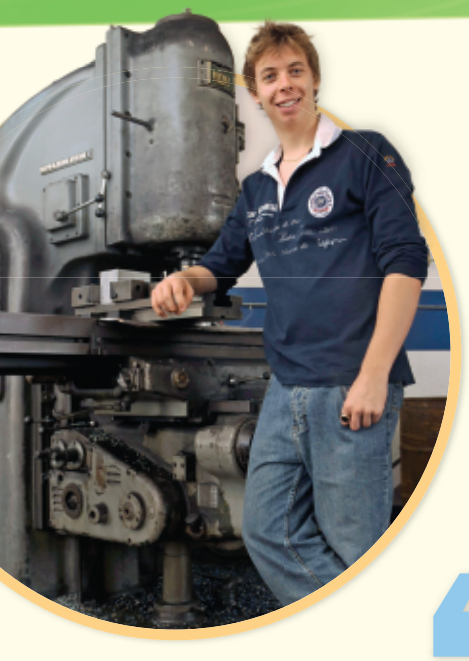
Science at Work



Ben used metal from one of his grandfather's engineering projects to create the Uno.

Canadians in Science

Thanks to a high school science project, Ben Gulak from Milton, Ontario, is going places. Ben combined his interests in motorcycles and science to invent a battery-powered riding machine that he named the Uno. With its two wheels positioned side by side, the Uno looks like a radically redesigned unicycle. It is controlled by simply leaning forward or backward to speed up or slow down.

Ben's invention earned him a top award at an international science fair and put him on the cover of *Popular Science* magazine. Ben is studying mechanical engineering at the Massachusetts Institute of Technology (MIT). In addition, he is working on plans to bring his eco-friendly invention to the market.

In Ben Gulak's Words

I started thinking about battery power during a visit to China. Seeing so many gasoline-fueled motorcycles and scooters gave me the idea to design a vehicle that has less effect on the environment. I am now on my third model, or prototype, as I work through some design and engineering challenges. I would like to have a product with appeal especially in Asia, Europe, and South America. In those regions, motorcycles and scooters really are part of the culture and are needed by many people to get around.

Engineering has interested me for a long time. I learned a lot from my grandfather, who was an engineer and inventor. Participating in a science fair also helped. It allowed me to meet many knowledgeable, skilled professionals. If you show a real interest in science and discovery, people in the scientific community are more than eager to offer guidance. My advice to students thinking about a science career is to check out every opportunity. Ontario has excellent mentoring programs linked to terrific resources at post-secondary institutions and science organizations.

An interest in transportation technology leads to many career opportunities. This is a great time to look at green technology, with governments and the private sector funding a lot of research. In today's environment, we can't afford not to look at energy efficiency and sustainability. I think there are possibilities that we haven't even considered yet. Today, you can buy electric sports cars that, 20 years ago, no one thought were possible. Who knows where technology will take us in the next 20 years?

The Uno, developed by Ben Gulak, uses wheelchair motors.

Electricity at Work

The study of electricity contributes to these careers, as well as many more!

Electrician

Electricians install, maintain, repair, and test electrical circuits in residential, commercial, and industrial settings. Electricians make sure that wiring, outlets, switches, and other devices work safely to provide the energy that lights homes, runs office equipment, and powers factories. In Ontario, many electricians have trade certification. People who meet trade standards in terms of training, education, and experience can become certified.

Power Station Operator

Power station operators run systems and equipment that generate electricity for distribution in power grids. They monitor energy systems and adjust electricity output to meet changes in energy demand. They also monitor production equipment in hydroelectric dams, nuclear reactors, and oil-fired or gas-fired turbines, to ensure that the equipment runs safely and efficiently. Entry-level operators usually have a high school diploma. Senior-level operators may have a diploma from a technical college or a university degree in either engineering or physical science.

Electrical Engineer

Electrical engineers design, build, and test electrical and electronic equipment. They also participate in leading-edge research to build better power generators, improve telecommunications technology, and enhance computer systems. Electrical engineers usually have undergraduate or post-graduate degrees in science or engineering.

Go to **scienceontario** to find out more

Over To You

1. Imagine that you have a background in electrical systems and are working with Ben Gulak. Write a short paragraph that describes some of the challenges you would face in designing a machine that, like the Uno, operates on battery power.
2. Ben refers to mentoring programs that help Ontario high school students interested in careers in science and technology. Research one of these programs, and share your findings with the class.
3. From the list of careers related to electricity, choose one that interests you. Use Internet and print resources to research this career. **What essential skills would you need for this career?**

Work Learning Life

Unit 4 Projects

Inquiry Investigation

Designing an Electrical Makeover

Devise a "green" design to improve the electrical plan of a room in your home.

