SECTION 1

Generating Electricity

Section Overview

Beginning with a list of reasons that record why people may not have access to electricity from a power company, students discuss what sources of electricity might be available and which type of electrical appliances they might choose. Student groups then investigate the requirements for an electrical circuit. By assembling a circuit with a hand-cranked generator as their energy source, they observe that a closed circuit is required for electrical energy to light a bulb, that cranking the generator with a different speed and direction changes how the bulb is lit, and that for a blinking bulb it is harder to crank the generator when the bulb is on. Students also explore the parts of a light bulb needed to close the circuit, and what happens to steel wool that is connected in a circuit. Their observations of steel wool in the circuit provide a foundation for understanding resistance, fuses, and filaments in light bulbs. They discuss the need for a closed circuit, energy transformations, and how a light bulb works using observations to support ideas. The concepts introduced in this section are applied by students to answer questions involving energy generation and transformation, closed circuits, and light bulbs.

Background Information

Energy supplied to our schools and homes comes from a variety of sources. Many electric companies primarily produce electricity by burning coal, which has contributed to global warming. The most common way to produce electricity is through electromechanical generators that are driven by heat engines, which use chemical combustion (e.g., coal, natural gas) or nuclear fission as their fuel. Other ways to generate electricity include using the kinetic energy from flowing water, solar energy, wind energy, and geothermal energy. Currently in the United States about 50% of our electrical energy is generated by coal, about 7% is generated by conventional hydroelectric means, 19% by nuclear, 19% by natural gas, 3% by petroleum, and 3% by other sources. In France approximately 78% of electricity is generated from nuclear energy, 4% from natural gas, 4% from coal, 11% from hydroelectric sources, 2% from fossil fuels such as petroleum, and 1% from other sources such as wind or waste-to-energy.

Once the electrical energy is created in a power plant it is transmitted through coaxial transmission lines, to substations and then to dwellings. Power plants became popular after it was realized that electricity could be transmitted great distances at low costs by using alternating current produced by power transformers. The first distribution of electrical energy from a central power station was created in 1881.

Energy sources for the world in 2005 are listed below in terawatt hours. (A terawatt-hour is equal to 1×10^{12} watt hours.)

Hydro: 2900 TWh, 16.71%

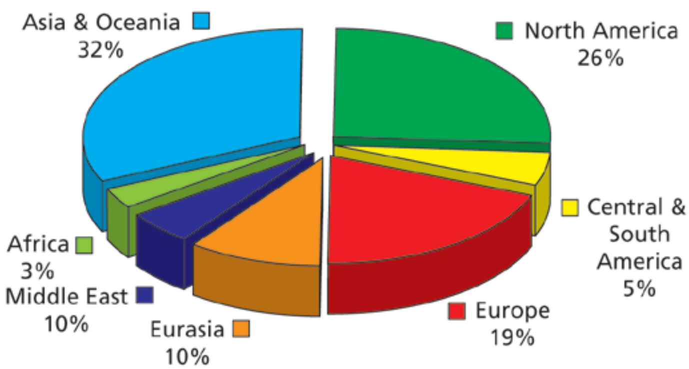
Nuclear: 2626 TWh, 15.13%

Renewable: 370 TWh, 2.13%

Thermal: 11,455 TWh, 66.02%

The United States has been the top producer of electricity, with a global share of at least 25%. The U.S. is followed by China, Japan, and Russia in electrical energy production. The following images use data from the Energy Information Administration.

2005 Energy Consumption in Quadrillion (10^{16}) BTU



You can find out more about the production of electrical energy by conducting an Internet search using the key words: electrical energy production. Consider reviewing the information at the *Energy Information Administration's* Web site. To find their website do an Internet search on their name.

North American Countries Contributing to 26% of the World's Energy Consumption in 2005

Country in North America	Percentage of North American Energy Consumption
3 countries contributing less than 1%	3%
Canada	12%
Mexico	6%
United States	82%

European Countries Contributing to 19% of the World's Energy Consumption in 2005

Country in Europe	Percentage of North American Energy Consumption
21 countries contributing less than 1%	6%
Austria	2%
Belgium	3%
Bulgaria	1%
Czech Republic	2%
Finland	1%
France	13%
Germany	17%
Greece	2%
Hungary	1%
Italy	9%
Netherlands	5%
Norway	2%
Poland	4%
Portugal	1%
Romania	2%
Spain	8%
Sweden	3%
Switzerland	1%
Turkey	4%
United Kingdom	12%

Countries in Asia and Oceania Contributing to 32% of the World's Energy Consumption in 2005

Country in Asia or Oceania	Percentage of Asian and Oceania Energy Consumption
35 countries contributing less than 1%	5%
Australia	4%
China	45%
India	11%
Indonesia	4%
Japan	15%
South Korea	6%
Malaysia	2%
Pakistan	2%
Singapore	1%
Taiwan	3%
Thailand	2%

Crucial Physics

- Energy can be transformed from one type to another.
- For an electrical current to exist in a circuit, the circuit must form a closed loop.
- As the output energy of a circuit increases, the input energy needed also increases.

Learning Outcomes	Location in the Section	Evidence of Understanding
Trace energy transformations.	***Investigate*** *Part B, Steps 5.b)-c)* ***Physics Talk*** ***Physics Essential Questions*** ***Physics to Go*** *Questions 6-9*	Students generate electrical energy to light a bulb using a hand-cranked generator and consider all the energy transformations that take place. They discuss the energy transformations and then apply what they have learned to describe energy transformations for various situations.
Plan a model for electricity.	***Investigate*** *Part B, Steps 1-5* ***Physics Talk*** ***Physics to Go*** *Questions 1-5*	Students investigate electric circuits and observe that for electricity to flow through a circuit it must form a closed loop. They observe that when too much electricity goes through steel wool, it burns it, opening the circuit.
Construct a circuit that lights a bulb.	***Investigate*** *Part B, Steps 1.a), 1.c), 2,* and *4*	Students construct circuits using a hand-cranked generator, light bulbs, wires, and steel wool.
Adjust the brightness of a light bulb with a hand generator.	***Investigate*** *Part B, Steps 1.b)* and *2.a)*	Students deliver electric energy to a light bulb using a hand-cranked generator and wires. They experience how the hand-cranked generator requires more force the brighter the bulb.

NOTES

NOTES

Section 1 Materials, Preparation, and Safety

Materials and Equipment

PLAN A		
Materials and Equipment	**Group (4 students)**	**Class**
Base (for mini light bulbs)	1 per group	
Generator, hand operated, DC, Genecon	1 per group	
Bulb, blinky	3 per group	
Pad, steel wool, fine	1 per group	
Light bulb, mini	1 per group	

*Additional items needed not supplied

Time Requirements

- Allow 30 minutes for the students to complete the *Investigate* of this section. Each student should experience what cranking the generator "feels" like under load and no load conditions.

Teacher Preparation

- Have one set of equipment pre-assembled to show the students how to connect the generator and the bulbs.
- Students should be made aware that a single strand of steel wool works best when replacing the bulb.
- Warn the students not to crank the hand generators very fast. The gears inside are usually nylon, and can be stripped.
- Test all the light bulbs to ensure they are working properly.

Safety

- Caution the students not to hold the steel wool when it is connected to the generator, and a student is cranking the generator.
- Remind the students that electricity can be dangerous. Although the currents and voltages are not likely to be harmful, the possibility for harm is there for students who may have heart or other bioelectrical problems.
- Light bulbs may break when being inserted into some sockets if they are not correctly aligned, or over-tightened. Dispose of broken bulbs immediately so they do not shatter and cause a broken glass hazard.
- If any glass breaks, clean up the pieces immediately and avoid handling broken pieces when possible.
- If doing the *Active Physics Plus*, caution the students not to directly connect a wire from the top of the battery (the positive terminal) to the bottom (negative terminal). A direct short such as this will result in the wire quickly becoming very hot.

Materials and Equipment

PLAN B		
Materials and Equipment	**Group (4 students)**	**Class**
Base (for mini light bulbs)	1 per group	
Generator, hand operated, DC, Genecon	1 per group	
Bulb, blinky	3 per group	
Pad, steel wool, fine	1 per group	
Light bulb, mini	1 per group	

*Additional items needed not supplied

Time Requirements

- Allow 30 minutes for the students to complete the *Investigate* portion of this section. Each student should experience what cranking the generator "feels" like under load and no load conditions.

