HOLT SCIENCE & TECHNOLOGY

Physical Science

Interactive Textbook

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Name ______________________ Class ______________ Date ____________

CHAPTER 1 The World of Physical Science

SECTION 1

Exploring Physical Science

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is science?
- How are matter and energy related to physical science?
- What are the branches of physical science?

National Science Education Standards

PS 1a, 3a

What Is Science?

You are eating soup and you see your reflection in the spoon. It is upside down. You wonder, "Why is my reflection upside down in a spoon, but not in a mirror?" Asking questions like this one is the first step in doing science. **Science** is a process of collecting information about the world. Much of the time, the first step in collecting information is asking a question.

You may not realize it, but you use science every day. When you use the brakes on your bicycle to slow down, you use your knowledge of science. You learned how hard you should apply the brakes by making observations. Making observations, asking questions, and trying to find the answers is what science is all about.

STUDY TIP

Compare After you read this section, make a chart comparing the two main branches of physical science. In the chart, describe what scientists in each branch study.

Say It

Discuss In a small group, talk about different ways that you use science in your everyday life.

Part of science is asking questions about the world around you.

TAKE A LOOK

1. Identify What is often the first step in gathering information?

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What Is Physical Science?

Science is divided into many *branches*, or parts. Three major branches of science are Earth science, life science, and physical science. **Physical science** is the study of matter and energy.

Matter is the "stuff" that everything is made of. Your shoes, your pencil, and the air you breathe are made of matter. *Energy* is the ability to do work. Matter and energy are related because all matter has energy.

Sometimes, you can see or feel energy, such as light or heat. Sometimes, you can tell that an object has energy because it is moving.

All matter contains energy, even if you cannot see or feel the energy. For example, food contains energy. When you eat the food, you get energy from the food. You can use the energy to do all of your daily activities.

STANDARDS CHECK

PS 3a Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.

2. Identify Give two examples of energy.

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The baseball has energy even before the boy throws it, because it is matter, and all matter has energy.

TAKE A LOOK

3. Explain Why does the baseball have energy before the boy throws it?

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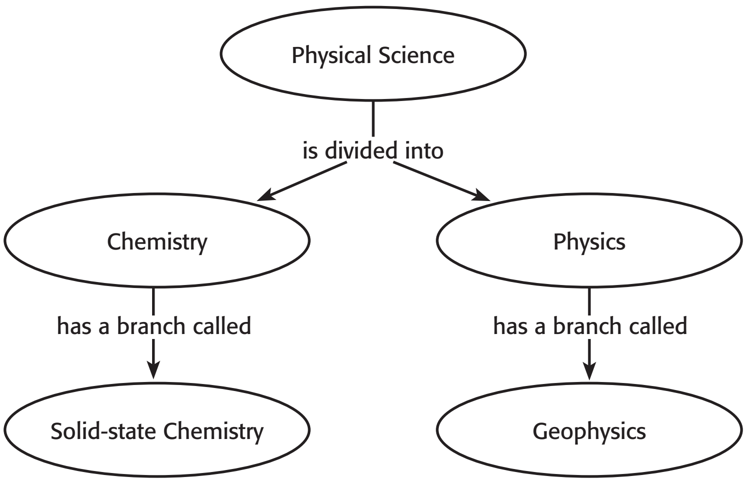
Why will paper burn, and gold will not? Why is throwing a bowling ball harder than throwing a baseball? How does water turn into steam? The answers to these questions have to do with matter and energy. As you study more about physical science, you will learn more about matter and energy. You will see how matter and energy are related to each other.

What Are the Branches of Physical Science?

Physical science is divided into two main branches: chemistry and physics. Both chemistry and physics can be divided into even smaller areas of study. For example, a smaller branch of chemistry is solid-state chemistry. *Solid-state chemistry* is the study of the reactions and behavior of solid materials. Another example is geophysics, a smaller branch of physics. *Geophysics* is the study of movements deep in the Earth. ☑



READING CHECK

4. Identify What are the two main branches of physical science?

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CHEMISTRY

Chemistry is the study of the structure and properties of matter. The structure and properties of a substance determine how it interacts with other matter. For example, sugar dissolves in water. A diamond has a different structure and properties, so it doesn't dissolve in water.

The structure and properties of matter also affect how it behaves under different conditions. For example, water is a liquid at room temperature. If the temperature decreases, the water may become solid. However, honey has a different structure and properties. It will become solid at a different temperature than water.