Inquiry Question

How might you reduce electricity use in your home?

Initiate and Plan

1. Select two rooms in your home. List the devices that require electricity in each room.
2. Explain how these devices are connected in a circuit. Include a description of the role of each of the following components: switch, fuse, electrical source, load, resistor. Summarize the information in a table.

Perform and Record

3. Draw a schematic diagram that supports your explanation.
4. Design and build a circuit board that models the wiring in each room. Test your circuit board to ensure that it works.
5. Determine the maximum current draw for each room. To do this, check the size and number of fuses or circuit breakers that service the room from the distribution panel.

Analyze and Interpret

1. Which room uses more electricity? Provide evidence to support your answer.
2. Alter the design of the room that uses more electricity so that it uses less electricity. Consider these criteria:
   - Flexibility
   - Cost-effectiveness
   - Safety
3. Draw a new schematic diagram for your "greener" room. Include at least one power bar or surge protector for all non-essential loads, and create a special label for this in your schematic diagram. Consider the types of lighting you choose, the size and type of television and/or computer monitor (if applicable), and the power requirements for the other devices.

Communicate Your Findings

4. Prepare a summary of your "greener" room design. Include your schematic diagram and an explanation of your new electrical plan. Present your summary using a visual format of your choice.

Assessment Criteria

Once you complete your project, ask yourself these questions. Did you...

- K/U describe accurately the components of the electrical circuit in the selected rooms of the home?
- C draw accurate schematic diagrams?
- C organize effectively the details about the components of the circuit?
- C present the summary of the "greener" room using an appropriate visual format?
- C use proper scientific conventions and vocabulary?
- T/I design a functional circuit board for each room using safe practices?
- T/I accurately determine the current values for each room using appropriate information from the distribution panel?
- T/I accurately identify with supporting evidence the room that uses more electricity?
- A accurately evaluate the circuit design for the "greener" room according to criteria of flexibility, safety, and cost-effectiveness?

An Issue to Analyze

A "Greener" Power Generation Mix

Since the turn of the 21st century, more and more non-traditional sources of electrical energy have been appearing in Ontario. Wind generators dot rural landscapes, and solar panels are becoming more common. Many large power-generation companies, however, still produce electricity from traditional sources of energy. In 2007, Ontario Power Generation produced electrical energy from 64 hydroelectric, five fossil-fuel (coal), and three nuclear generating stations. Despite these statistics, power generation companies in Ontario are making an effort to become "greener."

Issue

In what ways can one power generation company be "greener" than another?

Initiate and Plan

1. Imagine that you are a representative of a consumer organization. Research information about power generation companies that provide electricity to home-owners in Ontario. Choose two companies that produce electricity from distinctly different sources of energy.

Perform and Record

2. Create a table for each company. List the types of energy sources each uses to generate power. Include these headings to describe each energy source:
   - Traditional or non-traditional source of energy
   - Number of power generation plants
   - Total power output
   - Reliability
3. Create a separate table that focuses on the environmental impacts of the energy sources used by each company. Include these headings:
   - Renewable or non-renewable resource
   - Disruption of ecosystems involved (for example, scarring the landscape, rerouting waterways, laying pipelines)
   - Dependence on other resources (for example, scarce or non-renewable resources required, fuel needed for transportation)
   - Type of pollution produced (for example, air, water, thermal)
   - Waste production (for example, amount, type, treatment and/or containment required, danger level)
   - "Greener" sources for the future

Analyze and Interpret

1. Reorganize your findings in a risk-benefit-cost analysis chart for each company.
2. Based on your findings, decide which power generation company is currently "greener." Write your decision as a concluding statement.

Communicate Your Findings

Write a report for your organization that compares the two companies in terms of their environmental impact.

Assessment Criteria

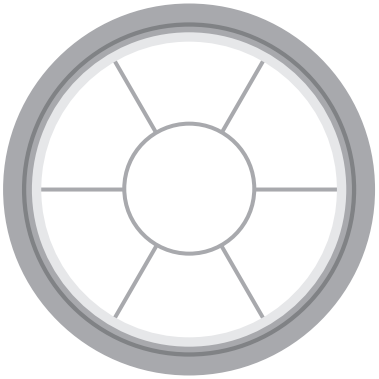
Once you complete your project, ask yourself these questions. Did you...