Teacher Preparation

- Have one set of equipment pre-assembled to show the students how to connect the generator and the bulbs.
- Students should be made aware that a single strand of steel wool works best when replacing the bulb.
- Warn the students not to crank the hand generators very fast. The gears inside are usually nylon, and can be stripped.
- Test all the light bulbs to ensure they are working properly.

Safety

- Caution the students not to hold the steel wool when it is connected to the generator and a student is cranking the generator.
- Remind the students that electricity can be dangerous. Although the currents and voltages are not likely to be harmful, the possibility for harm is there for students who may have heart or other bioelectrical problems.
- Light bulbs may break when being inserted into some sockets if they are not correctly aligned, or over tightened. Dispose of broken bulbs immediately so they do not shatter and cause a broken glass hazard.
- If any glass breaks, clean up the pieces immediately and avoid handling broken pieces when possible.
- If doing the *Active Physics Plus*, caution the students not to directly connect a wire from the top of the battery (the positive terminal) to the bottom (negative terminal). A direct short such as this will result in the wire quickly becoming very hot.

Meeting the Needs of All Students

Differentiated Instruction: Augmentation and Accommodations

Learning Issue	Reference	Augmentation and Accommodations
Understanding the purpose of an activity	***Learning Outcomes***	**Augmentation** • Students often complete activities as discrete items that are not connected to a common goal. This makes it much more difficult to analyze results, draw conclusions, and make meaning from new learning. Explicitly review the learning outcomes at the beginning of each section to set a purpose and make students aware of the big picture.
Using fine motor skills	***Investigate*** Part B, Step 3	**Augmentation** • Students who struggle with fine motor tasks will have difficulty pulling off tiny strands of steel wool, putting the steel wool in the socket, and/or securing steel wool in the alligator clips. Provide tiny strands of steel wool on a white note card for students to use. • If students are going to connect the steel wool to the alligator clips, it will help to have one student to hold the strand of wool while another student attaches the clips. Students may also have an easier time attaching the wool while it is lying on the note card instead of holding it. **Accommodation** • Attach the steel wool for the student.
Understanding essential concepts Reading comprehension	***Physics Talk*** Energy Transformations ***Physics to Go*** Steps 5-9	**Augmentation** • There are five energy transformations listed in the first paragraph of this section. Ask students to create a flow chart to represent the energy transformations that occurred to light the bulb with a hand generator. For example, chemical energy $\Rightarrow$ mechanical energy $\Rightarrow$ electrical energy $\Rightarrow$ light and heat. Then to check for understanding, ask students to provide examples of instances when similar energy transformations take place.
Completing long-term projects Identifying important details	***Reflecting on the Section and the Challenge*** ***Physics to Go*** Step 10	**Augmentation** • Time management is a difficult challenge for most students with learning disabilities and attention deficit hyperactivity disorder. These students also struggle to be successful with long-term projects. • As students reflect and prepare for this *Chapter Challenge*, maintain a class list (a poster or online document) of topics and content that should be included in the final project. Items to begin the list for this section include an illustration of a complete circuit, why input energy is required to get electrical energy, and how the energy is generated.

Strategies for Students with Limited English-Language Proficiency

Learning Issue	Reference	Augmentation
Vocabulary comprehension	***What Do You Think?***	• Be sure students understand "generate" in context. You may wish to discuss the use of emergency generators following natural disasters, or the generator in an automobile.
Accessing Prior Knowledge	***Investigate*** Part A, Steps 1-2	• If you have ELL students who come from a country where electricity is not widely available or common in households, ask them to share with the class what life is like in that country. Have them tell what life is like for those without electricity, and what life is like for those who do have electricity. Be sensitive to the students' possible unwillingness to talk about their personal home situation.
Comprehension	***Investigate*** Part B, Step 1.a)	• To check students' understanding, ask why the circuit they drew is called a closed circuit. Then have them speculate as to what an open circuit might be.
Comprehension	***Investigate*** Part B, Step 5.a)-5.c)	• Read students' paragraphs, or have ELL volunteers read their paragraphs aloud. Hold a class discussion to correct any misunderstandings. Model appropriate grammar and sentence structure during the discussion, and encourage ELL students to make corrections to their paragraphs accordingly.
Comprehension Answering higher order questions	***Physics Talk*** Energy Transformations	• Be sure students are able to follow all energy transformations involved in lighting the bulb. If they have trouble understanding that the electrical energy applied to the bulb turned into both light *and heat,* ask them to think back to when they used the steel wool in place of the bulb: What did the steel wool do that gave evidence for the presence of heat? • Also, have students think back to what happened when they cranked the generator faster. (The bulb got brighter.) Ask: "What is the connection between cranking faster and the bulb getting brighter?" If students have trouble answering, suggest that they think in terms of energy transformations.
Vocabulary comprehension	***Physics Talk*** How Does a Light Bulb Work?	• Be sure students understand the word "terminal" in context. It may help to have students think of a bus or train terminal, which marks the beginning or end point of a trip. You may wish to show them the terminals on the socket and the terminals inside the bulb.
Making inferences Using Contextual Clues	***Checking Up*** Question 3	• Fuses have not yet been introduced; they will be covered later in the chapter. However, the word "fuse" is used here. Ask students to infer what a fuse does and what it is used for, based on the context of the sentence.
Comprehension	***Physics Essential Questions*** What does it mean?	• "You can't get something for nothing" is a common saying in English, but it may not be common in other languages. Explain that such a saying is a statement widely believed to be true. Ask ELL students to verbalize in their own words what the saying means.
Vocabulary comprehension Making inferences	***Physics to Go*** Question 1	• Be sure students are able to figure out the meaning of the word "prong" and also determine the role of both prongs in an electric outlet.
Comprehension	***Physics to Go*** Question 10	• Check students' work to be sure their understanding of the key points of this section is on target and appropriate for the training manual outline. Reassure students that they cannot complete the outline at this point.

SECTION 1

Teaching Suggestions and Sample Answers

What Do You See?

Initiate a class discussion and consider using the overhead of the illustration as a focal point for the discussion. Elicit students' initial impressions of what they see in the illustration. Some students could describe the setting Sun and the need for another light source. Gather their ideas about how the person in the illustration might light the bulb and what is needed for the bulb to light. Accept all answers. You might want to ask your students why the person on the rock looks so surprised. Point out to them that how they view each image now may be different from what they see later as they continue to investigate the physics concepts presented in this section.

What Do You Think?

Ask students to use their own experiences and the illustration to help them answer the questions. Remind students to record their ideas in their log. Then have a class discussion, eliciting and recording students' ideas. Encourage students to ask each other questions during the discussion. Consider having students find what sources of their local energy provider uses to generate the electricity in their area. Ask students what physics concepts they think would explain the process that provides electrical energy when an appliance is plugged into the outlet. Reassure students that as they go through the chapter they will be introduced to the physics involved with generating and using electricity.

Chapter 6 Electricity for Everyone

Section 1 Generating Electricity

What Do You See?

Learning Outcomes

In this section, you will

- **Trace** energy transformations.
- **Plan** a model for electricity.
- **Construct** a circuit that lights a bulb.
- **Adjust** the brightness of a light bulb with a hand generator.

What Do You Think?

Usually, when you need electricity, all you have to do is plug an appliance into the wall.

- How is the electricity that you use generated?
- Oil can be used as an energy source to generate electricity. What other sources of energy can you identify?

Record your ideas about these questions in your *Active Physics* log. Be prepared to discuss your responses with your small group and the class.

Investigate

In this *Investigate*, you will explore how people use electricity to improve their lives. You will then set up a simple circuit to investigate the energy required to light a light bulb. Finally, you will investigate how a light bulb produces light from the electricity flowing in a circuit.

Part A: What Electrical Appliances Do You Really Need?

1. Before embarking on your study of electricity, discuss why some people may not, or cannot, use electricity available through utility power lines. Think about their needs and wants.

a) In your log, list some of the reasons why people do not or cannot access electrical power from utility power lines.

598

What Do You Think?

A Physicist's Response

The fundamental physics of how electrical energy is generated is that an energy source is used to rotate a metallic coil of wire or move a magnet in a generator. The relative motion between the coil of wire and magnet causes an electromagnetic interaction between the free electrons in the metal and the magnetic field. A force between the magnetic field and the charged electrons pushes the electrons in the metal causing them to move, producing electricity. In the United States the most common source of electrical energy is coal. Coal is burned to drive a heat engine that runs an electromechanical generator that generates electricity. Heat engines use chemical combustion (e.g., coal, oil, natural gas, etc.) or nuclear fission as their fuel. Other sources of energy used to generate electricity include the energy from flowing water, wind, solar energy, and geothermal energy. The purpose of these energy sources is to cause motion between a coil of wire and a magnet in a generator.

