Science ch. 17

Changing Energy Forms

Career

MACHINIST

Did you ever look at a car engine? It's an amazing machine. Hundreds of metal parts work together to make the car move. The parts work together because they are the exact shape and size they are supposed to be.

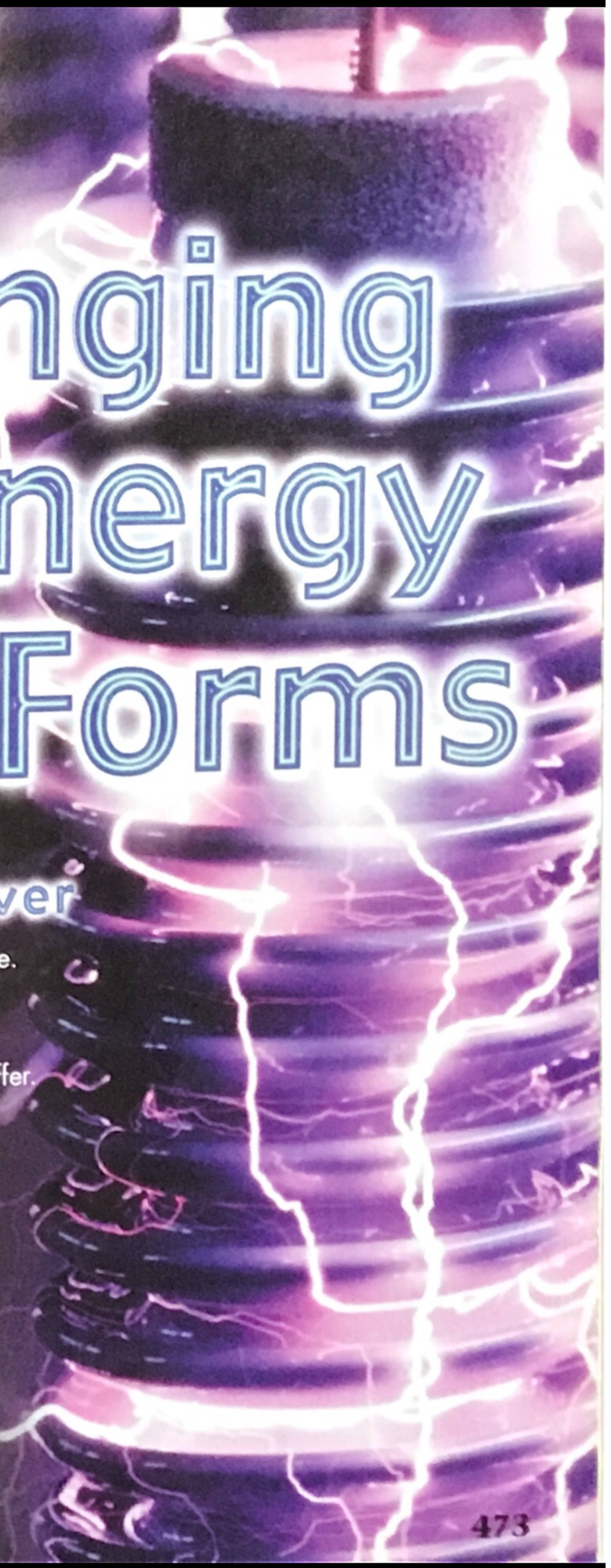
Machinists use machines to make precise metal parts. These parts are then put together to make many of the products that we use every day.

Machinists plan their work carefully. First, they study blueprints or written instructions for the part they will be making. Next, they decide what materials and tools to use. They plan out how they will shape the material each step of the way. Then they begin to cut, drill, shave, and shape the material to make the exact part needed.

A lot of the machines that make metal parts contain computers. So machinists often need some computer skills. Most machinists learn their skills in a technical school or two-year college after high school. Some become apprentices and learn through on-the-job training while attending classes.

Lab zone Take-Home Activity

Look at a machine that has metal parts. It might be a bicycle, a kitchen gadget, or a tool such as a wrench. Observe how the parts fit together. Then imagine that one of the parts was a different size or shape. How would that affect the working of the machine?



Chapter 17

Changing Energy Forms

You Will Discover

- what different kinds of energy are.
- what electric current and electric circuits are.
- how series and parallel circuits differ.
- how magnetic domains cause magnetic fields.
- how electricity and magnetism are related.

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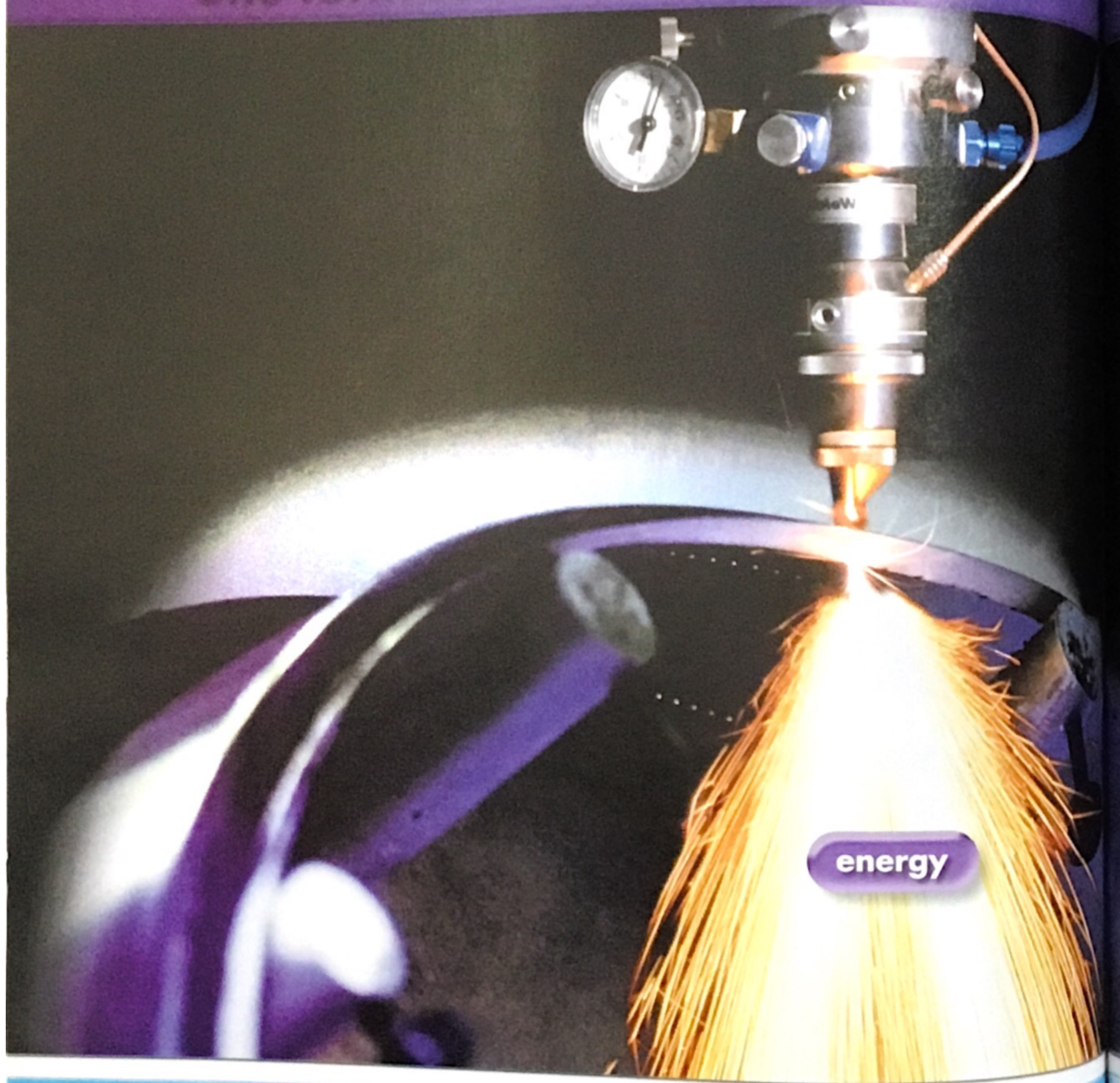
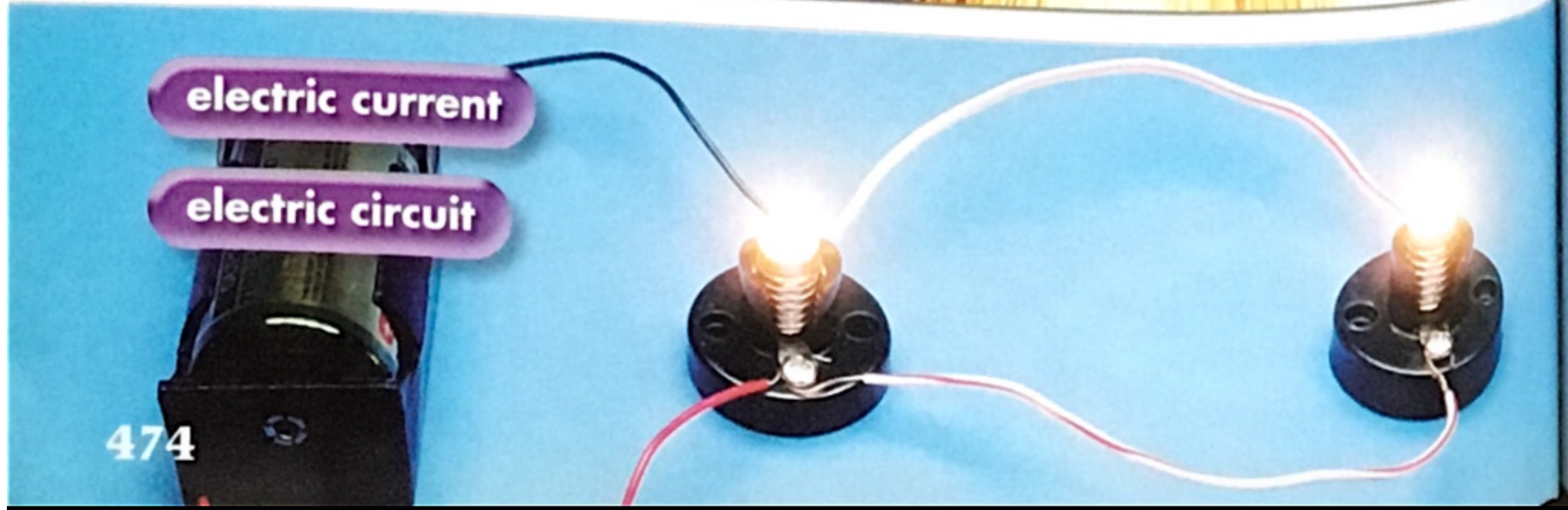
Build Background