- A clearly define your issue and position with supporting evidence?
- A describe multiple perspectives on the issue?
- A identify using an accurate and concise concluding statement which company is "greener" based on a summary of the risk-benefit-cost analysis?
- C gather and cite information from a variety of sources, including electronic, print, and/or human resources using an accepted form of academic documentation?
- C communicate findings using appropriate scientific vocabulary?
- C communicate information effectively for both your audience and purpose?

Unit 4 Review

Connect to the BIG IDEAS

Use this bicycle wheel graphic organizer to connect what you have learned in this unit to the Big Ideas, found on page 399. Draw one bicycle wheel for each Big Idea and write the Big Idea in the centre. Between the spokes of the wheel, briefly describe six examples of that Big Idea .



Knowledge and Understanding K/U

For questions 1 through 4, select the best answer.

1. When glass and silk are rubbed together

- **a.** protons are transferred from the silk to the glass
- **b.** electrons are transferred from the silk to the glass
- **c.** protons are transferred from the glass to the silk
- **d.** electrons are transferred from the glass to the silk

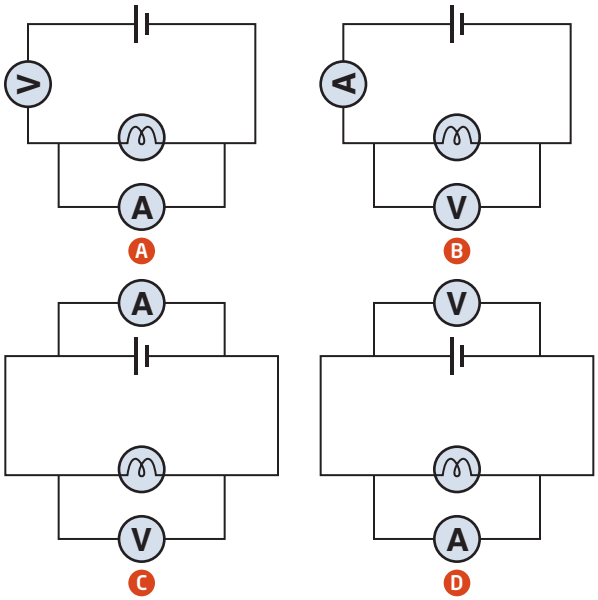
2. Three different pith balls (labelled P, Q, and R) are charged by contact. Then the pith balls are brought close to each other. Pith balls P and Q repel each other. Pith balls P and R attract each other. Which of these could be the charges on the three pith balls?

	P	Q	R
a.	–	+	+
b.	–	+	–
c.	–	–	+
d.	–	–	–

3. Electrical energy is measured in

- **a.** amperes
- **b.** volts
- **c.** watts or kilowatts
- **d.** watt-hours or kilowatt-hours

4. Which circuit could be used to measure the resistance of a lamp?



5. People sometimes rub sunglasses with a cloth to clean them. Why is this not a good way to clean sunglasses on a hot, dry day?

6. a. Explain why a neutral pith ball, suspended by a cotton thread, moves toward a negatively charged rod that is held nearby.

b. Explain why this pith ball is strongly repelled after it makes contact with the charged rod.

7. Classify each cell as wet or dry, and as primary or secondary.

- **a.** zinc-carbon cell
- **b.** nickel-cadmium cell
- **c.** lead-acid battery

8. A series circuit consists of a battery that is connected to two loads with different resistances. What are the properties of current and potential difference in this circuit?

9. A parallel circuit consists of a battery that is connected to two loads with different resistances. What are the properties of current and potential difference in this circuit?

10. What environmental problems are associated with using nuclear energy to generate electricity?

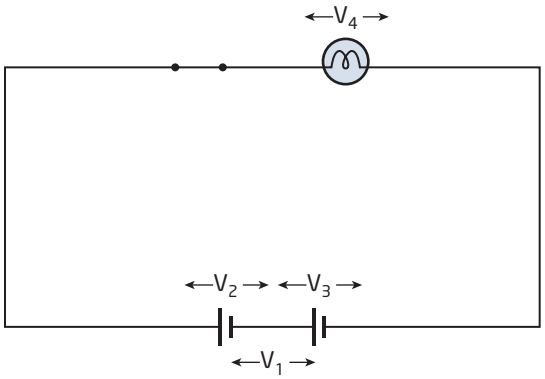
11. Distinguish between two different types of energy that are available from the oceans. What is the source of each type of energy?