Coal and petroleum are considered "dirty" sources of electrical energy because they produce so much carbon dioxide as they are burned. Carbon dioxide is the greenhouse gas that is most responsible for the global climate change. Coal is considered a non-renewable source of energy because it takes millions of years to form. The United States currently uses coal to generate about 50% of its electrical energy. About 7% is generated by conventional hydroelectric means (water), 19% by nuclear, 19% by natural gas, 3% by petroleum, and 3% by other sources such as wind, solar, geothermal, and biomass.

Investigate

Part A

1.a)

Some reasons people cannot or do not access electricity from the power companies might include the following:

- distance from power grid may make running wires impractical,
- lifestyle choice – deliberately choosing to live "off the grid,"
- unable to afford the cost of electricity, or
- may live in a country without the proper infrastructure.

Students' Prior Conceptions

This section establishes the foundation for students to seek consistent explanations for describing the elements necessary to create an electric circuit and how these elements interact with each other. Research in how students think about electric circuits indicates that students often use one of four models to describe electric circuits. These are:

1. **Unipolar Model:** A wire connects from a positive end of a battery to the bottom of a bulb; perhaps another wire returns from the circuit to somewhere on the battery.
2. **Clashing Currents Model:** Electricity from the positive and negative terminals comes together at the bulb and causes it to light.
3. **Current Consumption Model:** Current is used in each bulb, thus the current is attenuated as it goes through successive bulbs in a series circuit that contains more than one bulb.
4. **Current Conservation Model:** This is called the expert model; the same value of current is assigned everywhere in a single loop, regardless of the devices present in the series circuit.

As students explore making a series circuit that works with a bulb, connecting wires and a generator, show them that a bulb has two distinct connections that need to be considered when making a working series circuit. Many students may be aware of a positive and a negative end to batteries from their real-world experiences but not aware that other elements in a circuit also have two differentiated connections. Learning for students in this section involves how they interpret the phenomena and explain it. You should look for the discontinuity between students' predictions and their explanations of the *What Do You Think Now*? in order to ascertain which model was held by the students prior to the *Investigate* and how they are adjusting their thinking about how a circuit lights a bulb. These concrete experiences are the necessary foundation for students' understanding of simple series circuits and subsequent applications that foster revision toward a complete expert model.

NOTES

1.b)

Solar, wind, and water can provide electricity when connected to a generator, or personal generators that run on either fossil fuels or renewable fuels.

1.c)

Many foods would either have to be obtained fresh every day, or food sources would need to be those that do not require refrigeration. A fire would be needed for cooking or heating food.

1.d)

Students should come up with numerous answers including card games, board games, sing-a-longs, etc.

2.a)

Students lists will vary, but many may be naive, including things the students value, such as televisions, video games, air conditioners, etc. rather than vital appliances, such as refrigerators, water pumps, or a radio for the news.

3.

Students compare lists. Only limited discussion is needed at this point.

Part B

Discuss the equipment and safety issues with the class. Emphasize to the class that if they crank the generator too fast they could strip the gears, breaking the generator and that the steel wool used in *Part B* can get hot enough to burn.

Teaching Tip

Students can misconnect wires in this section when using the hand generator without any significant consequences. For future connections with batteries and power sources, be sure to check students wiring before allowing them to proceed.

1.a)

Students should sketch a drawing of the connected wires from the generator to the light bulb holder. Do not expect a schematic drawing at this point.

Students will discover that the bulb will not light if it is not properly tightened into the bulb base, if a wire is disconnected, or if the bulb is "burned out." You may want to include a burned-out bulb or two among those handed out to the students to show this possibility.

1.b)

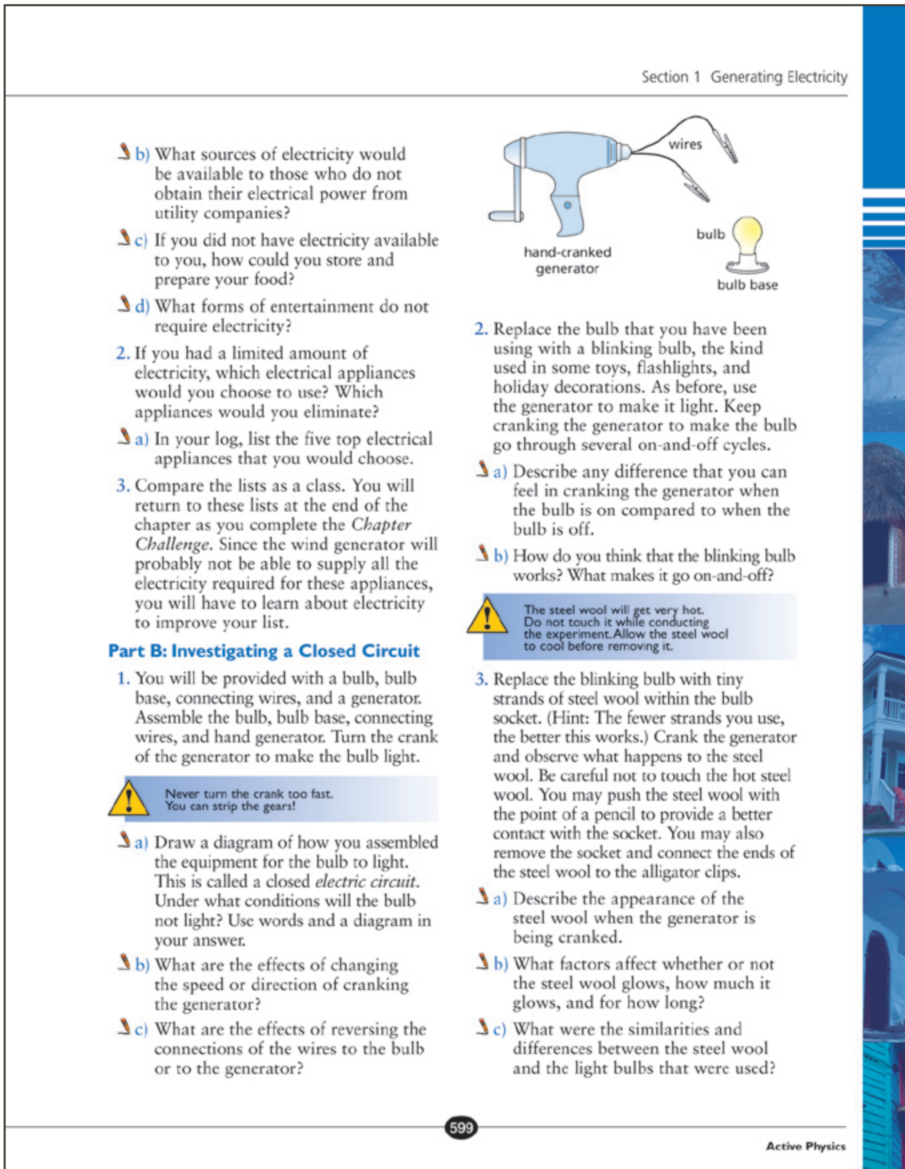
Increasing the "cranking" speed of the generator increases the voltage provided by the generator, which in turn increases the brightness of the bulb. Changing the direction of rotation has no visible effect on the bulb, although the current direction is reversed.

1.c)

Reversing the wire connections has no visible effect on the bulb.

Teaching Tip

If blinking bulbs are not available, you can ask your students to bring in any extra holiday light sets they or their parents may have at home. The bulbs are usually clear with a red strip on them to mark the blinking bulbs.



b) What sources of electricity would be available to those who do not obtain their electrical power from utility companies?

c) If you did not have electricity available to you, how could you store and prepare your food?

d) What forms of entertainment do not require electricity?

2. If you had a limited amount of electricity, which electrical appliances would you choose to use? Which appliances would you eliminate?

a) In your log, list the five top electrical appliances that you would choose.

3. Compare the lists as a class. You will return to these lists at the end of the chapter as you complete the *Chapter Challenge*. Since the wind generator will probably not be able to supply all the electricity required for these appliances, you will have to learn about electricity to improve your list.

Part B: Investigating a Closed Circuit

1. You will be provided with a bulb, bulb base, connecting wires, and a generator. Assemble the bulb, bulb base, connecting wires, and hand generator. Turn the crank of the generator to make the bulb light.