How can energy change from one form to another?





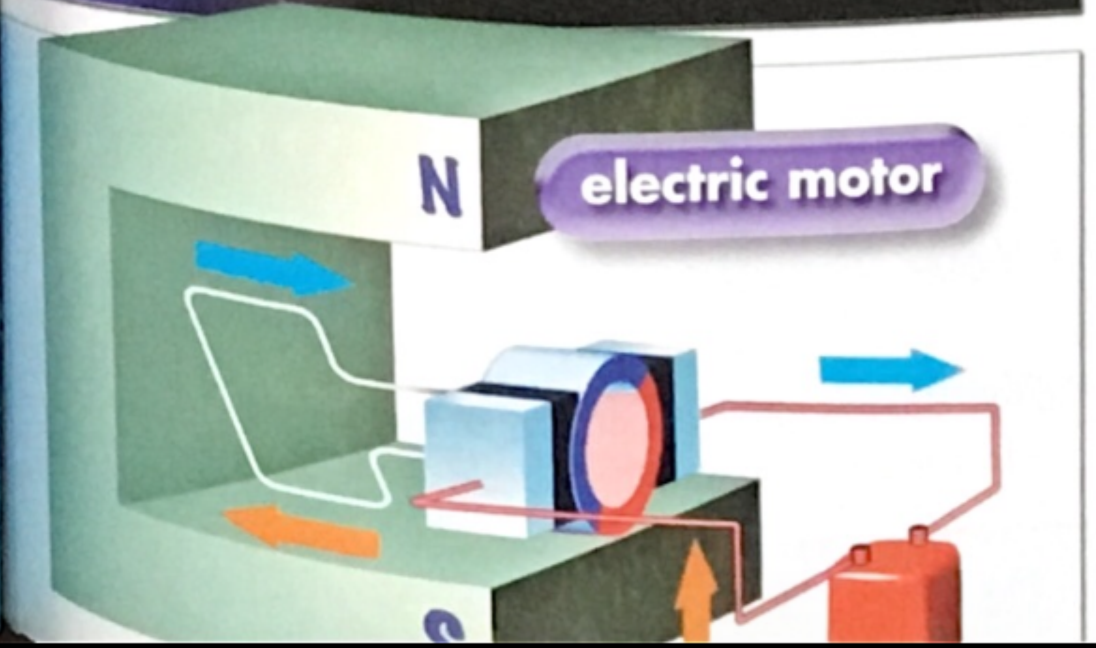
Chapter 17 Vocabulary

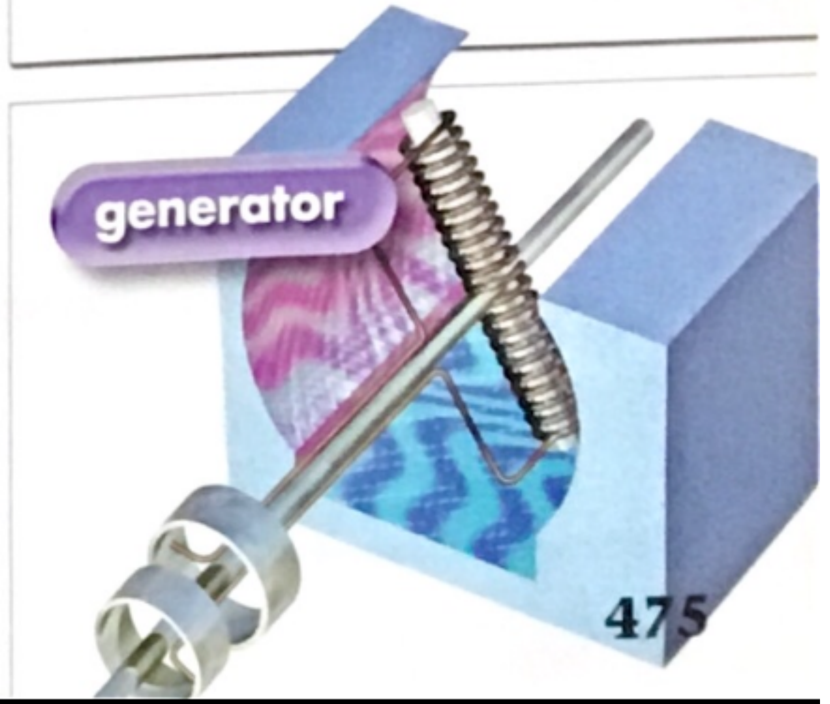
kinetic energy

The energy of a moving object

potential energy

The energy due to the position of an object





You Are There!

You watch through a protective window as the high-powered laser light is turned on. Blinding sparks of hot metal shoot out in all directions. Energy from the invisible light beam changes to heat energy that melts a smooth cut in the metal. It's a good thing you're watching through a protective window. This laser delivers a lot of energy to a small area. Even the reflection of the beam would damage your eyes or skin in less than a second.

Lesson 1

How can energy change?

Energy exists in many different forms. Energy can change from one form to another, but it is never lost completely.

Some animals, such as this electric catfish, use electrical energy to protect themselves by shocking their predators.

Energy and Work

Think of all the ways you change things. You change an apple by cutting it in half. You flip a switch to light up a room. Pushing a book changes its location. Every change involves energy, and energy is related to work. That's why energy and work use the same unit, the joule. When you do work, you change an object by transferring energy to it. **Energy** is the ability to cause change or to do work. Energy is a property of all matter.