Thinking and Investigation T/I

12. A friend complains that she sometimes experiences a small shock after using a telephone. She wonders whether the telephone has an electrical fault. You know that your friend often places the telephone handset on one of her shoulders while she talks. What is the likely reason for the shock? Outline a simple investigation to prove your hypothesis.

13. Suppose that you have a part-time job assembling electronic components at a factory. The electronic components arrive at your metal table after sliding through a plastic delivery tube. Some of the components you assemble do not work properly, and the manager thinks that you are responsible for this. Could the parts be faulty before you assemble them? Explain your reasoning. What suggestions would you make to solve the problem?

14. In the circuit below, new 1.5 V AA cells were connected and a series of potential differences were measured as indicated. What value would you predict for each measurement?



15. The potential difference in an operating electric circuit is doubled, and the resistance is halved. What change takes place in the current?

16. A solar array has an area of 4.0 m by 2.0 m, and the panels are 25 percent efficient at converting sunlight to electricity. On a day when the Sun is providing 5.0 kW·h per square metre, what is the electrical output from the solar array?

17. What is the monthly cost of operating a 60 W security light for 12 h each night? Assume that there are 30 days in a month and the electricity costs 7.0¢/kW·h.

18. An environmental website claims that a large coal-burning plant emits more radioactive materials into the atmosphere than a nuclear plant with the same generating capacity. Use Internet or print resources to investigate this claim. How can radioactive materials be emitted from each type of generating plant? State whether you agree or disagree with this claim.

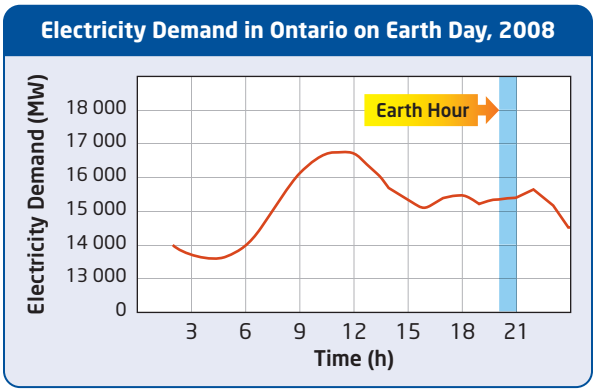
Communication C

19. Draw a diagram of an electroscope. Identify each labelled part of the electroscope and state which type of material (insulator or conductor) it is.

20. Draw and label two wet cells that are connected in series to make a battery.

21. Draw a Venn diagram. Label one circle "direct current" and the other circle "alternating current." Write as many statements as you can in the three sections of the Venn diagram.

22. The first Earth Hour in Ontario took place between 8:00 P.M. and 9:00 P.M. on Saturday, March 29, 2008. During Earth Hour, people were encouraged to use less electricity. A graph of the demand for electricity on March 29, 2008 is shown below.



During Earth Hour, the demand for electricity actually increased slightly compared with the previous hour's demand. Explain why the organizers of Earth Hour still claimed that Earth Hour was a success.

23. Describe the factors that contribute to the environmental costs of burning fossil fuels to generate electricity.

24. Using the data in the table below, identify the major differences in the energy mix in Ontario and Alberta. Then suggest reasons why these differences exist.

Sources of Electricity

Energy Source	Ontario (%)	Alberta (%)
Nuclear	52	—
Hydroelectric	21	7
Coal	18	49
Gas	8	38
Wind and other	1	6

Application A

25. Suppose that you want to connect speakers in your bedroom to the stereo system in the living room. How will you ensure that the speakers receive the strongest possible signal?

26. The heating element in a toaster is a metal wire. What electrical properties do you expect that the wire has? What other properties are important in this type of application?

27. Some people, especially those living in remote locations, use a small electric generator if there is a power failure. When a refrigerator motor turns on and off, it may cause a fluctuation in the output supplied by the generator to other devices. Explain why this happens and how sensitive equipment, such as a computer, can be protected.

28. Two examples of secondary cells are the lead-acid cell and the lithium-ion cell.

a. What is a secondary cell?