Never turn the crank too fast. You can strip the gears!

a) Draw a diagram of how you assembled the equipment for the bulb to light. This is called a closed *electric circuit*. Under what conditions will the bulb not light? Use words and a diagram in your answer.

b) What are the effects of changing the speed or direction of cranking the generator?

c) What are the effects of reversing the connections of the wires to the bulb or to the generator?

2. Replace the bulb that you have been using with a blinking bulb, the kind used in some toys, flashlights, and holiday decorations. As before, use the generator to make it light. Keep cranking the generator to make the bulb go through several on-and-off cycles.

a) Describe any difference that you can feel in cranking the generator when the bulb is on compared to when the bulb is off.

b) How do you think that the blinking bulb works? What makes it go on-and-off?

The steel wool will get very hot. Do not touch it while conducting the experiment. Allow the steel wool to cool before removing it.

3. Replace the blinking bulb with tiny strands of steel wool within the bulb socket. (Hint: The fewer strands you use, the better this works.) Crank the generator and observe what happens to the steel wool. Be careful not to touch the hot steel wool. You may push the steel wool with the point of a pencil to provide a better contact with the socket. You may also remove the socket and connect the ends of the steel wool to the alligator clips.

a) Describe the appearance of the steel wool when the generator is being cranked.

b) What factors affect whether or not the steel wool glows, how much it glows, and for how long?

c) What were the similarities and differences between the steel wool and the light bulbs that were used?

2.a)

The students are likely to be surprised to discover that when the blinking bulb goes from "on" to "off," the generator suddenly becomes much easier to turn. When the generator does not have to supply electricity to the circuit, the work necessary to turn it is decreased.

2.b)

Students will probably not have an understanding of how a blinking bulb works. Most work on a bimetallic strip that will bend as it heats up with the current, interrupting the circuit. When the current is shut off, the strip inside the bulb cools down, and bends back to its original position, closing the circuit.

Teaching Tip

One strand of fine steel wool works best. Multiple strands will not heat up sufficiently to glow.

3.

Directly connecting the steel wool strand to the alligator clips of the generator seems to work better than trying to make the proper connections in the bulb base. When done properly, the steel wool strand should glow (much as the filament of a light bulb), and then burn out, making the generator easier to turn once again.

3.a)

The students should record that the steel wool appears to be metal strand(s) that glow when the generator is being cranked.

3.b)

The steel wool should glow when the generator is turned quickly, but usually not when it is cranked slowly. The faster the generator is cranked, the brighter the steel wool glows, and the more quickly it burns out.

3.c)

The similarities between the steel wool and the light bulb are that both will glow when heated, and that the more current provided the brighter they will glow. Both will burn out if too much current is provided.

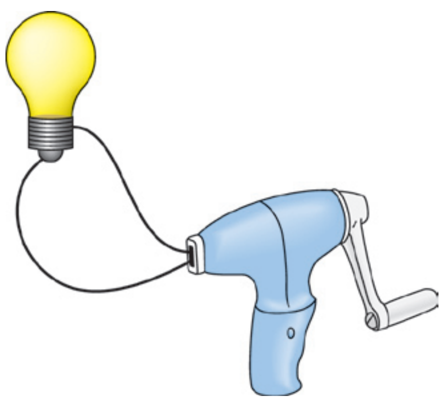
The primary difference is that the filament in the light bulb is encased in a glass bubble that is filled with gas, which is without oxygen to support combustion. The steel wool strand in air is exposed to oxygen, which allows the steel wool at these high temperatures to oxidize quickly and fall apart.

3.d)

If too much current were to flow through a wire in the wall of a house, the current would cause the wire to overheat (glow) causing the insulation to melt and starting a fire.

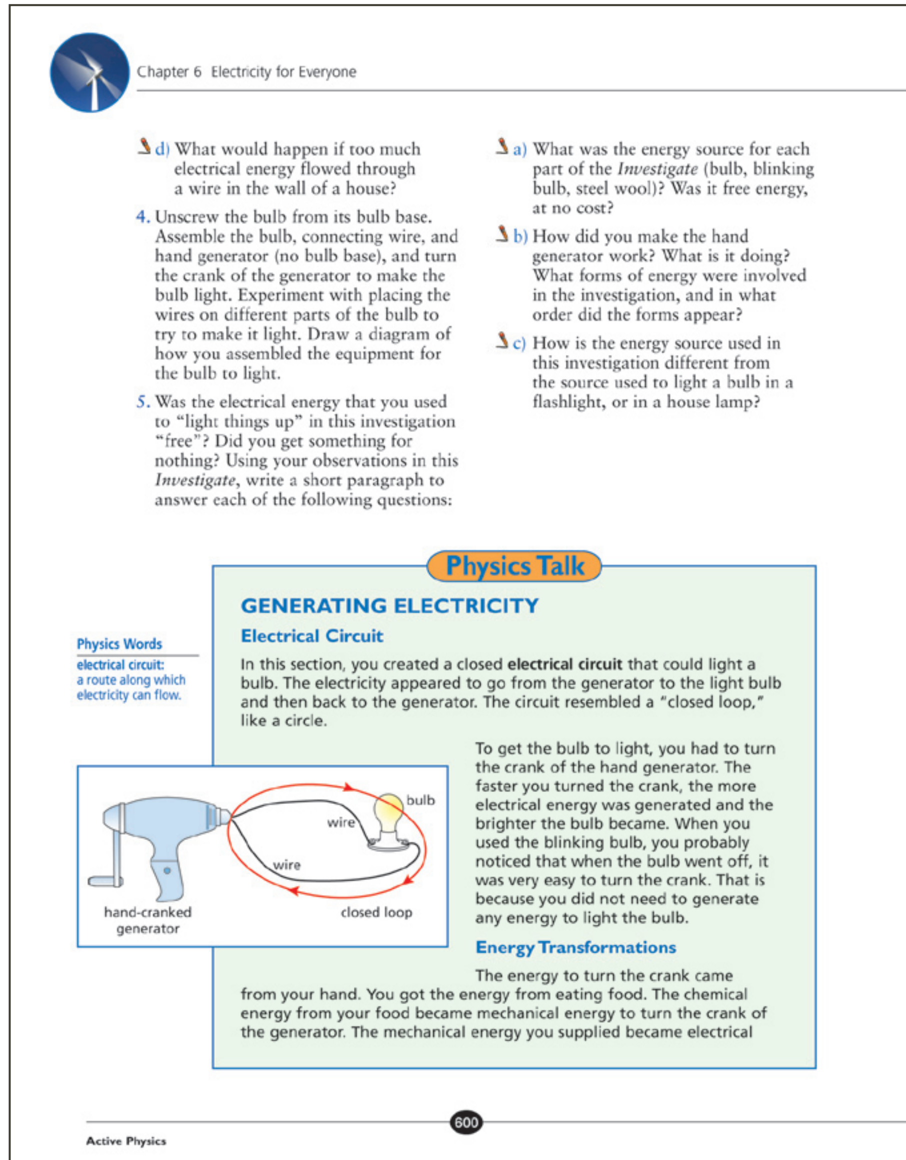
4.

Students set up experiment. They should discover that the bulb will only light when one side of the generator is connected to the screw threads on the side of the bulb, and the other side connected to the "bump" on the bottom of the bulb. The connections should be as shown in the diagram below.



5.a)-c)

Students should realize that the electric energy needed to power the light bulb was not free. Check that their paragraph includes things such as their muscles being the energy source for the generator, and the generator converting their muscle power into electrical energy. The chemical energy stored in their muscles was converted to mechanical energy of movement of the generator. The generator converted the mechanical energy to electrical, and the light bulb converted the electrical energy to light energy and heat energy. The only difference between the *Investigate* and the energy provided by a flashlight is that the flashlight uses the chemical energy stored in the batteries to directly supply the electric energy to the light bulb. The electricity from the house uses a different source of energy to power the bulb.



Chapter 6 Electricity for Everyone

d) What would happen if too much electrical energy flowed through a wire in the wall of a house?

4. Unscrew the bulb from its bulb base. Assemble the bulb, connecting wire, and hand generator (no bulb base), and turn the crank of the generator to make the bulb light. Experiment with placing the wires on different parts of the bulb to try to make it light. Draw a diagram of how you assembled the equipment for the bulb to light.