Forms of Energy

Mechanical energy is the energy an object has because of its movement or position. **Kinetic energy** is the mechanical energy of a moving object. A ball rolling across the floor has kinetic energy as long as it keeps moving. **Potential energy** is mechanical energy due to position. Any object above the ground, such as your book sitting on your desk, has potential energy.

Energy has many other forms. Chemical energy is stored in the bonds between atoms. You get chemical energy from the food you eat. A car's engine uses chemical energy stored in gasoline. The nucleus of an atom stores nuclear energy. This energy can be released when atoms break apart. Reactions like this take place in nuclear power plants.

Another kind of energy, thermal energy, moves from one object to another as heat. Electrical energy is energy that results from the movement of electrons. Televisions and lights rely on electrical energy.

1. ✓ Checkpoint Describe the two types of mechanical energy. Give an example for each.
2. Writing in Science **Narrative** Write about how you used chemical, thermal, and electrical energy during the past day.

Energy Changes

Almost everything that happens around you involves the change of energy from one form to another. Think about the different forms of energy involved in drinking a glass of orange juice. The energy changes begin with the Sun. The Sun's nuclear energy changes to radiant energy that travels through space to Earth. The leaves of an orange tree take in this radiant energy. During photosynthesis, the leaves change the radiant energy to chemical energy stored in the plant's cells. When you drink orange juice, you take in this stored chemical energy. Your body changes some of the chemical energy to thermal energy to keep you warm. Some thermal energy is lost to the air as heat. You change chemical energy to kinetic energy as you move around.

All forms of energy can be used to create forces to do work. Think about the kinetic energy of moving wind and water. It can create forces strong enough to blow down trees or move rocks. Geothermal energy in hot underground springs can force geysers to spurt water high into the air. At the seashore, the energy of tides and waves results in forces that wear away sand and rocks.

Each kind of energy can be changed into thermal energy. Rub your hands together. What happens? Do your hands get warmer? That's because of energy changes that result from friction. Friction causes the mechanical energy of your moving hands to change to thermal energy.

Thermal energy also results when something burns. For example, chemical energy is stored in wood. When wood is burned, some of the chemical energy changes to thermal energy. The thermal energy may move as heat that warms the nearby air. Some of the chemical energy changes to radiant energy that warms you if you stand near the burning wood.

A geyser can release a lot of stored energy.

What kinds of energy are stored in each of these objects?

Conservation of Mass and Energy

In all of these energy changes, energy is never lost completely. It only changes form. Think about this example. If you drop a rubber ball onto a hard floor, the ball bounces a few times and then stops. Each bounce is lower than the one before it because the ball loses some energy as heat and sound. The energy lost from the ball is gained by the floor and the air.

Until the 1900s scientists had never found a process in which energy was lost. This fact had been observed so often that scientists called it the law of conservation of energy. Scientists also had stated a similar law about matter, called the law of conservation of mass. First discovered by Antoine Lavoisier in 1784, it stated that matter could not be created or destroyed.

Then scientists discovered that energy and matter can be changed into each other under extraordinary conditions. For example, nuclear energy results when matter changes to energy. Because of this new evidence, scientists developed a new law that states that the total amount of matter and energy does not change.

Both this firefly and the light wands convert chemical energy into light energy.

✓ Lesson Checkpoint

1. Where do plants get the chemical energy they need to grow?
2. Explain why the work needed to operate a machine must always be more than the work done by a machine. Hint: Think about friction.
3. **Writing in Science** **Descriptive** Write a paragraph describing the energy changes involved in tossing a ball into the air.

Lesson 2

How are electricity and magnetism related?

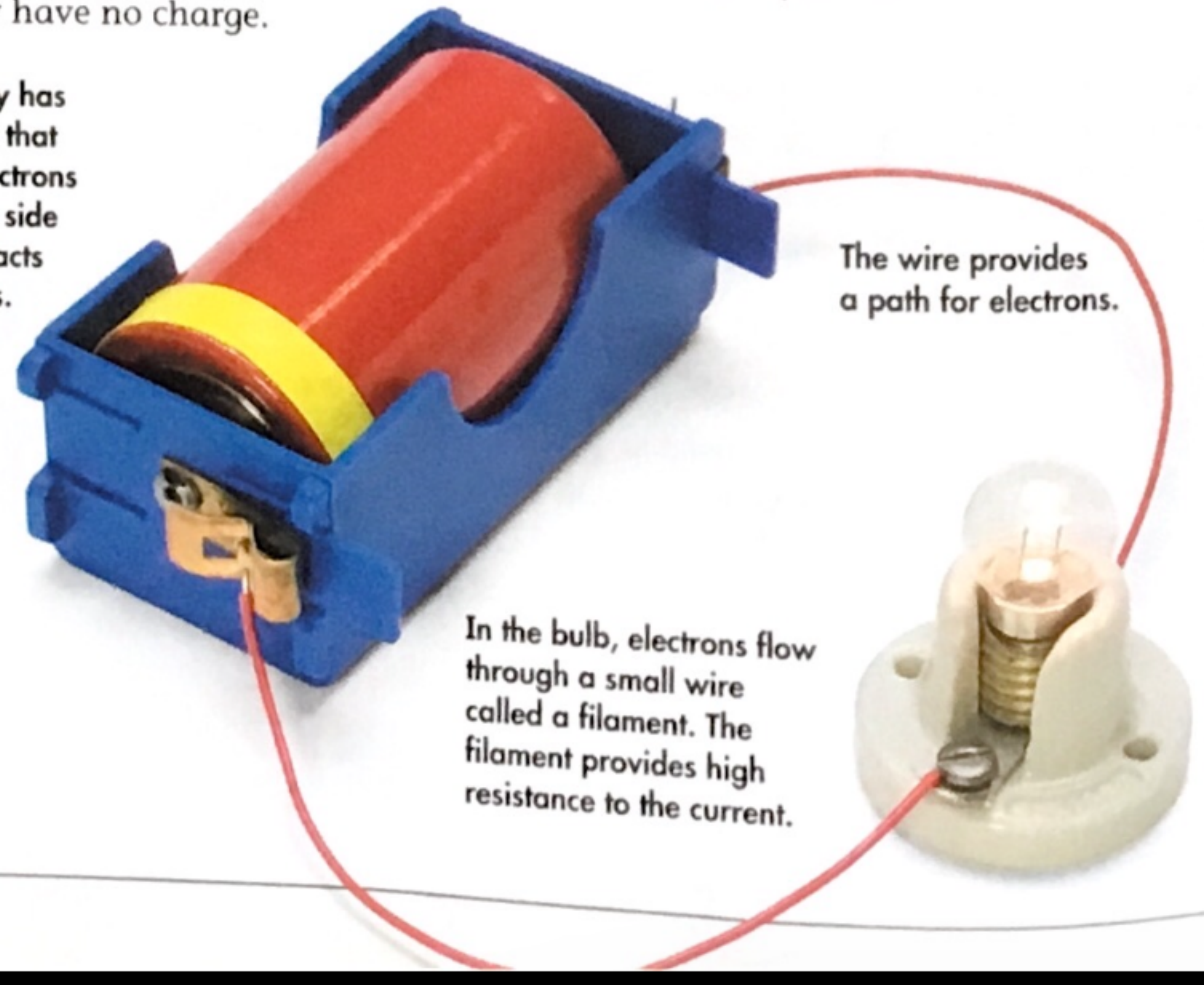
Electric charges travel as an electric current in a circuit. Magnets are surrounded by a magnetic field. Moving electric charges produce a magnetic field. A changing magnetic field produces an electric current.

Water turns giant blades called turbines at a power plant, changing mechanical energy to electrical energy.

Electric Current

What would your life be like if you had no electrical energy? Lamps, computers, stoves, flashlights, cars, and all other things that use electrical energy would be useless. What would schools, dentist offices, and stores be like? Hardly a minute goes by each day without electrical energy affecting your life.

Recall that atoms have a central nucleus surrounded by a cloud of electrons. The nucleus has protons with positive charges and neutrons with no charge. The electrons have negative charges and are held around the nucleus. In most atoms, the number of positive and negative charges are equal. For that reason, atoms usually have no charge.



A battery has one side that loses electrons and one side that attracts electrons.

The wire provides a path for electrons.