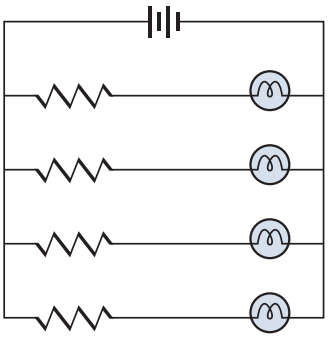
b. What properties distinguish a lead-acid cell from a lithium-ion cell?

c. State one application for each cell.

29. This circuit is used to illuminate four bulbs at the corners of a mirror.

a. Suggest a reason for having a resistor in series with each bulb.

b. If one bulb burned out, what change would occur in the brightness of the other three bulbs?



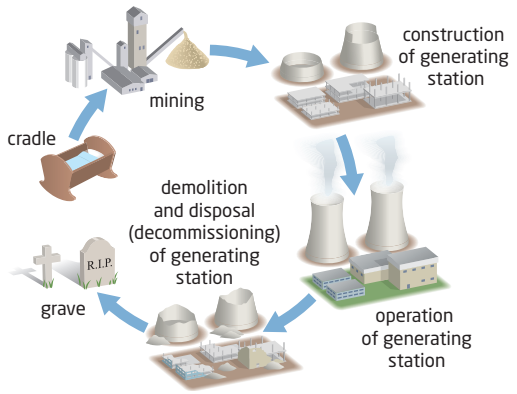
30. A worker received a severe electrical shock when she inserted the end of a plug into the broken socket of a portable machine and then touched the metal casing of the machine. The broken socket allowed the plug to be inserted 90° clockwise from the appropriate connection. Explain why the worker received a shock.

Literacy Test Prep

Read the selection below, and answer the questions that follow it.

Life Cycle Assessment

Life cycle assessment or analysis (LCA) is an assessment of the environmental impact of a product or technology over its full life cycle. It is often referred to as a cradle-to-grave analysis. The LCA for an electricity generating station starts with the environmental impact of mining raw materials for construction and operation. The LCA ends with the demolition and disposal of the station, called its decommissioning.



Different types of electricity generating stations can be compared over the lifetime of their operation.

Different kinds of generating stations affect the environment in different ways, but an LCA can be used to make a direct comparison between them. Because CO_2 is an important greenhouse gas, one type of LCA compares how much CO_2 different kinds of stations emit into the atmosphere during their life cycle. All generating stations result in CO_2 emissions over their lifetime, because energy and materials are required for their construction (at "cradle") and decommissioning (at "grave"). Solar-cell production results in relatively large emissions of CO_2 because the silicon that is used to produce the cells is obtained by heating quartz sand to a high temperature.

Comparisons that are based on CO_2 emissions discriminate against fossil-fuel stations, which emit large quantities of CO_2 during their operation. A large coal-burning station may require 3 000 000 tonnes of coal a year. The coal must be mined and transported to the station. About 200 000 m^3 of ash are generated, and about 6 000 000 tonnes of CO_2 are sent into the atmosphere. The capture and storage of CO_2 (for example, in the oceans or underground) would drastically change the LCA for coal-burning stations. This technology, however, has not yet been shown to be practical.

Multiple Choice

In your notebook choose and record the best or most correct answer.

31. In paragraph 2, you learned that

- **a.** life cycle assessments are only used to compare electricity generating stations
- **b.** life cycle assessments compare the costs of building different generating stations
- **c.** cradle-to-grave means the full life cycle of a product or technology
- **d.** carbon dioxide emissions are one measure for comparing generating stations

32. A life cycle assessment for an electricity generating station

- **a.** evaluates only the cost of constructing the station
- **b.** evaluates the cost of decommissioning the station
- **c.** compares the price of the fuel that is used to operate the station
- **d.** assesses the environmental impact of the station

33. Carbon dioxide emissions are often used to make a life cycle assessment because

- **a.** CO_2 is a gas
- **b.** CO_2 is a greenhouse gas
- **c.** CO_2 levels are easily measured
- **d.** fossil fuels emit large quantities of CO_2

34. The diagram reminds us that an LCA

- **a.** must include cradle-to-grave environmental impacts
- **b.** emphasizes the emissions during the operation of a generating station
- **c.** discriminates against fossil-fuel generating stations
- **d.** shows how mining has the greatest impact on the environment

Written Answer

35. Summarize this selection. Include the main idea and one relevant point that supports it.