5. Was the electrical energy that you used to "light things up" in this investigation "free"? Did you get something for nothing? Using your observations in this *Investigate*, write a short paragraph to answer each of the following questions:

a) What was the energy source for each part of the *Investigate* (bulb, blinking bulb, steel wool)? Was it free energy, at no cost?

b) How did you make the hand generator work? What is it doing? What forms of energy were involved in the investigation, and in what order did the forms appear?

c) How is the energy source used in this investigation different from the source used to light a bulb in a flashlight, or in a house lamp?

Physics Talk

GENERATING ELECTRICITY

Electrical Circuit

In this section, you created a closed **electrical circuit** that could light a bulb. The electricity appeared to go from the generator to the light bulb and then back to the generator. The circuit resembled a "closed loop," like a circle.

Physics Words
electrical circuit: a route along which electricity can flow.

To get the bulb to light, you had to turn the crank of the hand generator. The faster you turned the crank, the more electrical energy was generated and the brighter the bulb became. When you used the blinking bulb, you probably noticed that when the bulb went off, it was very easy to turn the crank. That is because you did not need to generate any energy to light the bulb.

Energy Transformations

The energy to turn the crank came from your hand. You got the energy from eating food. The chemical energy from your food became mechanical energy to turn the crank of the generator. The mechanical energy you supplied became electrical

600

Active Physics

Physics Talk

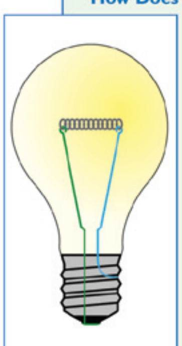
This *Physics Talk* supports students' observations that a closed circuit is required for electrical energy to flow and the input energy is directly proportional to the output energy observed in the bulb. There is also a discussion of energy transformations and a description of how a light bulb works. Connections are made between students' observations of the glowing steel wool and the light bulb and a foundation for fuses is built.

Have a class discussion on the importance of having a closed circuit. Electricity cannot flow if the circuit does not create a closed loop. Ask students to describe their observations that support this phenomenon. Point out that when more energy was used to turn the hand generator the bulb became brighter. Connect this observation energy. This electrical energy then turned into the light and heat of the bulb. There are lots of energy transformations required to light a bulb.

Electricity for your home is also created by a generator. The details of how a generator produces electricity will be explored in another chapter. The generators needed to produce the amounts of electricity required in a city are much, much larger than your hand generator. People cannot turn these large turbines. Wind or falling water is needed to turn the turbines in similar ways to you turning the crank of the hand generator. Steam can also be used to turn the turbines. To make the steam, heat is produced by burning oil, coal, or gas, or causing uranium to fission.

The production of electricity requires a source of energy. That energy can come from you (as in the *Investigate*), the wind (as in the dwelling in the *Chapter Challenge*), or from large power plants.

How Does a Light Bulb Work?



When you used a tiny strand of steel wool, you found that the steel wool would glow when electricity flowed through it. When Thomas Edison invented the light bulb, he tried thousands of different materials until he found one that would not burn out but would continue to glow when electricity ran through it. It was necessary to put that tiny piece of material (the filament) in a glass-enclosed container. To make the connection to the wires, the light bulb you used has two terminals — one for each side of the wire.

One side of the wire is connected to the bottom of the bulb. The other side is connected to the metal on the side of the bulb that also is used to screw the bulb into the socket. That was a clever technology — to use the metal screw threads as one end of the wire.

The glowing and burning steel wool also shows you the danger of too much electricity in a circuit. Without safety measures, wires get overheated and cause fires. Fuses are one such safety measure that you will learn about in a later section.

Light bulbs are just one device that uses electricity to do something useful. Electric motors convert electricity into mechanical work. Ovens and stoves convert electrical energy into heat to cook food. Refrigerators and air conditioners use electrical energy to cool things. Fans convert electrical energy into mechanical energy to move air. Electrical energy is also used to produce light and sound in your televisions and computers. Try living for a weekend without using any electrical device of any kind!

Checking Up

1. Energy is necessary to make a light bulb light. Where did the energy come from to light the bulb during your investigation?
2. Why was it easier to turn the handle of the generator connected to the blinking bulb when the blinking bulb was off?
3. Compare and contrast the glowing steel wool with the filament of a light bulb.

to the law of conservation of energy. Ask students what they observed with the blinking bulb and why the generator handle was easier to turn when the bulb was off. Elicit students' ideas on what energy transformations occurred during the investigation. Then discuss the energy transformations that occurred using the information in the *Student Edition*.

Emphasize that the production of electricity requires a source of energy. Ask students how they think a light bulb works, making connections to their observations of the steel wool. Discuss how Edison took years to develop a commercial light bulb by finding a material that would not burn out but glow brightly, and by realizing the need for the material to be put in vacuum.

Ask students what would happen if the material burned rather than glowed. Draw connections with students' observations of the steel wool in the *Investigate*. Point out that when the material burns the circuit is no longer closed and electricity does not flow in an open circuit. Students should know that this is the basis for fuses, which are safety features in a circuit designed to open the circuit when too much electricity flows through it. Discuss devices other than the light bulb, that use electricity and what they are used for.

Checking Up

1.

Responses should include that the energy supplied to the bulb came from the electrical energy supplied from the generator, which came from the mechanical energy they supplied to the generator. Some may include a description of the energy being stored in their bodies as chemical energy obtained from food, or that the energy originated from the food they ate, or the Sun that is the ultimate energy source for all food on the planet. Emphasize the need to transfer mechanical energy to the generator in order to create electrical energy. This is true for all generators of electricity.

2.

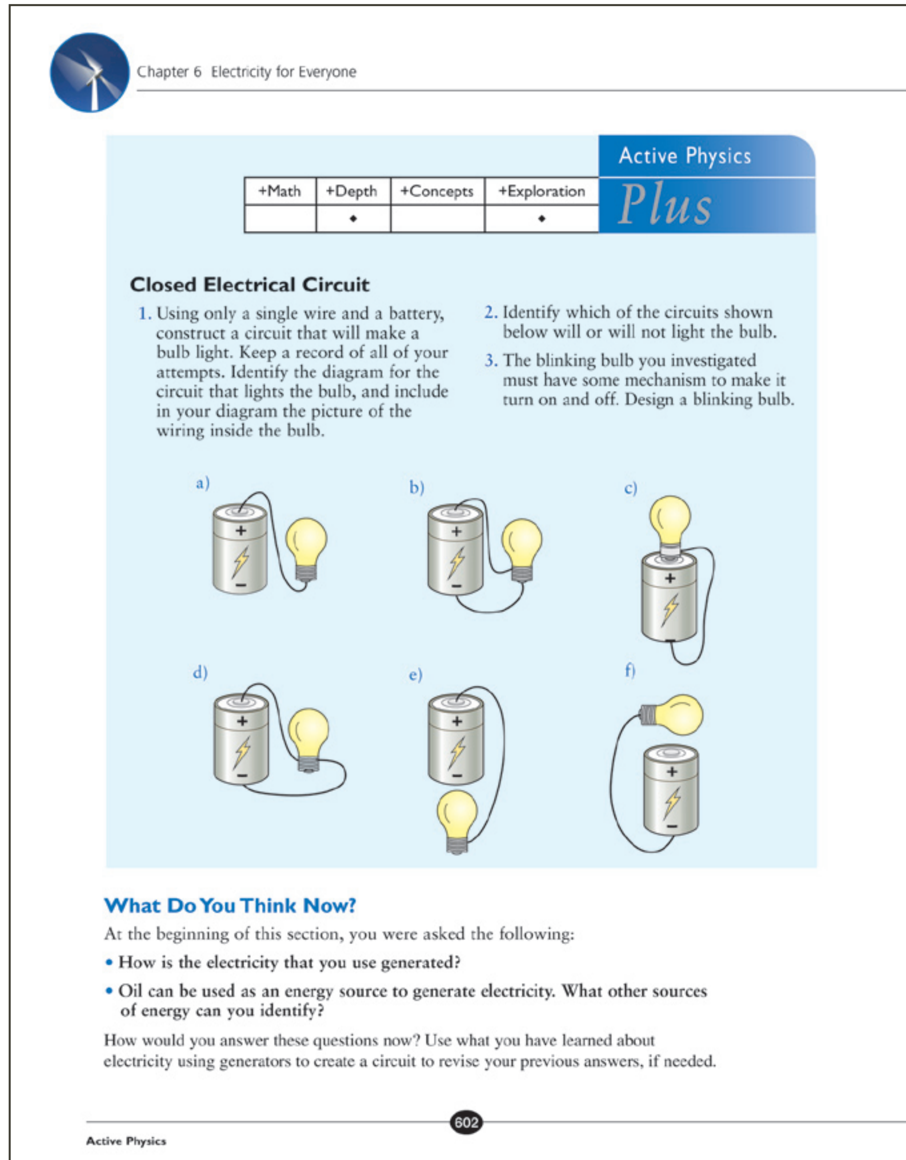
When the bulb is off there is no energy being transferred to it (or no electricity flowing) so the handle is easy to turn. It is when the bulb is on that the energy in turning the handle is transformed into electrical energy to light the bulb. Consider mentioning that the circuit is open when the bulb is off.