In the bulb, electrons flow through a small wire called a filament. The filament provides high resistance to the current.

In some materials, such as copper, electrons are not tightly held by the atoms. These electrons can move from atom to atom. This flow of electrons causes an electric charge to move along atoms. For example, when you turn on a light, electrons start flowing through the wire in the lamp. All electrons have negative charges, so they repel, or push away from, each other. When the electrons from one atom flow to the next atom, the repelling effect pushes the electrons in the second atom along to the next atom. This process continues as electric current. An **electric current** is a flow of electric charge in a material.

A material that allows electrons to flow easily through its atoms is a good electrical conductor. Copper is a good conductor. This property makes copper a good choice for electrical wires. In other materials, called insulators, electrons do not move easily. Current does not flow easily in an insulator. Rubber is a good insulator.

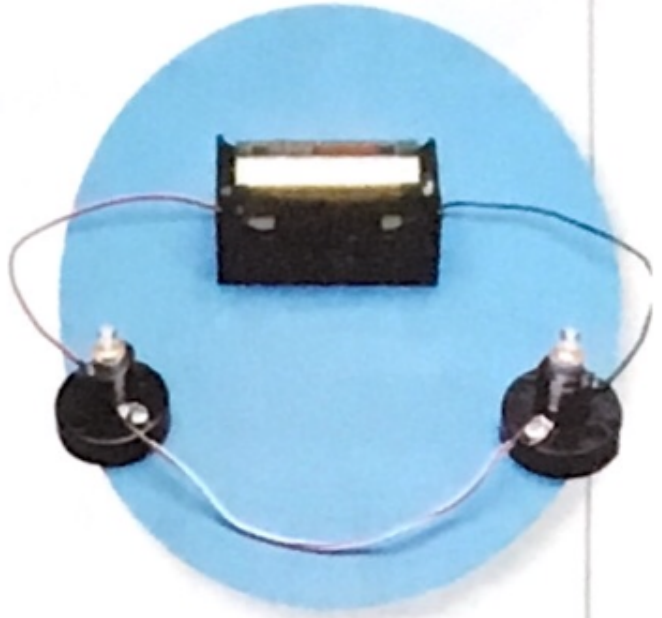
Electric Circuit

Electric current can flow only when it can travel in a complete path back to its starting position. An **electric circuit** is a closed path along which current can flow. A simple circuit must have a source of electrical energy, such as a battery. A circuit also needs a wire or other material through which the current can flow. Many electric circuits also have a switch. When the switch is open, a break in the circuit prevents the flow of current. A device such as a light bulb that can change the electrical energy to a useful form of energy is also part of a simple circuit.

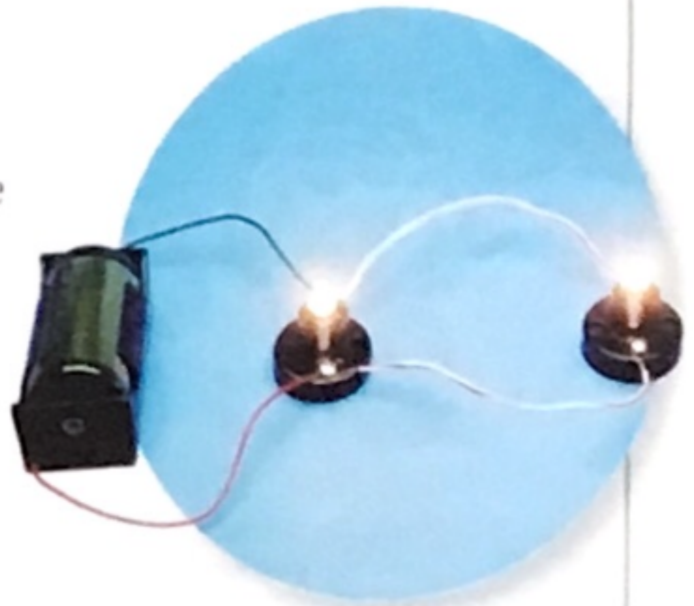
The wire inside a light bulb resists, or slows, the flow of electrons. This resistance causes electrical energy to change to thermal and radiant energy. The result is the light you see when electricity travels through a light bulb.

The energy source in a circuit provides the push that moves electrons through an electric circuit. Volts measure how strongly the electrons are pushed. Electric stoves and a few other home devices use 220-volt electric current. Toasters and most everything else in your home use 110-volt current. Using the wrong amount of volts can damage an electric device.

1. **Checkpoint** What advantage do parallel circuits have over series circuits?
2. **Sequence** Look at the series circuit on this page. Describe the movement of current as it leaves the negative side of the battery until it reaches the positive side.

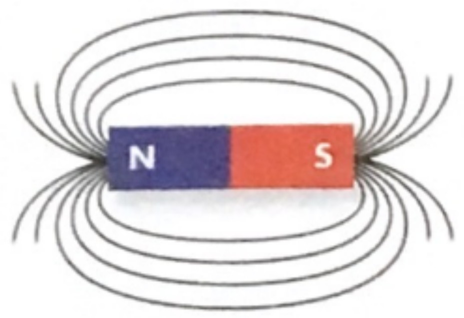


Series Circuit
A series circuit has only one path along which current can flow. Current flows from the negative side of the battery, through each of the light bulbs, and back to the positive side of the battery. If you remove a bulb, the circuit is broken and the other bulb will go out.



Parallel Circuit
A parallel circuit has more than one path along which current can flow. Homes and businesses use this type of wiring. If one bulb is taken out, the other bulb still glows. The current still has a path along which to flow.

Magnetic Fields



Magnetic field

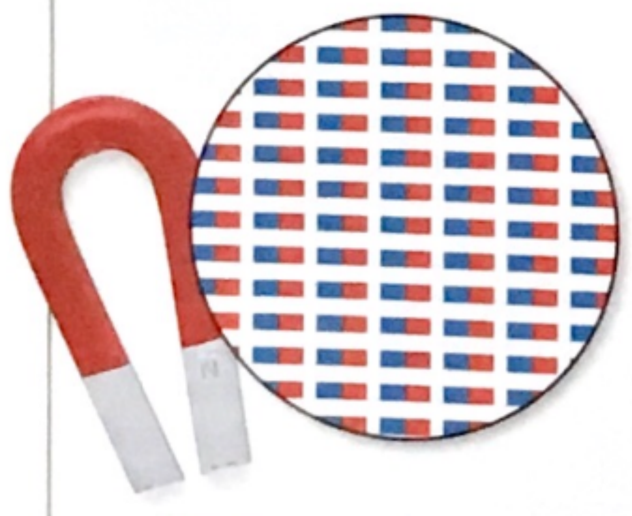
Have you ever played with magnets? If you did, you probably know that each magnet has a north pole and a south pole. As you can see in the picture below, if you bring opposite poles of two magnets together, the magnets will attract, or pull toward, each other. If you bring similar poles together, the magnets will repel, or push away from, each other. The space around a magnet in which the magnet can exert a force on other magnets is called the magnetic field. The field is strongest at the poles. Magnets attract or repel because of their magnetic fields.

Not all materials can be magnetic. The movement of electrons about the nucleus of an atom causes each atom to be slightly magnetic. For most materials, the magnetic fields face in every direction and cancel each other out. But in some materials, such as iron, cobalt, and nickel, the magnetism of the atoms is stronger. The atoms line up in groups called domains. A **magnetic domain** is a large number of atoms with their magnetic fields pointing in the same direction.

