UNIT

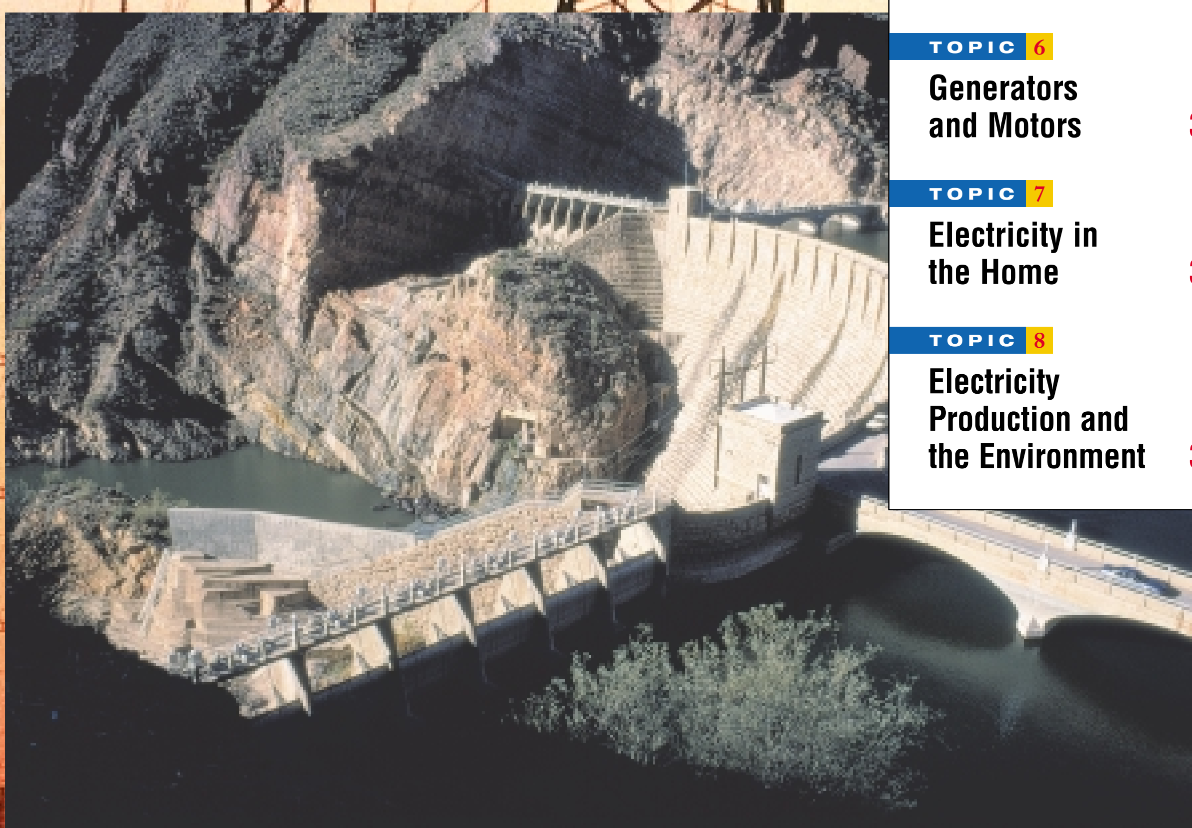
4

Electrical Principles and Technologies

Electricity is a bit like magic for many people. It seems that electricity simply appears when you turn on a lamp, start up your computer, or push the "on" button on a television's remote control. How and where is electricity produced before it gets to a wall socket? What happens inside a battery or cell that leads to the production of electricity? How do solar cells power a calculator or a space station? You will examine these questions and many others in this unit as you unravel the mysteries of producing electricity.

Producing electricity is one challenge. Finding ways to control and use electricity is an equally important task. From simple light switches to the complex circuits of a television or computer, we are surrounded by equipment which harnesses electrical energy to do useful tasks. By building and studying the basic types of electric circuits, in this unit you will learn how to measure and calculate important characteristics of any electrical device.