3.

A fuse is a part of a circuit that burns away or breaks when too much electrical energy flows through it, creating an open circuit. The steel wool is similar to a fuse because it burns away when too much electricity flows through it.

Active Physics Plus

This *Active Physics Plus* is geared toward increasing students' depth of understanding where they further explore open versus closed circuits.



Chapter 6 Electricity for Everyone

Active Physics *Plus*

+Math	+Depth	+Concepts	+Exploration
	•		•

Closed Electrical Circuit

1. Using only a single wire and a battery, construct a circuit that will make a bulb light. Keep a record of all of your attempts. Identify the diagram for the circuit that lights the bulb, and include in your diagram the picture of the wiring inside the bulb.
2. Identify which of the circuits shown below will or will not light the bulb.
3. The blinking bulb you investigated must have some mechanism to make it turn on and off. Design a blinking bulb.

What Do You Think Now?

At the beginning of this section, you were asked the following:

- How is the electricity that you use generated?
- Oil can be used as an energy source to generate electricity. What other sources of energy can you identify?

How would you answer these questions now? Use what you have learned about electricity using generators to create a circuit to revise your previous answers, if needed.

Active Physics 602

1.

Students should attempt to light a bulb in as many ways as they can with a single wire, a battery, and a bulb. They should record all of their attempts and label the circuits that lit the bulb.

2.

Closed circuits will light the bulb and open circuits will not. To be closed, a loop must be formed from one terminal of the battery through the bulb (by connecting to the bottom and side of the bulb) and then to the other terminal of the battery.

2.a)

not lit, only one terminal of the battery is used and one part of the bulb

2.b)

lit, both terminals of the battery and bulb are used

2.c)

lit, both terminals of the battery and bulb are used

2.d)

not lit, only the sides of the bulb are used, one wire needs to be on the side and one on the bottom

2.e)

not lit, only one terminal is used on both the battery and bulb

2.f)

lit, the bulb's side is connected directly to one terminal of the battery, the other terminal of the battery is connected to the bottom of the bulb with a wire

3.

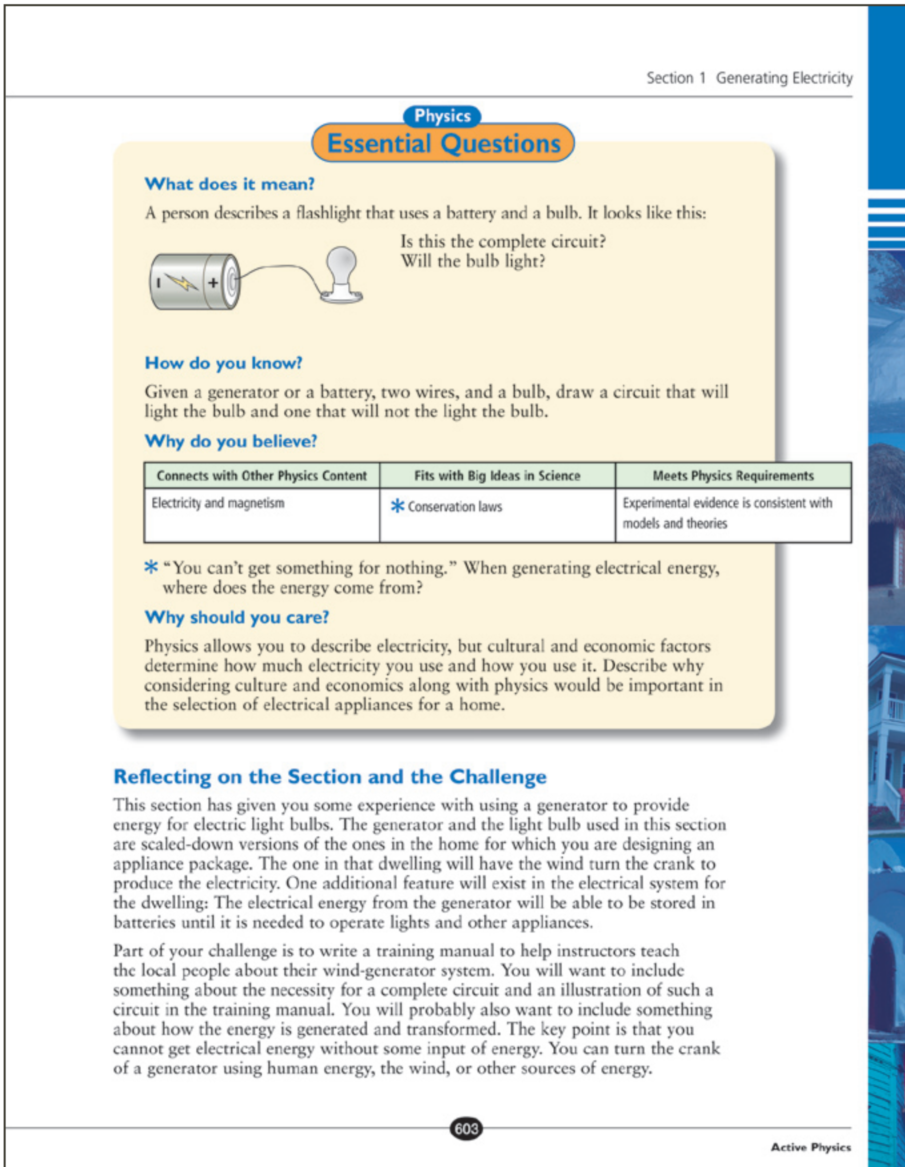
Designs should include a mechanism that opens and closes the circuit. The bulb is on when the circuit is closed and off when the circuit is open. Students might create something with a switch. Consider discussing how blinking bulbs are created. One method is to use a special bulb that has a bimetallic strip in it. As the bulb heats up, the metallic strip bends back, opening the circuit. As it cools it moves back to its original location closing the circuit and allowing the electricity to flow through the lights. Another method uses multiple substrands wrapped together to make one strand and a control box. The control box contains circuitry with transistors that open and close the circuit for different substrands of lights, causing a selected pattern of lit bulbs.

What Do You Think Now?

Have students revisit the *What Do You See?* illustration and ask them to describe how the person in the illustration could light the bulb. Consider asking students what other ideas they have about how electricity is generated and what sources of electrical energy they can now identify. Students should apply ideas from the *Investigate*. Share the information provided in *A Physicist's Response* to elicit their opinions. Encourage them to update their answers and discuss their responses with each other. Remind students that their responses should reflect their understanding of electricity—how it is generated, and how it can be used.

NOTES

NOTES



Physics Essential Questions

What does it mean?

A person describes a flashlight that uses a battery and a bulb. It looks like this:

Is this the complete circuit?
Will the bulb light?

How do you know?

Given a generator or a battery, two wires, and a bulb, draw a circuit that will light the bulb and one that will not the light the bulb.

Why do you believe?

Connects with Other Physics Content	Fits with Big Ideas in Science	Meets Physics Requirements
Electricity and magnetism	* Conservation laws	Experimental evidence is consistent with models and theories

* "You can't get something for nothing." When generating electrical energy, where does the energy come from?

Why should you care?

Physics allows you to describe electricity, but cultural and economic factors determine how much electricity you use and how you use it. Describe why considering culture and economics along with physics would be important in the selection of electrical appliances for a home.

Reflecting on the Section and the Challenge

This section has given you some experience with using a generator to provide energy for electric light bulbs. The generator and the light bulb used in this section are scaled-down versions of the ones in the home for which you are designing an appliance package. The one in that dwelling will have the wind turn the crank to produce the electricity. One additional feature will exist in the electrical system for the dwelling: The electrical energy from the generator will be able to be stored in batteries until it is needed to operate lights and other appliances.