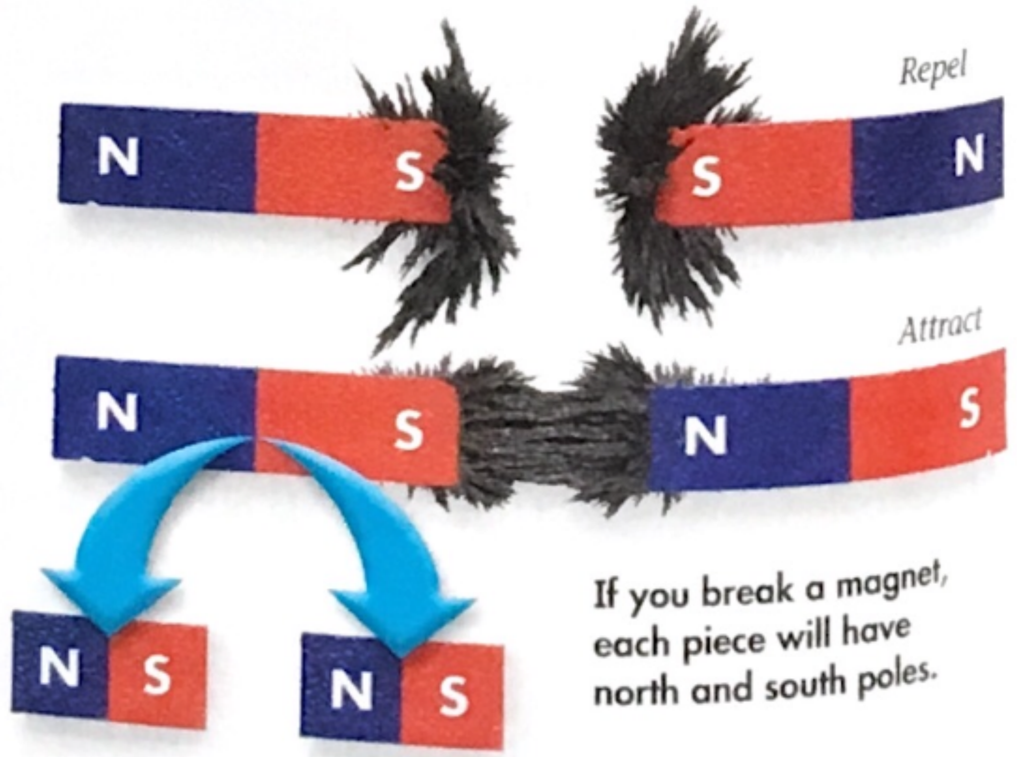
Each magnetic domain is like a small magnet, with a north and south pole. If the domains are pointing in different directions, the material is not a magnet. Some materials can be made into magnets. If they are placed in a magnetic field, their domains will line up with the field. The materials will then be magnets.

What do you think would happen to a magnet if you broke it in half? Would you have a north-pole magnet and a south-pole magnet? If you break a magnet in half, you don't end up with a north-pole magnet and a south-pole magnet. The magnetic domains still point in the same direction as the original magnet. You end up with two smaller magnets, each having a north and a south pole.

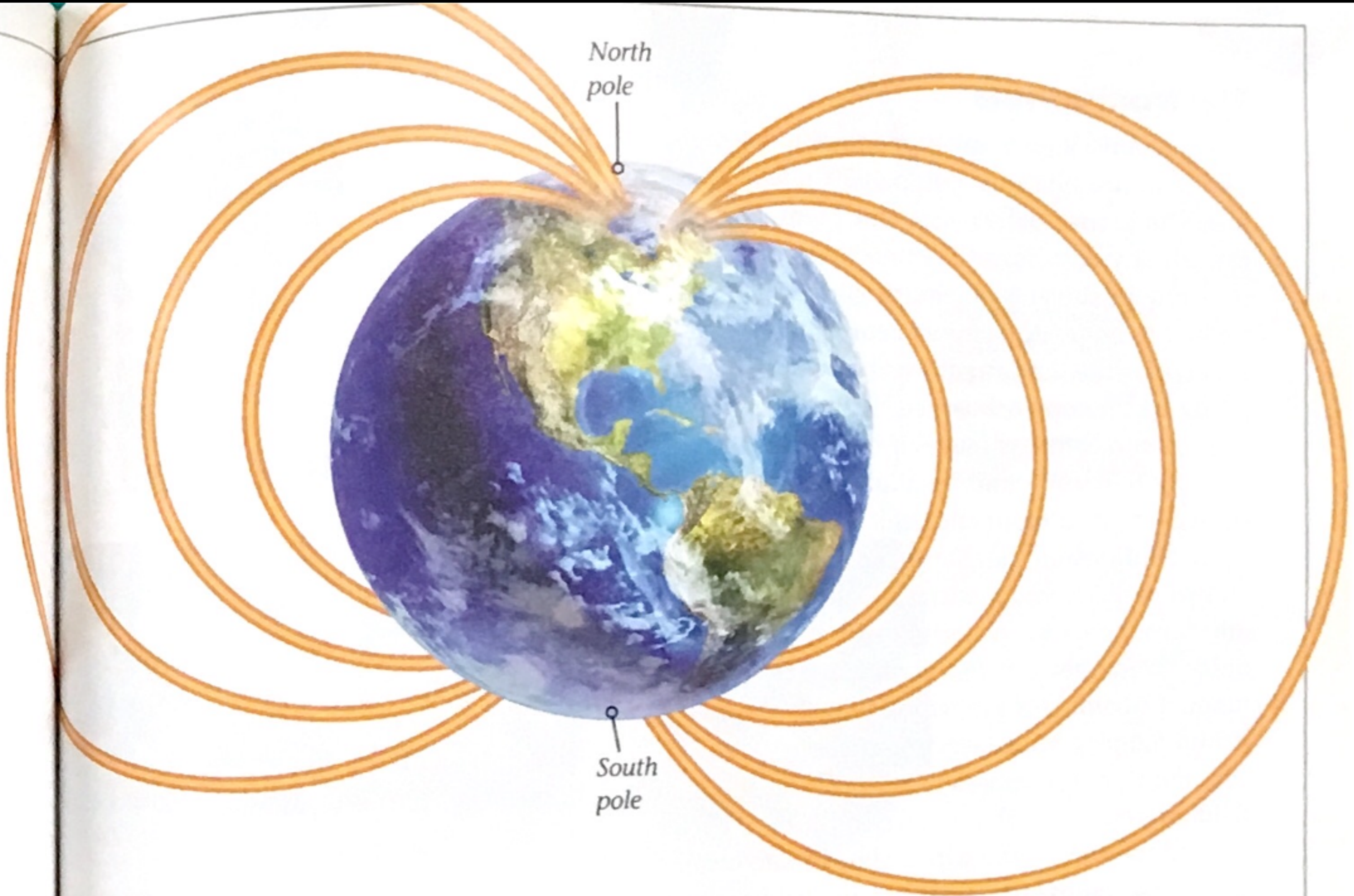
This iron is not magnetized. The magnetic domains of its atoms point in different directions.



Most magnetic domains in a magnet point in the same direction.



If you break a magnet, each piece will have north and south poles.



Earth acts like a giant magnet.

Earth as a Magnet

All compass needles align in a north/south direction. Did you ever wonder why? In 1600, an English physician, William Gilbert, suggested that the reason is because Earth acts like a giant magnet.

Imagine a giant bar magnet running through Earth. Earth is surrounded by a magnetic field, similar to the field around a bar magnet. The poles of the imaginary magnet are located near, but not exactly at, Earth's geographic poles. You can imagine lines of magnetic force that start inside Earth and push out from the South Pole. The force lines circle around to the North Pole. A compass points to Earth's magnetic north and south.

1. ✓**Checkpoint** Why can't a magnet have just a north pole?
2. **Writing in Science** **Narrative** Write a short story about a person with a "magnetic personality." Relate your story to things you know about magnetism.

