon sign to glow a specific colour
   d) a robot to frown like a human being

6. a) Describe the relationship among mechanical energy, potential energy, and kinetic energy.
   b) Explain how a geothermal generating station transforms thermal energy into electrical energy.

7. A generating system is sometimes referred to as simply a generator. Why is this technically incorrect?

8. Consider the terms nuclear fission and nuclear fusion.
   a) How do these two nuclear reactions differ?
   b) Which is currently used to generate electrical energy in Canada?

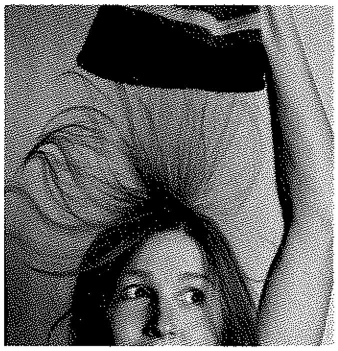
9. Describe the law of electric charge.

10. Use the analogy of a worker to explain how chemical energy does work to create an electrical potential difference in a cell.

11. Which "batteries" that you use in your daily life are not actually batteries? Explain.

12. A series circuit has a battery, a switch, and a load. Explain why the load goes off when you open the switch. Base your answer on the necessary conditions for circuits.

13. Use the terms "electrically charged" and "electrically neutral" to explain what has caused the phenomenon on the right.



14. Write out Ohm's law in your own words.

15. a) How does a short circuit form?
    b) Explain how a short circuit might be dangerous.

16. Describe one way that a series circuit is the same as a parallel circuit and one way that it is different.

17. Explain what happens to the current from a source when it encounters two branches of a parallel circuit.

18. Describe the danger associated with running too many appliances on the same parallel circuit in a building.

19. Explain why a radio might still use electrical energy when it is switched off.

20. In Canada, electrical energy is generated mainly by hydroelectric dams, nuclear reactors, and fossil fuel-burning generating stations. Which of these use renewable energy sources?

21. Identify three different ways that renewable energy sources are currently used to generate electrical energy in B.C.

22. a) How is the slogan "every kilowatt counts" relevant to you as a consumer of electrical energy?
    b) How is the slogan relevant to the environment?

23. Explain the ideas behind First Peoples Ecosystem Based Management in your own words.

What Do You Know?
Connecting to Competencies

Developing Skills

24. a) Design a procedure to investigate how the distance between buildings and wind turbines affects the amount of electrical energy generated by the wind turbine. Include a materials list and safety precautions.
    b) What might your results suggest about where wind turbines should be situated in urban centres?
    c) What other factors might you want to investigate in order to better answer question b?

25. Create a sketch that explains the role of electrodes and an electrolyte in a cell.

26. Draw a sketch and write a caption that explains the connections among the following as they apply to electrical potential difference: cell, electrons, protons, chemical energy, positive terminal, negative terminal.

27. You want to build a circuit with a source, a switch, a motor, and a lamp. You want the lamp to indicate if the motor stops working. Draw the circuit.

28. There are three light bulbs, A, B, and C, in a circuit. The circuit has only one switch which turns on all of the light bulbs. When A burns out, B and C remain on. When B burns out, A remains on but C goes out. When C burns out, A remains on but B goes out. Draw a circuit diagram with these three light bulbs that would give these results. Explain why each light bulb responds as described.

Thinking Critically and Creatively

29. A solid metal ball is sitting on a rubber mat. If it is given a negative charge, will the charge remain on the surface or spread through the ball? Use your understanding of conductors and the properties of charges to explain your answer.

30. Objects A and B are suspended from insulating threads. A positively charged balloon attracts Object A and repels Object B. Can you determine the charge of each object? Explain your reasoning.

31. An AA cell is smaller than an A cell. Does it necessarily have a smaller electrical potential difference? Explain.

32. A battery has an electrical potential difference of 6 V. A bulb with a resistance of 50 Ω is connected to the battery in series. The bulb burns out. What is the current through the bulb? Explain.

33. A hair dryer fan starts as soon as the switch is closed. The cord on the hair dryer is 100 cm long. However, electrons take about 1 minute to travel 3 cm. Explain the apparent contradiction.

34. A forensics team is investigating a fire. They find a burnt-out wall outlet with the remains of two extension cords plugged into it. Several appliances are plugged into each extension cord. Explain a possible cause of the fire.