Chemistry also includes the study of how matter changes. Substances can change during chemical reactions. A *chemical reaction* happens when one substance interacts with another substance to form a new substance. Chemical reactions are happening all the time. When your body digests food, a chemical reaction is taking place. Chemical reactions are what make flashlights work. They also allow car engines to run.

Critical Thinking

5. Explain Why don't all substances behave the same way under the same conditions?

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Critical Thinking

6. Compare How is physics different from chemistry?

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PHYSICS

The second area of physical science is physics. Like chemistry, physics has to do with matter. *Physics* is the study of how energy affects matter. The study of physics can help you understand how a roller coaster works and what keeps it on its tracks.

You can tell that a roller coaster has energy. When you study physics, you will learn what makes the roller coaster ride so exciting.

Say It

Ask Questions Write down four questions that physics may be able to help you answer. Share your questions with a small group.

Why does a ball roll down a hill? Why doesn't a brick roll down the same hill? How does a parachute let someone jump out of an airplane without getting hurt? How can a compass tell you which way is north? Physics can help you answer questions like these.

Motion, force, gravity, electricity, light, and heat are parts of physics. They are also things that you experience in your everyday life. For example, when you ride a bike, you are dealing with force and motion. If you fall off the bike, you are affected by gravity.

How Do Other Branches of Science Use Physical Science?

You learn about matter and energy when you study physical science. However, matter and energy are important in other branches of science, too. Many kinds of scientists use ideas from physical science in their work.

METEOROLOGY

The study of Earth's atmosphere, weather, and climate is called *meteorology*. Scientists who study meteorology are called *meteorologists*. You may have seen meteorologists on the news, forecasting the weather. Other meteorologists study severe weather, such as hurricanes and tornadoes. They may be able to predict where severe weather will form so they can warn people. ☑

Before they can predict the weather, meteorologists need to understand pressure, motion, and force. These are ideas that you will study in physical science.

READING CHECK

7. Define What is meteorology?

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GEOLOGY

The study of the history, structure, and formation of Earth is called *geology*. One kind of geologist is a geochemist. A *geochemist* is a person who studies the chemistry of rocks, minerals, and soil. Geochemists also need to know about heat and force to understand how parts of Earth formed and how they have changed. ☑

READING CHECK

8. Identify Give two reasons that geochemists need to understand physical science.

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This geochemist takes rock samples from the field. Then, she studies them in her laboratory.

BIOLOGY

Believe it or not, life science and physical science are related. Chemistry and physics can explain many things that happen in biology. For example, a chemical reaction explains how animals get energy from food.

Plants make sugar. Animals eat plants and breathe in oxygen. In animals, the sugar reacts with the oxygen to make carbon dioxide, water, and energy. You will learn about this and other chemical reactions when you study physical science.

Name ______________________ Class ______________ Date ______________

Section 1 Review

NSES PS 1a, 3a

SECTION VOCABULARY

physical science the scientific study of nonliving matter	**science** the knowledge obtained by observing natural events and conditions in order to discover facts and formulate laws or principles that can be verified or tested

1. **Identify** What are three main branches of science?

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2. **Define** What are matter and energy? How are they related?

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3. **Infer** A scientist is studying the forces that act on a hockey puck. What branch of physical science is the scientist probably using? Explain your answer.

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4. **Explain** Why does a meteorologist need to understand physics?

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5. **Apply Ideas** You are building a go-cart. You want to know how you can make it go as fast as it can. Explain how you can use both chemistry and physics to help you build your go-cart.

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6. **Explain** Why does a biologist need to understand chemistry?

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SECTION 2

Scientific Methods

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What are the steps in scientific methods?
- How do scientists form a hypothesis?
- What do scientists do before telling others about their experimental results?

What Are Scientific Methods?

Two scientists wanted to find a better way to move ships through the water. They thought that studying the way penguins swim might give them some ideas about how to improve ships. In this section, you will learn how these scientists used scientific methods to answer their questions.

Scientific methods are the ways in which scientists answer questions and solve problems. As scientists look for answers, they often use the same steps. However, there is more than one way to use the steps. Look at the figure below. ☑

This figure shows six steps that are part of most scientific methods. Scientists may use all of the steps or just a few steps during an investigation. They may repeat some of the steps or do the steps in a different order.

STUDY TIP

Outline As you read this section, make a chart showing how two scientists used the steps in scientific methods to improve ships.