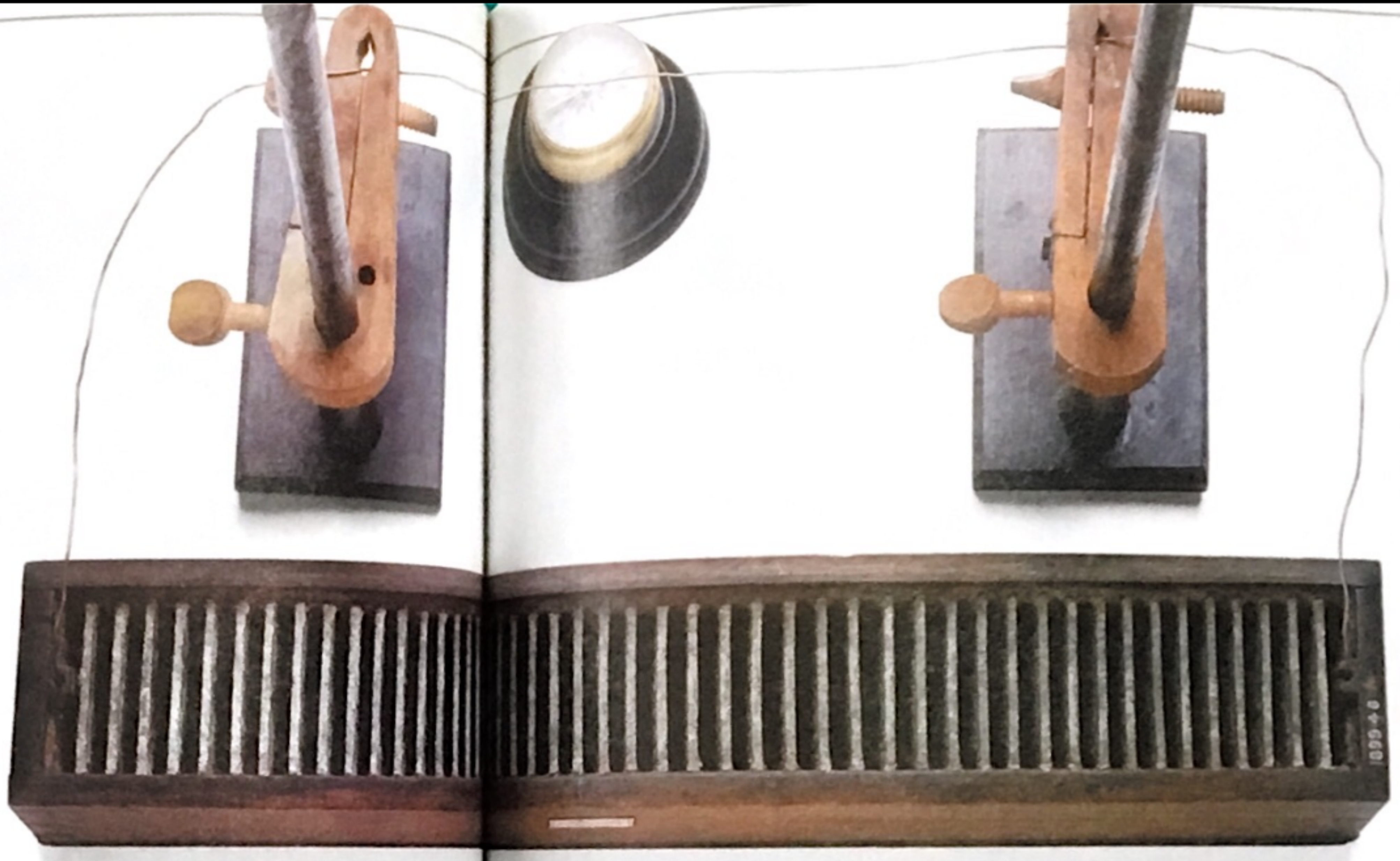
The magnetic tip on a compass aligns with Earth's magnetic field.

Electromagnets

People have known about magnetism for more than a thousand years. But in 1820, a teacher made an amazing discovery. One night, the Danish physicist Hans Christian Oersted was showing his students an electric current in a wire. He had a magnetic compass nearby. He noticed that each time the current was turned on, the needle in the compass moved. Oersted already knew that a compass moves if it is in a magnetic field. He had just found out that moving electrical charges create a magnetic field.

The relationship that Oersted discovered is known as electromagnetism. All electric charges are surrounded by an electric field. If the charges are moving, they are also surrounded by a magnetic field. This property is useful for making strong magnets called electromagnets.

How does electromagnetism work? The magnetic field around a wire that is carrying current circles around the wire. If the wire is shaped into a coil, the overall magnetic field is like the field around a bar magnet. You can make the magnetic field stronger by adding more coils or by putting an iron core into the coil of wire. As current flows through the wire, it magnetizes the iron. This adds to the magnetic field.



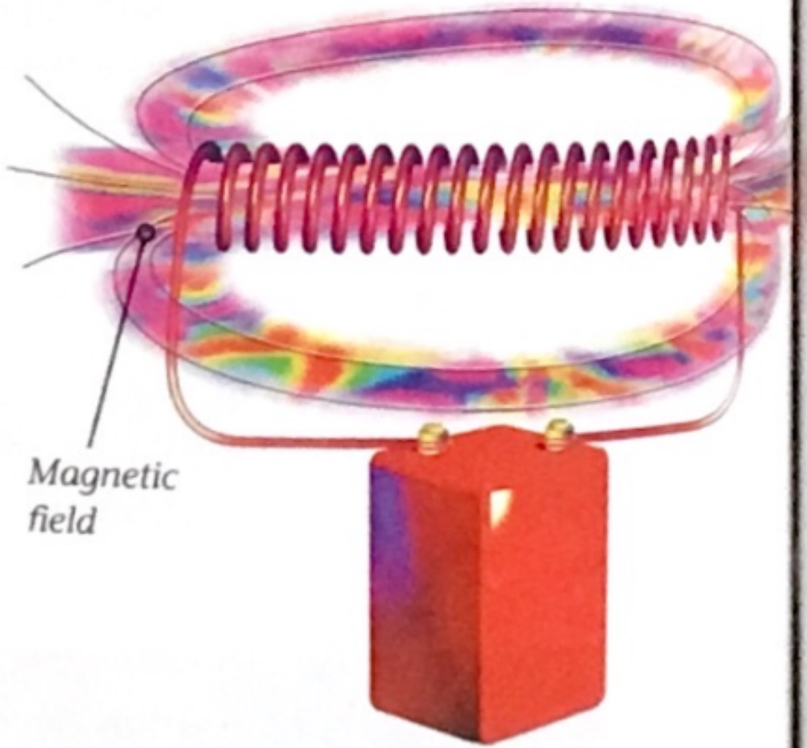
Oersted accidentally discovered the relationship between moving electric charge and magnetism while using a setup like this.

Using Electromagnets

Electromagnets are very useful because the current in the wire can be controlled. It can be turned on or off. Electromagnets only attract magnetic objects when the current is turned on. This property is used when large electromagnets in cranes move heavy loads of metal. Turn on the current, and the magnet picks up the metal. Turn off the current, and the magnet releases it.

You probably use electromagnets very often. Televisions, CD players, and radios use electromagnets to change electrical energy to mechanical energy. The mechanical energy is used to make sounds by causing the speaker to vibrate. Fans, hair dryers, computers, and anything else with an electric motor use electromagnets.

When electricity flows through this wire a magnetic field forms around the wire.