As Earth's population and the demand for modern technology grow, the demand for electricity will also increase. What is the environmental impact of producing and transmitting electricity? In the twenty-first century, the electrical industry will need to develop new technologies for generating, distributing, and storing electricity. New types of batteries and generators will likely be invented. Some electric devices may themselves turn out to be part of the solution to today's environmental challenges.



Unit Contents

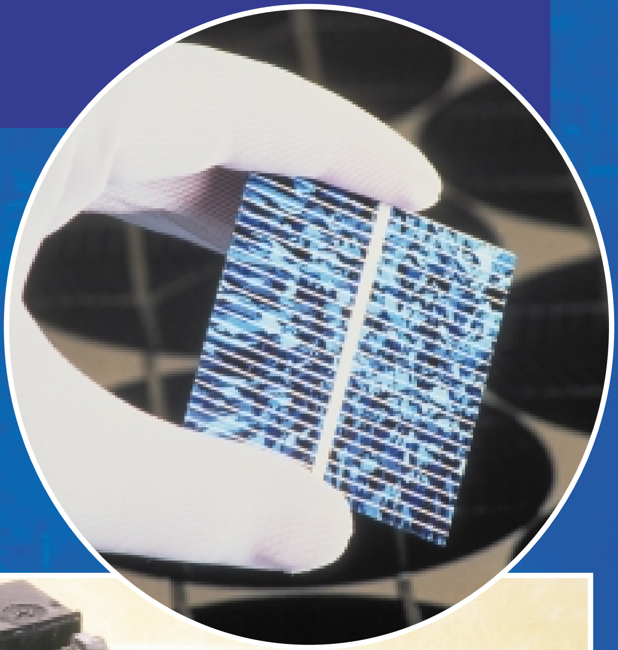
UNIT 4

Preview

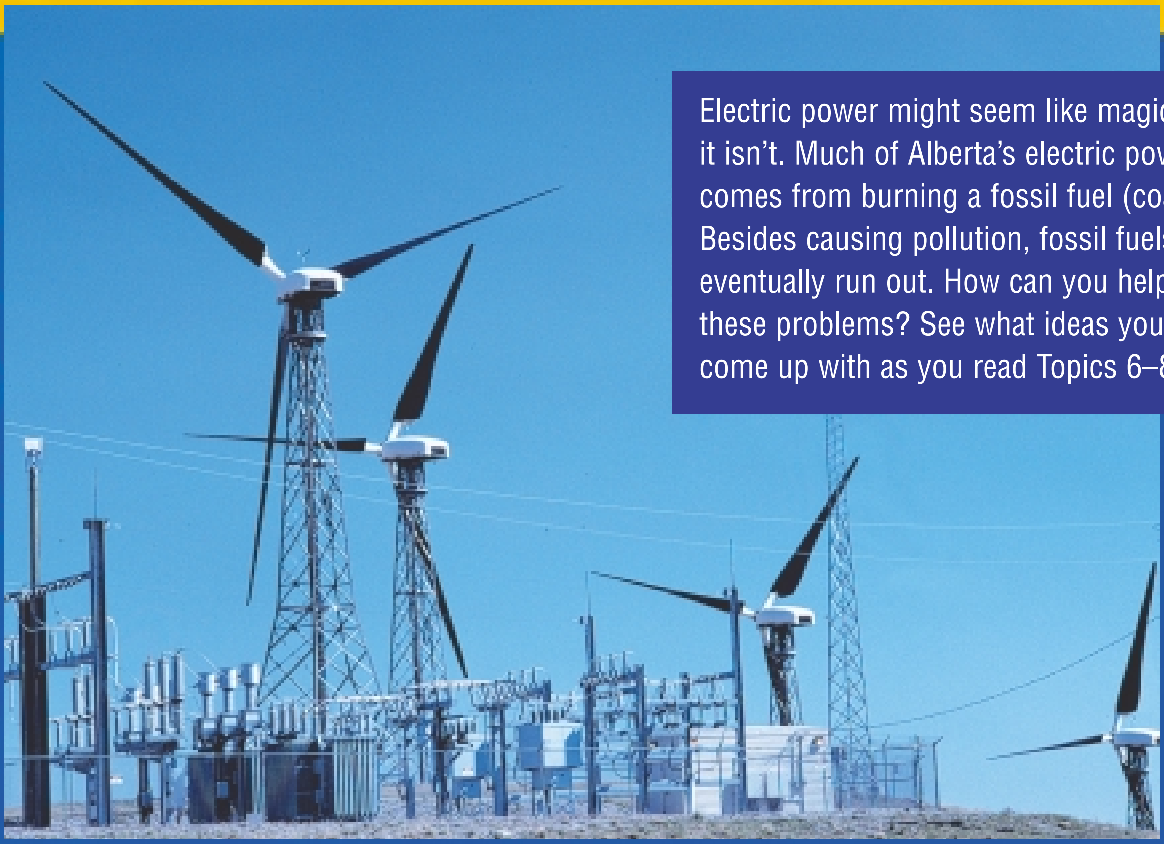
Focussing Questions

- How do we turn coal in the ground or water behind a dam into electric energy that you can use in your home?
- How are we able to control the energy so that the various appliances we use receive just the right amount?
- What new technologies can we develop to help us use energy in less environmentally demanding ways?

Hey presto! Bring an electric charge into existence! Make the charge do some work for you. Now make it stop. And find out when electric charges can be a nuisance for people and machinery. You can do all of these things by reading Topics 1–3.



Is it possible to use chemical energy to produce electricity? Can you produce electricity by using light? And when you've figured out how to do that, can you find a way to store the electricity until you need it? You'll be able to do all of these and more after reading Topics 4–5!

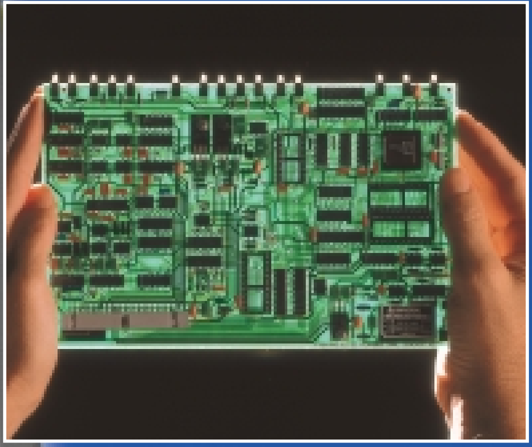


Electric power might seem like magic, but it isn't. Much of Alberta's electric power comes from burning a fossil fuel (coal). Besides causing pollution, fossil fuels will eventually run out. How can you help solve these problems? See what ideas you can come up with as you read Topics 6–8.

Looking Ahead

Look ahead to pages 346–347, My Amazing Electric Invention. In this project, you will work with a group to invent and build your own electric device based on the principles you learned throughout the Topics. As you work through the unit, pay close attention to information about electric devices and components that may help you invent and build your device. You may want to

- draw several designs for possible devices as you learn about loads, circuits, resistors, and other electrical principles
- use a paper or electronic file to keep track of important information that could aid in making your invention work
- discuss your design ideas and knowledge about electricity with your group members



TOPIC 1

Electric Charges

Storm clouds roll in on a summer evening. Suddenly the sky is split by an enormous lightning bolt, far too energetic to harness or control. By comparison, sparks created when you comb your hair, or the electrical currents created by a battery, are tiny indeed. Scientists have, however, developed a unified explanation for all these phenomena: the idea of electric charge. The electrical devices you use everyday, from lightbulbs to computers, use the energy of moving charges to do useful work. This Topic will introduce you to the theory and laws of electric charge.

Find Out ACTIVITY

Charge It

Many combinations of materials, such as shoes on carpets and clothes in a dryer, will become electrically charged when they are rubbed together. How do charged and uncharged objects react to each other? Can you come up with a set of rules that could describe their behaviour?