35. A washing machine has a power rating that is many times greater than a television. However, a washing machine uses less electrical energy in a year in an average home than a television. Suggest why this is true.

Understanding Big Ideas
Making New Connections

Applying Your Understanding

36. Whenever a new hydroelectric dam is built, unavoidable flooding of plants and other organic materials results in the release of mercury compounds as they decompose. This leads to harmful mercury build-up in food chains and, in particular, in valuable fish stocks. Over a period of 10 to 30 years, decomposition rates slow and mercury in the environment decreases.

a) How should we value the electrical energy generated by a hydroelectric dam versus the damage caused by mercury pollution?

b) Many First Peoples depend on fish in B.C. rivers. If you depend on fish in a region where a dam is built and have to stop eating them, should you be compensated for your loss? Explain your reasoning.

c) In light of the environmental harm a dam can cause, can it be part of a sustainable energy system? Explain your reasoning.

37. Electric vehicles are common sights in British Columbia, especially in urban areas. These vehicles are often described as environmentally friendly. However, two people driving identical electric vehicles for the same distance each year can have very different environmental impacts depending on the energy source they use to charge their car batteries. Explain why this is the case.

38. Many scientists and environmentalists are opposed to drinking water from plastic bottles even though most bottled water is sold in bottles made out of recyclable plastic.

a) How might consuming bottled water waste electrical energy?

b) How might it affect the environment?

Thinking Critically and Creatively

39. B.C.'s forests could produce a large amount of biomass energy.

a) What are the pros and cons of using a natural forest as a source of biomass?

b) Do you think devoting large areas of forest to growing biomass to generate electrical energy is a good idea? What factors would you consider?

c) Suggest one benefit and one drawback of using farmland instead of forest to produce biomass for electrical energy.

40. Your family is trying to decide whether to install photovoltaic cells on your roof.

a) Identify one benefit of installing photovoltaic cells.

b) Identify one problem related to installing them.

c) Describe what other factors you would take into account when choosing whether to install this technology.

d) Many provinces offer subsidies that help homeowners pay for renewable energy technology they install in their homes. Others buy back excess electrical energy produced by the consumer. Do you think these programs will increase the number of people using this technology? Would it influence your decision? Explain.

Connecting to Self and Society

41. People living in different countries have very different rates of electrical energy consumption. In general, developed countries use the most electrical energy while developing countries use the least. How do you think this information should influence how much responsibility different countries have in moving to a sustainable energy system?

42. As shown below, Abbotsford Middle School has installed a wind turbine to generate electrical energy. The school also has solar panels and a bicycle generating system all linked up to the computer lab.

How is the school moving toward a sustainable energy system or following the principles of First Peoples Ecosystem Based Management?

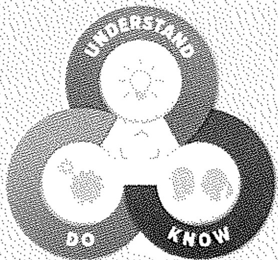
43. Refer to "First Peoples Perspectives in Science" on page xxii near the start of the textbook.

a) Review and reflect on the four themes of interconnectedness, transformation, renewal, and connections with place.

b) In a journal or in small groups, share ideas about how the concepts you have been learning about in this unit relate to these four themes.

Unit Assessment

How can you "green" the electrical plan of a home?



A large-scale shift toward sustainable energy is taking place all around the world. For the first time, the development of renewable energy sources is surpassing that of nonrenewable sources. But small-scale change is taking place as well, as people conserve electrical energy in their daily lives. We can create greener rooms that use less electrical energy in any home or building. Understanding the electrical plan (how each room is wired and how much current each device or appliance draws) is a starting point. This can help people make decisions about nonessential loads, devices with phantom loads, and energy-efficient appliances. It can also help people assess electrical safety in the home.

Work as part of a group to do the following.

STEP 1 ▶ Reflect on the three options, their photos, and the question asked for each option.

STEP 2 ▶ Brainstorm at least three more options and questions of your own about ways to green a home's electrical plan.

STEP 3 ▶ Decide on one of the six option questions to investigate.

STEP 4 ▶ Plan and conduct a scientific inquiry to explore your question.

STEP 5 ▶ Organize and analyze the data and information that you find and collect.

STEP 6 ▶ Communicate the results of your inquiry in a suitable manner.