READING CHECK

1. Describe What are scientific methods?

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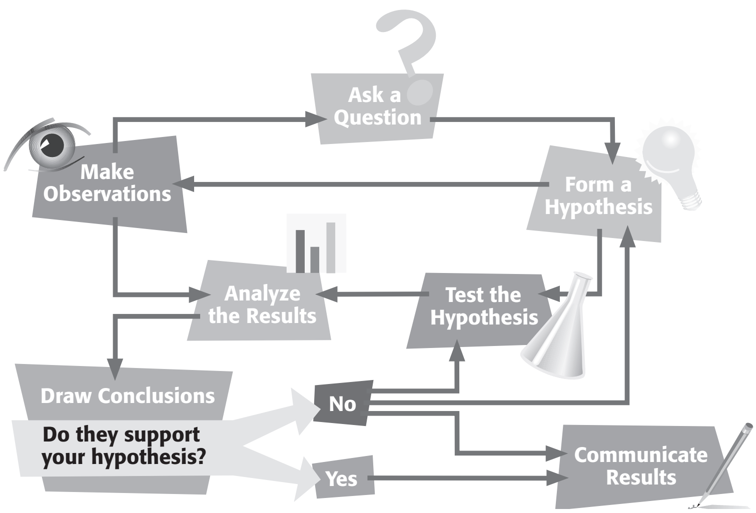
Steps of Scientific Methods



TAKE A LOOK

2. Identify What is the usual next step after analyzing results?

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Why Do Scientists Ask Questions?

Asking questions helps scientists focus on the reason for an investigation. Questions arise at every step of scientific methods. However, the question that becomes the focus of an investigation often comes from observation. **Observation** is the process of using your senses to collect information.

REAL-WORLD EXAMPLE

Two engineers, James Czarnowski and Michael Triantafyllou, wanted to improve the way ships moved through the water. An *engineer* is a scientist who builds things using scientific knowledge. Czarnowski and Triantafyllou used scientific methods to improve how ships move. ☑

READING CHECK

3. Describe What is an engineer?

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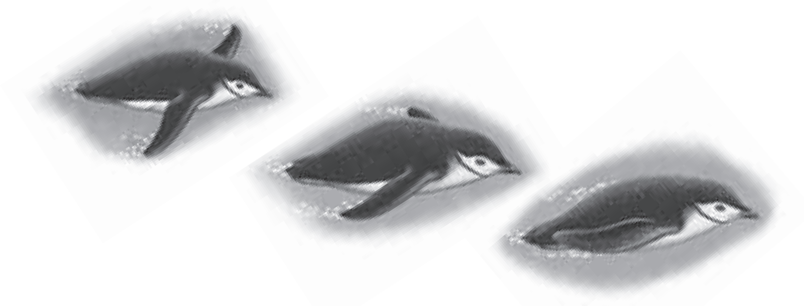
The two engineers studied how the propellers on ships work. They found that ships use a lot of fuel to push themselves through the water. They asked the question, “How can we make ships move faster with less fuel?” That is, they wanted to improve the efficiency of ships. A ship that is *efficient* does not use as much fuel as other ships to travel the same distance.

The engineers looked to nature to find a way to make ships more efficient. They observed sea animals to learn how some of them swim faster than others. The engineers observed that penguins are very efficient swimmers. Penguins have stiff bodies, just like ships. However, they are able to push themselves through the water with ease.

Now, the scientists had a new question. They wanted to know, “How can we make a ship that moves through the water more easily?”



Penguins use their wings as flippers to “fly” underwater. As their wings are pulled inward, they push against the water. This movement pushes the penguins forward.

TAKE A LOOK

4. Identify How do penguins use their wings?

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How Do Scientists Form a Hypothesis?

Once a scientist has made observations and asked a question, he or she is ready to predict an answer. This is called forming a hypothesis. A **hypothesis** (plural, *hypotheses*) is a possible explanation for, or guess at, an answer to a question. ☑

READING CHECK

5. Describe What is a hypothesis?

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A POSSIBLE ANSWER FROM NATURE

The ship engineers had observed the slow movements of ships and the fast swimming of penguins. Their observations led them to form a hypothesis. They guessed, "A propulsion system that imitates the way a penguin swims is more efficient than a system that uses propellers."

ANOTHER WAY TO WORD PREDICTIONS

Scientists often state their predictions as *if-then statements*. For example, the engineers' prediction might have been: "If we use flippers instead of a propeller to move a boat, then it will be more efficient." An if-then statement makes it easier to determine whether your prediction is true.

The table below gives some examples of if-then statements.

Critical Thinking

6. Explain How does an if-then statement make it easier to determine whether a prediction is true?

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"If" statement	"Then" statement
If car A uses less gasoline than car B during the same trip . . .	. . . then car A is more efficient than car B.
If more force is needed to stop an object with a large mass than an object with a small mass . . .	. . . then ____________ force is needed to stop a large truck than a compact car.
If a grape and an orange fall at the same rate . . .	. . . then, when dropped from the same height, they will hit the ground at ____________ time.