Materials

watch glass (at least 10cm diameter)
2 acetate strips (at least 12 cm long)
2 vinyl strips (at least 12 cm long)
1 sheet of paper towel

Procedure

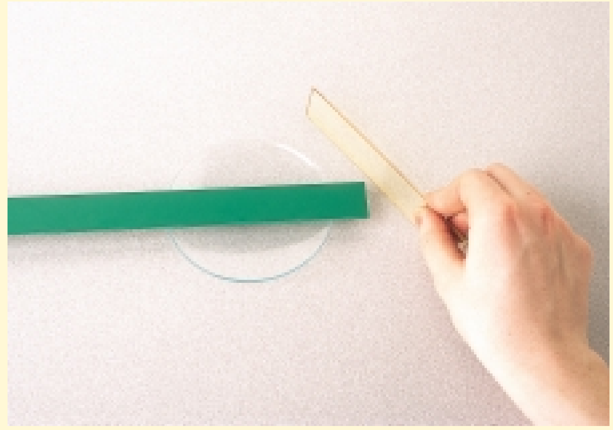
Performing and Recording

1. Copy the observations table and then experiment to complete it.
2. Just before each trial, remove any charges from the watch glass or any "uncharged" strip by gently wiping them with your hand.
3. Charge plastic strips by pulling them gently through a folded paper towel several times.
4. Balance one strip on the watch glass without letting it touch the table or anything else.
5. Move the handheld strip near one end of the balanced strip. Note any movement. If the strips touch, you will need to recharge them.

Trial	Strip balanced on the watch glass	Hand-held strip	Behaviour of balanced strip (attracts, repels, nothing)
1	uncharged acetate	uncharged acetate	
2	uncharged acetate	charged acetate	
3	charged acetate	charged acetate	
4	charged acetate	uncharged vinyl	
5	charged acetate	charged vinyl	
6	charged vinyl	charged vinyl	
7	uncharged vinyl	uncharged vinyl	

What Did You Find Out? Analyzing and Interpreting

1. Describe the behaviour(s) you observed between:
   (a) two uncharged strips.
   (b) two charged strips.
2. Were the behaviour(s) between charged strips always the same? Explain either why they were the same, or why they were different.
3. Write three rules that describe the possible behaviours that occur when objects with different charges are brought close to each other.



Producing Charges

Materials that attract and repel other materials are said to be charged, or carry an electric charge. It is these charges that were being collected when you rubbed the plastic strips with paper towel in the Find Out activity. The charge is responsible for the change in the material's characteristics after rubbing or touching. In the Find Out Activity, for example, the plastic strips were able to attract or repel each other if one or both of them became electrically charged.

How are electric charges produced? Many combinations of materials become charged when they are rubbed, touched, or moved close together and then separated. Think, for example, of shuffling across a carpet. Both you and the carpet develop an electric charge. As a result, your body behaves differently when you touch a door handle or another person. You receive an electric shock, and may even notice a spark — a tiny bolt of lightning. In a thunderstorm, water droplets and ice crystals in the clouds are buffeted by the strong winds, colliding and rubbing against each other. When you walk across a room, your shoes or socks rub against the carpet.

Cool Tools

Electric charge can be detected by an instrument called an electroscope. Pocket-sized electroscopes called dosimeters are used to measure exposure to atomic radiation. Charged particles produced by the radiation are detected by the dosimeter. There are strict limits to the amount of radiation exposure that workers may receive.

Figure 4.1 A Van de Graaff generator produces large electric charges on a metal sphere. How can you tell that the girl touching the generator has also become electrically charged?

In many cases, charges produced by rubbing or touching remain stationary, so they are sometimes called **static electricity**. There are, however, many instances when these charges move, so **unbalanced charges** is a more accurate way of describing the phenomenon.

It is difficult to measure electric charge directly. Fortunately, that is seldom necessary, because the amount of charge can usually be calculated from other measurements. The quantity of electric charge is expressed in coulombs (C). A bright light bulb, for example, allows about 1 coulomb of electric charge to pass through it every second.

Making Sense of Electric Charges

As you have discovered, charged objects attract neutral objects. Some charged objects repel each other, while others attract each other. There are three interactions to be explained. Scientists explain these interactions in terms of positive and negative charges in the materials themselves.

Figure 4.2 The charge on an object depends on the balance between positive and negative charges in the object.

(a)	(b)	(c)
+ + − + − − − − + − + +	+ + + + − + − − + + + +	− − + − − + − − − + − +
(a) neutral ("uncharged") equal positive and negative charge	(b) positive charge excess positive charge	(c) negative charge excess negative charge

Pause & Reflect

In your Science Log, explain whether electrons would need to move onto or off an object in order to charge the object negatively. How could an object be charged positively by moving electrons?