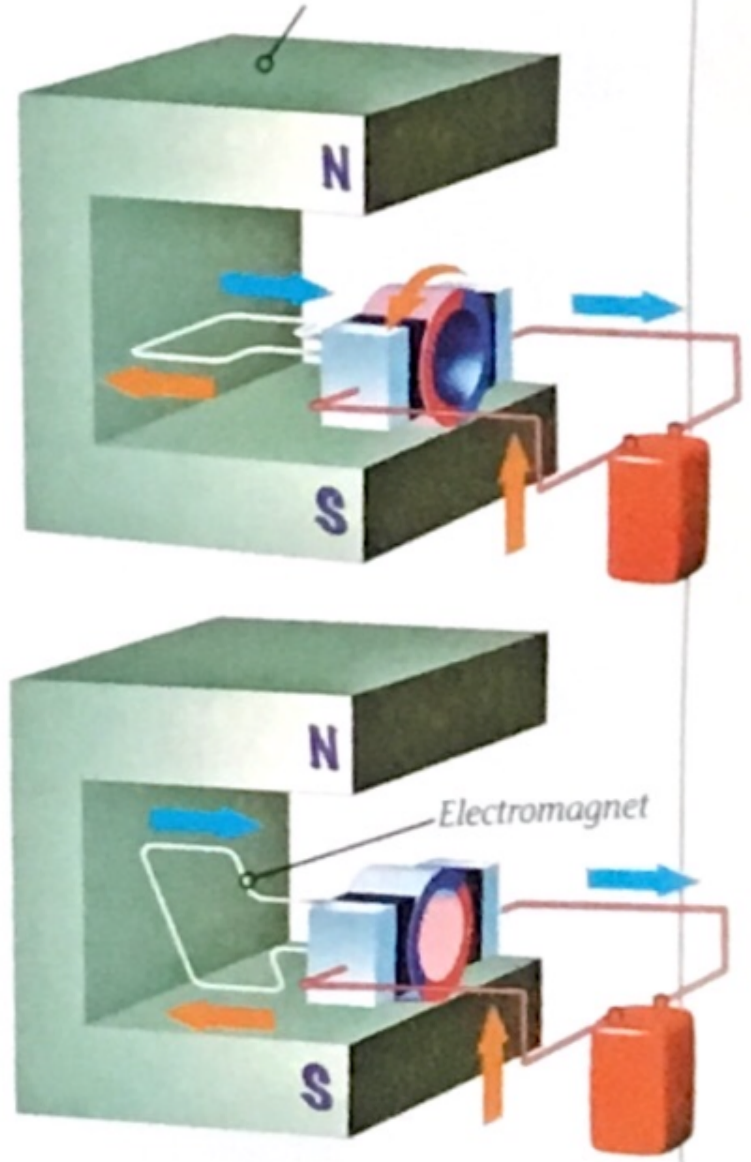
Electric Motor

An **electric motor** is a device that changes electrical energy to kinetic energy. One common kind of small motor is composed of a permanent magnet, an electromagnet, and a device that changes the direction of the electric current flowing through the electromagnet.

When current passes through the electromagnet, each pole is attracted to the opposite pole of the fixed magnet. This causes the electromagnet to turn. Just as the unlike poles line up, the direction of current in the electromagnet reverses, and the poles of the electromagnet reverse. Because two like poles are now near each other, they repel each other. This causes the electromagnet to keep turning. The current in the electromagnet constantly changes direction after each turn.

1. **Checkpoint** Draw an electric motor. Use labels to explain how electricity and magnetism work together in the motor.
2. **Sequence** Make a numbered list, in your own words, of steps in which an electric motor changes electrical energy to kinetic energy.

An Electric Motor



Changing Magnetism into Electricity

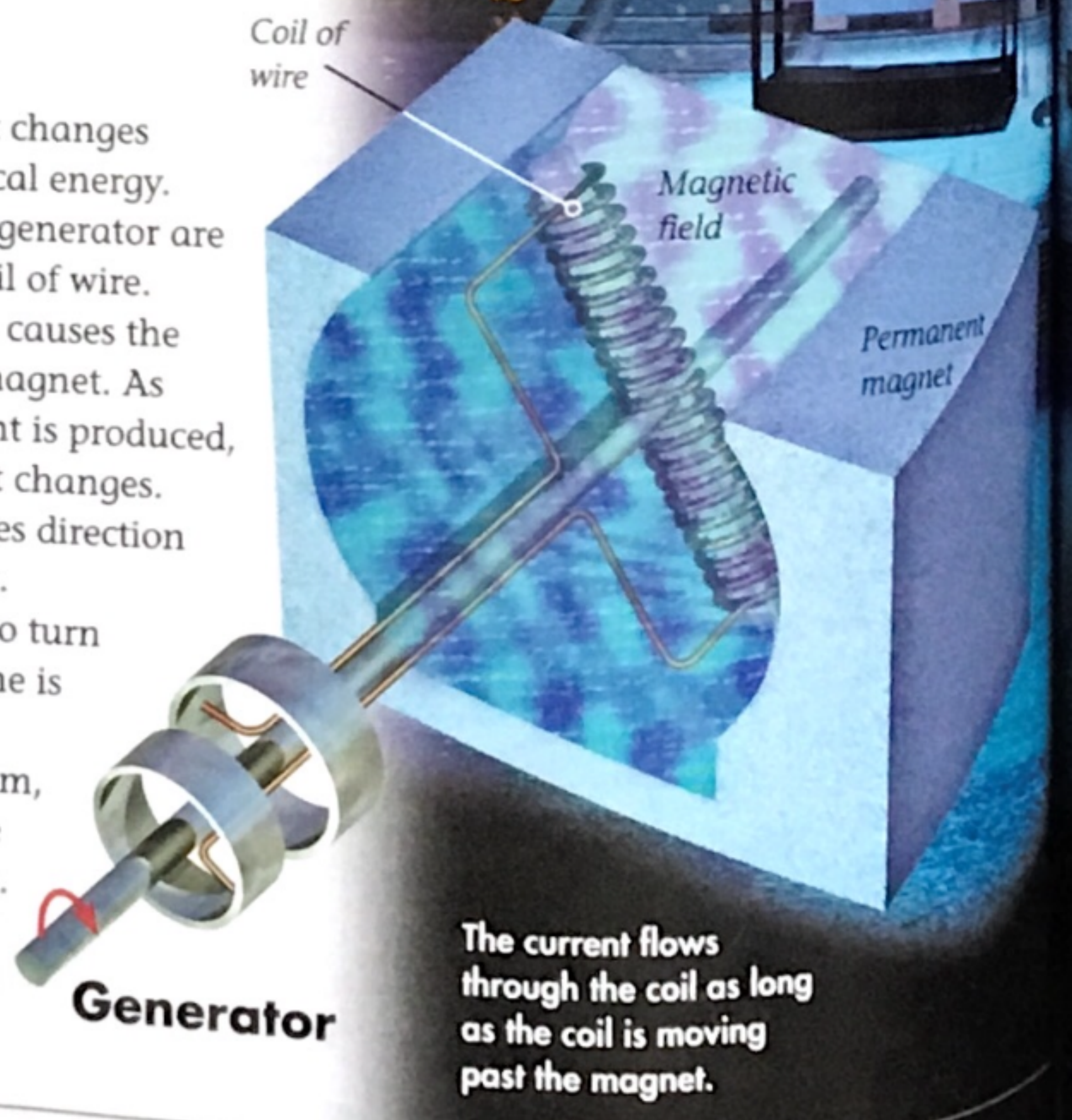
Oersted had shown that moving electric charges produce a magnetic field. The natural question, then, was whether a magnetic field could also produce an electric current in a wire. In 1831, the English scientist Michael Faraday showed that the answer is "yes."

Electromagnetic induction is the process in which a changing magnetic field produces an electric current. If you move a bar magnet through the center of a wire coil, the wire experiences a changing magnetic field. This produces a current in the wire. Moving the magnet faster produces a stronger current. You can also produce a current by moving the wire and keeping the magnet still. Electromagnetic induction is used to produce almost all of the electrical energy for homes, schools, and work. Study the concert picture to see how electrical energy can be changed to other useful forms of energy.