Part of your challenge is to write a training manual to help instructors teach the local people about their wind-generator system. You will want to include something about the necessity for a complete circuit and an illustration of such a circuit in the training manual. You will probably also want to include something about how the energy is generated and transformed. The key point is that you cannot get electrical energy without some input of energy. You can turn the crank of a generator using human energy, the wind, or other sources of energy.

Reflecting on the Section and the Challenge

Have a discussion based on the paragraph in the *Student Edition*. Emphasize that when students complete the *Chapter Challenge* they will need some device to turn the crank of a generator, and that the electrical energy from the generator can be stored in batteries until it is needed. Ask students what ideas they are considering for turning the crank and how it depends on the location of their generator (e.g., near a river, in a location that doesn't get much sunlight, and so on). Students should gather ideas that will help instructors to teach the local people about their wind generator system. Have them reflect on their circuit diagrams and how energy is generated and transformed.

Physics Essential Questions

What does it mean?

The bulb will not light because the circuit is not complete (closed). Another wire from the other end of the bulb to the other end of the battery is needed to close or complete the circuit.

How do you know?

A single wire must go from one terminal of the battery to one terminal of the bulb. A second wire must go from the other terminal of the battery to the other terminal of the bulb.

Why do you believe?

Chemical energy in your body is used to control muscles that moved the handle of the generator. The handle is connected to gears and other parts, such as a coil of wire that moves with it. The generator converts the mechanical energy of the moving handle and parts in the generator into electrical energy.

Why should you care?

Different cultures have different customs and values. Some cultures cook all their food on stoves and have no need for an oven.

Physics to Go

1.

Responses should be supported with reasoning. For example, two prongs are needed to connect to the two open sides of a circuit. This closes the circuit and allows electrical energy to flow.

2.

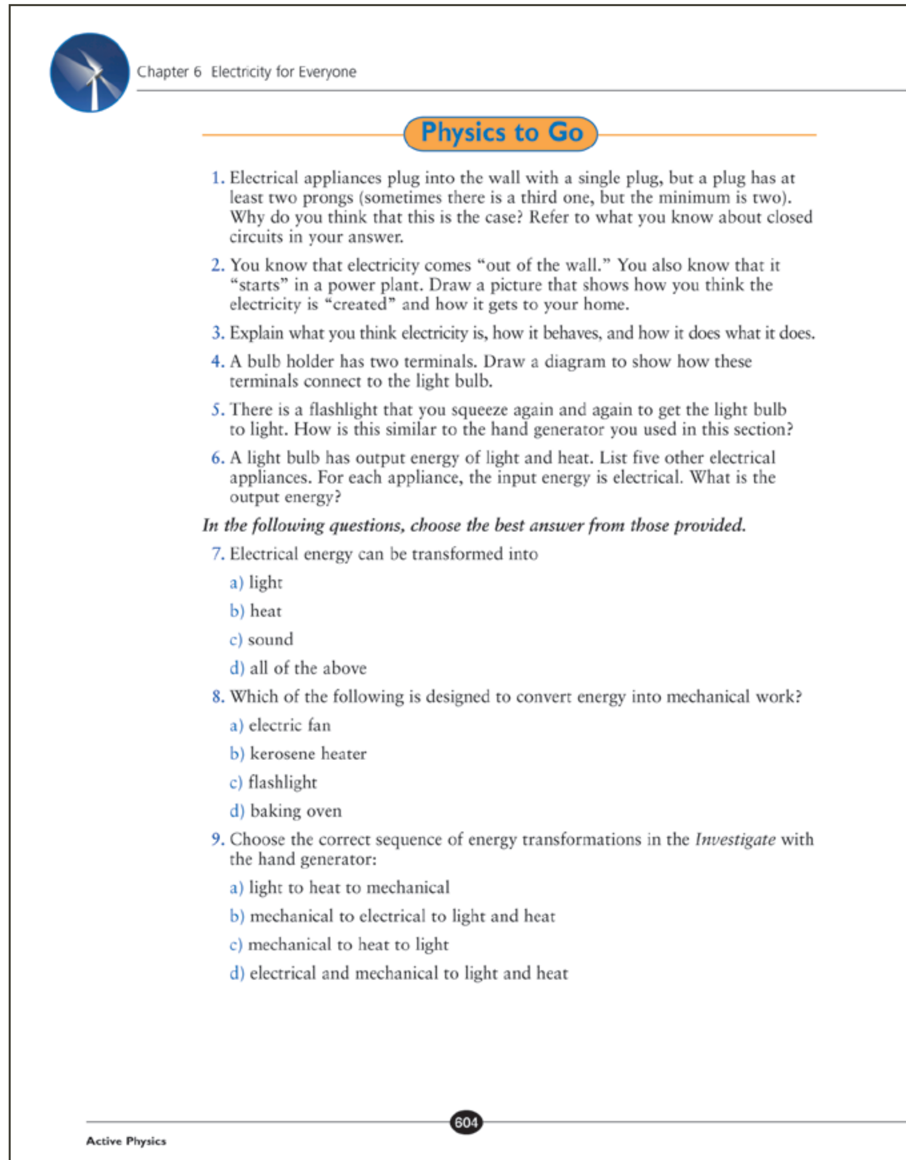
Diagrams should include how students think electricity is created along with labels or words describing the process, and how that electrical energy then gets to houses.

3.

Students' explanations should make a claim supported with reasons. The answers will vary, and some may include the concept of moving electrons that may have been discussed in earlier grades. However, they must include the purpose of the battery, the wires and how the light is generated in the bulb. You will probably encounter numerous prior conceptions about how electricity flows, (some correct, some incorrect).

4.

Diagrams should show how the bottom metal plate of the bulb holder makes contact with the bottom of the bulb and one of the terminals, and the plate that the bulb screws into makes contact with the side of the bulb and one of the terminals of the bulb holder.


Chapter 6 Electricity for Everyone

Physics to Go

1. Electrical appliances plug into the wall with a single plug, but a plug has at least two prongs (sometimes there is a third one, but the minimum is two). Why do you think that this is the case? Refer to what you know about closed circuits in your answer.
2. You know that electricity comes "out of the wall." You also know that it "starts" in a power plant. Draw a picture that shows how you think the electricity is "created" and how it gets to your home.
3. Explain what you think electricity is, how it behaves, and how it does what it does.
4. A bulb holder has two terminals. Draw a diagram to show how these terminals connect to the light bulb.
5. There is a flashlight that you squeeze again and again to get the light bulb to light. How is this similar to the hand generator you used in this section?
6. A light bulb has output energy of light and heat. List five other electrical appliances. For each appliance, the input energy is electrical. What is the output energy?

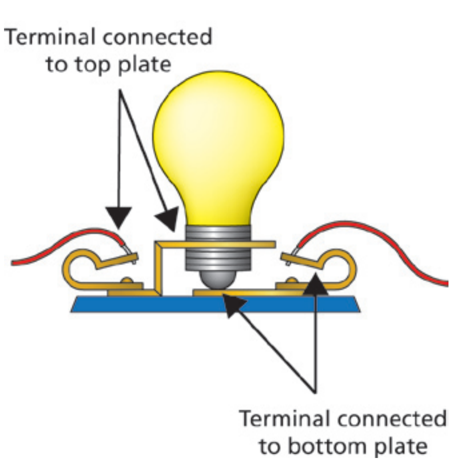
In the following questions, choose the best answer from those provided.