American inventor and politician Benjamin Franklin (1706–1790) was the first to use the terms "positive" and "negative" to describe charges. Franklin called the charge on amber that had been rubbed with fur *negative*. The charge left on the fur was called *positive*. Two different charges, one positive and one negative, are called *unlike* charges. Two charges of the same type (both positive or both negative) are called *like* charges. Benjamin Franklin lived before scientists understood that all matter consists of atoms, which in turn contain positively charged particles (protons) and negatively charged particles (electrons). According to modern theory, unbalanced charges on solid materials are due to the movement of electrons from one object to another. Even without this knowledge, however, Franklin's experiments helped establish the **Laws of Charges** that describe the behaviour between charged and uncharged objects.

1. Unlike charges attract.
2. Like charges repel.
3. Charged objects attract uncharged (neutral) objects.

Conductors, Insulators, and In-Between

For many materials, such as rubber, a charge stays on the spot where you rub the object. Such materials fit into a class called **insulators**. Insulators are materials that do not allow charges to move freely on or through them. Materials that allow charges to move freely, are classified as **conductors**. Most metals are conductors and most non-metals are insulators.

Since electrons are the charges that move through solids, a conductor must be a material that holds its electrons loosely. Insulators, on the other hand, are materials that hold their electrons very tightly. Some materials are not perfect insulators, but they are not good conductors either. These "fair conductors" allow electrons to move, but not at all freely. Table 4.1 classifies some common materials by their electrical conductivity.

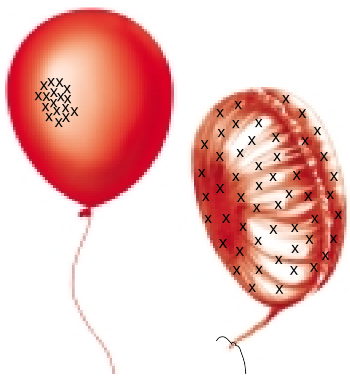


Figure 4.3 When you rub a rubber balloon, the charges (x) remain in place. When you rub a metallic balloon, the metal conductor allows the charges to move freely over the entire surface.

Table 4.1 Some Common Conductors and Insulators

Good Conductors	Fair Conductors	Insulators
aluminum	silicon	cotton
copper	carbon	glass
gold	human body	paper
nickel	humid air	plastic
platinum	nichrome	porcelain
silver	water (salty)	rubber
tungsten		water (pure)

Pause& Reflect

In your Science Log, list several common applications for materials with each type of electrical conductivity. Where would you expect to find good conductors, fair conductors and insulators being used in typical electrical devices like lights, calculators, extension cords, and stoves?

Semiconductors are materials with higher conductivity than insulators but with lower conductivity than metals. Their conductivity is often increased by implanting foreign atoms into the otherwise pure material. Two commonly used semiconductors are silicon with gallium added and germanium with phosphorus added.

Superconductors are materials that offer little, if any, resistance to the flow of charges. Certain materials become superconductors when they are subjected to extremely low temperatures — about –137.15°C to –273.15°C. Superconductors are usually made of metal alloys and ceramics. Some applications of superconductors include components for electric generators, high-voltage power lines, and supercomputers. Superconductors take up less space and can carry higher charges than ordinary conductors. In one power transmission application, about 114 kg of superconducting wire replaced about 8200 kg of copper cable, making it more than 7000% more space efficient.

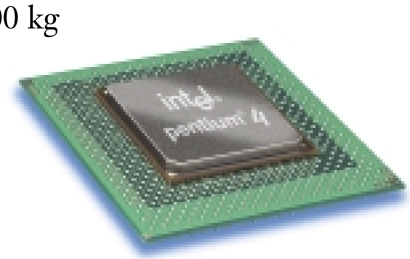


Figure 4.4 Silicon semiconductors are used extensively to make computer microchips.