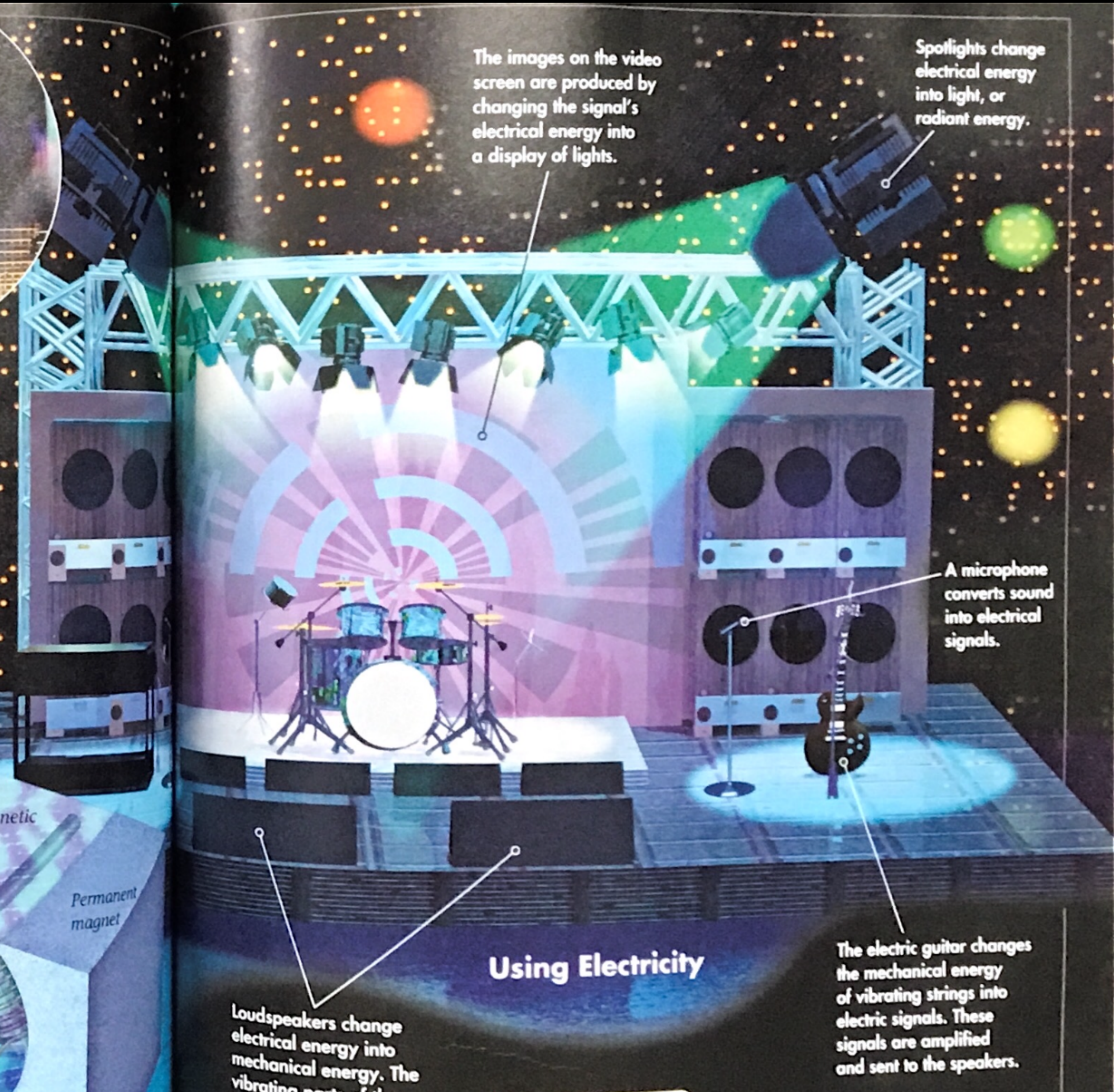
Generators

A **generator** is a device that changes mechanical energy into electrical energy. The two main parts of a small generator are a permanent magnet and a coil of wire. A source of mechanical energy causes the coil to spin in the field of the magnet. As the coil spins, an electric current is produced, and the direction of the current changes. A current that regularly changes direction is called an alternating current.

Sometimes a turbine is used to turn the coils in generators. A turbine is a wheel attached to a rod that attaches to the coil. Water, steam, and other sources of energy are used to make the turbine move. Study the picture to see how a generator can produce electricity to run a concert.



Generator



Using Electricity

✓ Lesson Checkpoint

1. Make diagrams of a series circuit and a parallel circuit. Then use arrows to show the flow of electricity through each circuit.
2. Why does the coil have to spin in a generator?
3. **Technology in Science** Use the Internet to learn how fossil fuels and water are used at power plants as a source of mechanical energy for generators.

Math in Science

Solving Energy Problems

Fossil fuels are limited, but there are many other sources of energy. Energy sources that can be replaced are called renewable resources. Wind, solar, and tidal energy are examples of renewable energy sources. If you have ever been hit by a large ocean wave, you know that it has energy—the ability to do work. The challenge for scientists and engineers is to change these renewable sources of energy into other, useable forms.

Hydroelectric generators change the renewable potential energy of water into electricity. The hydroelectric complex at the Itaipu Dam, between Paraguay and Brazil, is considered one of the marvels of the modern world. The amount of energy produced by Itaipu each year for Brazil and Paraguay is about the same as California's total energy requirement. Each year, use of this dam avoids more than 61 million metric tons of carbon dioxide emissions by not using fossil fuels. The table below contains some other facts about this amazing energy converter.

In the table you will see some units that might be unfamiliar. The letter *P* is the symbol for the metric prefix *peta*, which means "quadrillion," or "10^{15}." So, *PJ* stands for "petajoule" or "1 quadrillion joules." The letter *G* is the symbol for the metric prefix *giga*, which means "billion," or "10^9." Remember *Wh* means "watt-hour." So, *GWh* stands for "1 billion watt-hours."

Itaipu Hydroelectric Power Plant

Height of the dam	196 m
Area of lake	1,350 sq. km
Elevation of lake surface	222 m above sea level
Elevation of water intake	187 m above sea level
Potential energy of lake	94.8 PJ
Potential energy actually used	54.9 PJ
Energy produced yearly	75,000 GWh
Cost to build	$20 billion U.S. dollars

Use the information on page 492 to answer each question.

1. How far below the lake's surface is the water intake?
2. What percent of the lake's potential energy is actually used? Round your answer to the nearest tenth of a percent.
3. Itaipu Dam is about the same height as a building of how many stories? One story is about 3 meters high.
4. If the value of electrical energy is $100,000 for 1 GWh, what is the value of the energy produced by the plant each year? About how many years would it take for the energy plant to produce $20 billion worth of electricity? In your opinion, was it a good idea to build the Itaipu power plant? Explain.

Lab zone Take-Home Activity

Make a list of as many things as you can from around your home, school and community that use energy. You can include both living and nonliving things. Then try to create three different systems for classifying all the items on your list. For example, classify them as living or nonliving or by what type of energy they use.

Chapter 17 Review and Test Prep

Use Vocabulary

electric circuit (p. 483)	**generator** (p. 488)
electric current (p. 483)	**kinetic energy** (p. 479)
electric motor (p. 487)	**magnetic domain** (p. 484)
energy (p. 479)	**potential energy** (p. 479)

Use the vocabulary term from the list above that best completes each sentence.

1. A large number of atoms with their magnetic fields pointing in the same direction is a(n) _____.

2. The ability to cause change or to do work is _____.

3. A(n) _____ is a device that changes electrical energy to mechanical energy.

4. A changing magnetic field produces a(n) _____ in a wire.

5. Electric charge can only move through a(n) _____ if it is closed.

6. A(n) _____ changes mechanical energy into electrical energy.

7. The mechanical energy of a moving object is _____.

8. The mechanical energy due to position is _____.

Explain Concepts

9. Explain the energy changes that occur when you use an electric fan.

10. Why does the wire in an electric motor have to be coiled?

11. Suppose you have two bar magnets. Magnet A has its north and south poles marked. Magnet B does not have its poles marked. How can you identify the poles on Magnet B?

12. The diagram shows an electrical circuit. The piece of foil acts like a switch. Would electric current travel through this circuit? Explain your answer.

Process Skills

13. Model Draw a diagram of a series circuit with two bulbs. Use labels to show the energy transfer that takes place.

14. Predict whether a generator would work if the permanent magnet rotated rather than the coil of wire.

Sequence

15. Make a copy of the graphic organizer shown below. Fill in the blanks to show energy conversions that may be involved if you eat an apple and then use the energy for running. Start with the Sun's energy hitting a leaf of the apple tree.

First
Radiant energy changes to _____.

↓

Next

↓

Then

↓

Finally

Test Prep

Choose the letter that best completes the statement or answers the question.

16. Which is the energy stored in the bonds between atoms?
Ⓐ chemical energy
Ⓑ electrical energy
Ⓒ nuclear energy
Ⓓ thermal energy

17. What term refers to the push that moves electrons through a circuit?
Ⓕ charge
Ⓖ current
Ⓗ resistance
Ⓘ voltage

18. What effect does increasing the number of coils have on an electromagnet?
Ⓐ Magnetic field increases.
Ⓑ Energy is destroyed.
Ⓒ Magnetic field decreases.
Ⓓ Energy is created.

19. Explain why the answer you chose for Question 18 is best. For each of the answers you did not choose, give a reason why it is not the best choice.

20. Writing in Science **Expository** Compare and contrast an electric motor and a generator. Discuss their designs, uses, and energy conversions.