7. Electrical energy can be transformed into
   a) light
   b) heat
   c) sound
   d) all of the above
8. Which of the following is designed to convert energy into mechanical work?
   a) electric fan
   b) kerosene heater
   c) flashlight
   d) baking oven
9. Choose the correct sequence of energy transformations in the *Investigate* with the hand generator:
   a) light to heat to mechanical
   b) mechanical to electrical to light and heat
   c) mechanical to heat to light
   d) electrical and mechanical to light and heat

604

Active Physics

Diagram of bulb holder with labels describing contacts made



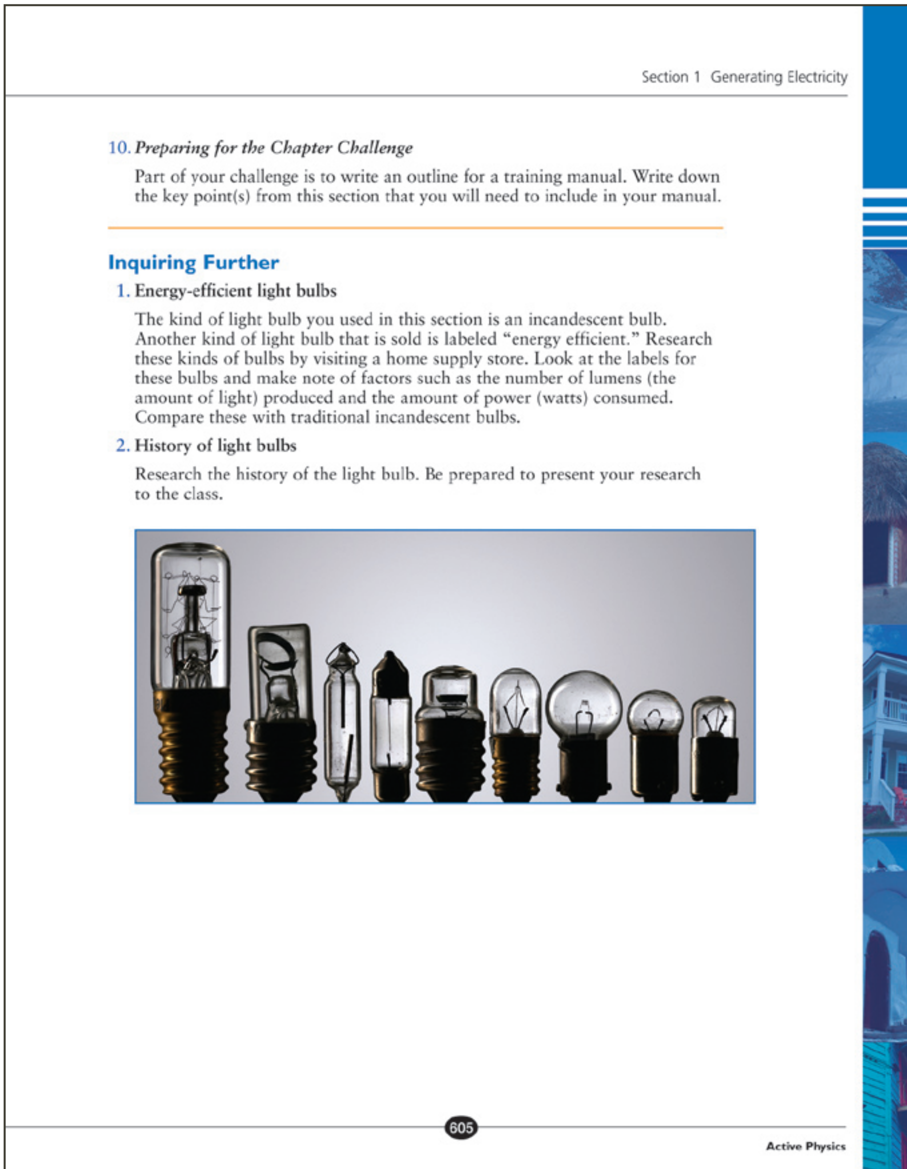
5.

Both are generators that transform mechanical energy to electrical energy.

6.

Students should list five electrical appliances and describe the output energy. For example, the output energies for

- microwave ovens are microwaves, visible light from the bulb, sound, and heat.



10. *Preparing for the Chapter Challenge*

Part of your challenge is to write an outline for a training manual. Write down the key point(s) from this section that you will need to include in your manual.

Inquiring Further

1. **Energy-efficient light bulbs**

The kind of light bulb you used in this section is an incandescent bulb. Another kind of light bulb that is sold is labeled "energy efficient." Research these kinds of bulbs by visiting a home supply store. Look at the labels for these bulbs and make note of factors such as the number of lumens (the amount of light) produced and the amount of power (watts) consumed. Compare these with traditional incandescent bulbs.

2. **History of light bulbs**

Research the history of the light bulb. Be prepared to present your research to the class.

- toasters are heat, visible (red) light, and mechanical energy (involved with the switch).
- radios are heat and sound.
- televisions are light, heat, and sound.
- computers are light, heat, and sound.

7.d)

All of the above. Electrical energy can be transformed into all types of energy.

8.a)

Electric fan. An electric fan converts electrical energy into mechanical energy. A kerosene heater produces heat energy. A flashlight outputs light energy. A baking oven outputs heat energy.

9.b)

Mechanical to electrical to light and heat.

10.

Preparing for the Chapter Challenge

Students should list the following key points from this section to include the following in their manual:

- The necessity of a closed circuit for electricity to flow
- The generation of electrical energy from mechanical energy, using a generator
- Electrical energy can be stored in a battery.

Inquiring Further

1.

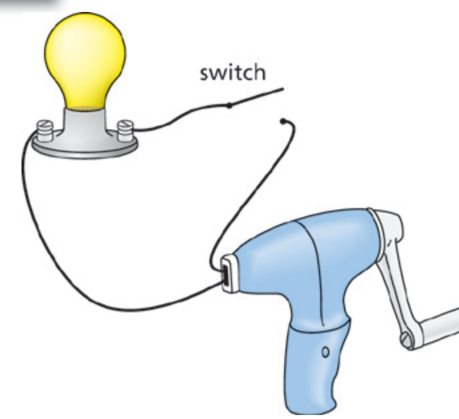
Students compare regular incandescent bulbs to energy-saving bulbs such as mercury, halogen, fluorescent, compact fluorescent, and/or LED's. They should list the wattage (power), energy, and lumens. Emphasize to students that the most cost efficient and environmentally friendly bulbs are the LED bulbs.

2.

Students research and present to the class the history of the light bulb. Students should include the year the commercially available light bulb was invented (1879), who invented it, and some of the milestones that occurred.

SECTION 1 QUIZ

6-1a **Blackline Master**



1. Which of the following is necessary for the light bulb to be lit in the diagram to the right:

   a) The switch must be closed.

   b) The generator must be cranked.

   c) The generator must also be connected to steel wool.

   d) Both a) and b).

2. After the bulb lights in *Question 1*, what happens to the brightness of the bulb if the generator is rotated in the opposite direction at the same speed?

   a) Nothing, the bulb glows with the same brightness.

   b) The bulb does not light at all.

   c) The bulb lights, but dimly.

   d) The generator spins by itself as the bulb lights.

3. The light bulb in the diagram is replaced with a blinking bulb. Which statement below best describes what happens to the generator when the bulb goes from off to on?

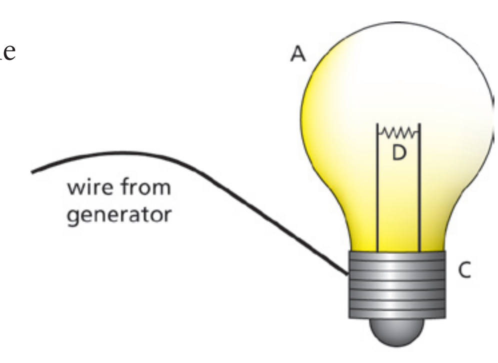
   a) The generator is easy to turn whether the bulb is on or off.

   b) The generator is hard to turn whether the bulb is on or off.

   c) The generator is easy to turn when the bulb is off but hard to turn when the bulb is on.

   d) The generator is easy to turn when the bulb is on but hard to turn when the bulb is off.

4. The diagram to the right shows a light bulb without the bulb base and one wire from a hand generator. The wire from the generator is connected to the bulb. Where should the second wire from the generator be connected for the bulb to light?



   a) A   b) B

   c) C   d) D

5. When the glowing piece of steel wool used in the *Investigate* burned out as the current became too large, it was most similar to which piece of protective, electrical equipment?

a) a generator

b) conducting wires

c) a fuse

d) a light bulb

SECTION 1 QUIZ ANSWERS

1. d) For an electrical current to exist in the circuit, the switch must be closed, and a voltage source (cranking the generator) must be supplied.

2. a) Nothing, the bulb glows with the same brightness. It does not matter which way the hand-cranked generator is cranked. This affects the direction of the current, but not the amount of current going through the bulb or the voltage drop across the bulb.

3. c) The generator is easy to turn when the bulb is off but hard to turn when the bulb is on. Only when the bulb on the circuit is closed and energy is transferred to the bulb to light it. When the bulb is off there is no current being supplied because the circuit is open. It is like turning the generator when nothing is attached to it.

4. b) B. To close the circuit, the second wire from the generator has to make contact with the other side of the wire in the bulb, which is connected to the bottom of the bulb.

5. c) A fuse. Fuses are used to open a circuit if the current going through them goes above a certain value. The fuse is usually a piece of wire that burns.