Figure 4.5 When a gasoline truck rolls down the highway through blowing wind and dust and over bumpy roads, it often becomes charged. Before the truck delivers gasoline, it is grounded. This prevents sparking that could cause gasoline fumes to explode. The movement of gasoline through the hose also produces charges, so the grounding cable must remain attached during the delivery, as well as before it starts.

Figure 4.6 Hand-held ionizers can neutralize electrostatic charges on non-conductors.

Figure 4.7 Coatings and sprays are applied to surfaces to prevent buildup of charges and to dissipate charges that are already present.

Neutralizing Unbalanced Charges

Have you ever battled "static cling" when removing clothing from a drier on a dry day? You probably felt, and even saw, small sparks—an electric **discharge**—as accumulated charge on the clothing was **neutralized** (became balanced). Electric discharges are a serious safety hazard, because they can shock people, damage electronic equipment, and cause fires and explosions. Their cause is simple. In a discharge, electrons either enter an object to make up for a shortage, or an excess of electrons leaves the object.

Connecting an object to Earth with a conducting wire — **grounding** the object—is an easy way to neutralize conductive materials. Earth is so large that it can easily supply enough electrons to neutralize a positively charged object. Similarly, Earth can absorb extra electrons from a negatively charged object.

Non-conductors, or insulators, usually must be neutralized with ionization. Ionization devices produce both positive and negative ions. These ions are attracted to materials with an opposite charge, transferring charges until the material is neutralized. Ionizers come in a variety of sizes and shapes ranging from small hand-held devices to large wall-mounted models that are installed in manufacturing facilities.

Preventing Electrostatic Buildup

Buildup of unbalanced charge can be costly, even if there is no electric discharge. Charged objects attract dust and contaminants. They also stick together and jam equipment such as photocopiers. To decrease static buildup, antistatic sprays and coatings can be applied to carpets and other surfaces on which charge accumulates. After materials have become charged, sprays can also be used to dissipate (scatter) the charge (see figure 4.7).

Electronic components like computer memory cards are especially sensitive to electrostatic discharge, so they are often shipped in special antistatic packaging. Before handling sensitive components, electronic technicians may fasten a "grounding strap" on their wrist. The strap contains conductive materials, so that when one end is grounded, any unbalanced charge on the technician's hand or body is neutralized without harmful electric discharge.

Find Out ACTIVITY

Putting Electrostatics to Work

The understanding of how positive and negative charges interact has led to many useful applications for electrostatics.

Materials

poster paper
drawing, writing, and colouring supplies
reference sources, such as the Internet, school library, and resource people

Procedure ✶ Communication and Teamwork

1. Choose a topic that interests you in the field of applications of electrostatics. You might consider electrostatics in painting, farming, negative ion generators, electrostatic precipitators, photocopiers, how electrostatic air filters clean the air in homes and hospitals, how fabric softeners reduce static cling, or how electrostatics is used in studying living cells. Phrase your topic in the form of a question, plan the steps of your research, and discover the answer. Present your information orally to the class, using visual aids, such as posters or a multimedia presentation.

What Did You Find Out?

1. What surprised you about the information you learned in your research?
2. List all the technologies presented by classmates. What additional questions do you have about the applications of electrostatics? List at least three questions you would like to answer.

You have seen how the attraction between positive and negative charges can be harnessed and put to use in a variety of technologies. When the movement of electric charge is controlled within conducting wires, many other fascinating technologies become possible. In Topic 2 you will deepen your understanding of electricity by investigating electric circuits.

TOPIC 1 Review

1. List the three "Laws of Charges." For each law, give an example of the law being applied.
2. Describe the difference between a negatively charged object and a positively charged object.
3. Why is the phrase "unbalanced charges" a more accurate way of describing the phenomena we often refer to as "static electricity"?
4. How do charged conductors and insulators differ from each other? Name two examples of conductors and two examples of insulators.
5. Describe two different ways in which a charged object can be discharged.
6. **Apply** Describe a situation in which electrostatic discharge could pose a problem. Explain how the problem could be solved. Describe an application that uses electrostatic charges in a positive way. Explain how the charges are used.
7. **Thinking Critically** What do you think would happen if you rubbed two identical objects together? Would they attract each other, repel each other, or neither attract nor repel each other? Why?