TAKE A LOOK

7. Complete In the table, complete the "then" statements.

Why Do Scientists Test a Hypothesis?

All hypotheses must be testable. A scientist tests a hypothesis by gathering more information or by doing an experiment. Scientists test a hypothesis to find out if it answers their question correctly.

CONTROLLED EXPERIMENTS

One way to test a hypothesis is to do a controlled experiment. Suppose you want to know how much air will make a basketball bounce highest. You gather 15 basketballs that are all made by the same company. All the basketballs are the same size and are made of the same material. You divide the basketballs into three groups.

You inflate the balls in the first group with the amount of air that the maker recommends. You put more air in the balls in the second group. You put less air in the balls in the third group. Then, you drop each ball from the same height and measure how high it bounces. This is a controlled experiment.

A *controlled experiment* is an experiment in which only one factor changes at a time. The factor that changes is called the *variable*. In your experiment, the variable was the amount of air in the balls. Everything else about the balls was the same. ☑

READING CHECK

8. Define What is a variable?

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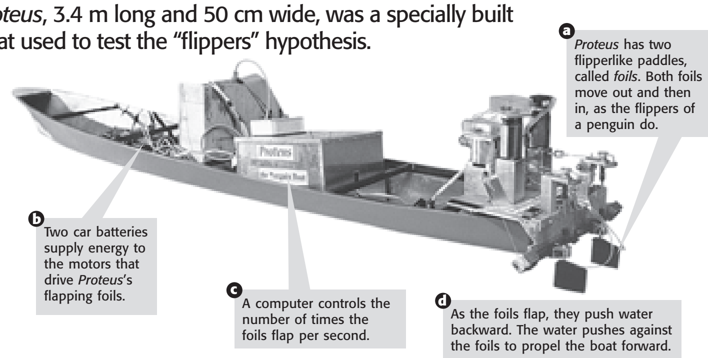
Doing a controlled experiment allows a scientist to determine the effects of a variable more easily. Suppose you had used basketballs that were not all made of the same material. It would have been harder to determine whether the air or the material caused some to bounce higher than others.

Sometimes, it is not possible to do a controlled experiment. In these cases, scientists test their hypotheses by making observations or doing research.

BUILDING A TEST BOAT

The engineers who were trying to design an efficient boat thought they should test their hypothesis by building one. They built *Proteus*, the penguin boat. It had flippers like a penguin so that the scientists could test their hypothesis about propulsion through the water.

Proteus, 3.4 m long and 50 cm wide, was a specially built boat used to test the "flippers" hypothesis.



TAKE A LOOK

9. Identify What does *Proteus* use instead of a propeller to move through the water?

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How Did the Scientists Test *Proteus*?

Instead of using many groups, you can do a controlled experiment by repeating the test several times. For each test, you change one factor. That's what the engineers did with *Proteus*.

The engineers took *Proteus* to the Charles River in Boston. For each test, they paddled the boat across the river for the same distance with the same weather. The variable was the flapping rate of the flippers. ☑

READING CHECK

10. Identify What two factors stayed the same when *Proteus* was paddled across the river?

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11. Identify What was the variable for each trip?

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Proteus, the "penguin boat," was tested in the Charles River in Boston.

The engineers collected data on the speed of the boat and the amount of energy used to move its flippers. **Data** (singular, *datum*) are pieces of information collected from experiments. The data recorded for the first trip were considered the control data. The control data were compared with the data from all of the other trips. ☑

READING CHECK

12. Define What are data?

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The experimental part of the test began with the second trip. The engineers changed the variable by increasing the flapping rate of the flippers. Then, they recorded the speed and the energy used during the trip. The engineers made several more experimental trips. Each time, they set a different flapping rate and collected data on the energy used and the speed.

When all the data were collected, the engineers compared the results of the trips. They interpreted their results to find out which flapping speed used the least energy. That is, they learned which was the most efficient.

How Do Scientists Analyze Results?

After scientists collect data, they must analyze it. To *analyze* data means to interpret what the data mean. One way to analyze data is to organize them into tables and graphs. Tables and graphs make the patterns in the data easier to see. ☑

It's always a good idea to perform your experiment several times. Repeated tests can tell you whether your data are accurate. If you get similar results every time, then you can be more sure that the results are accurate. If the results support your hypothesis, you know that your hypothesis is probably correct.

READING CHECK

13. Describe What does it mean to analyze data?

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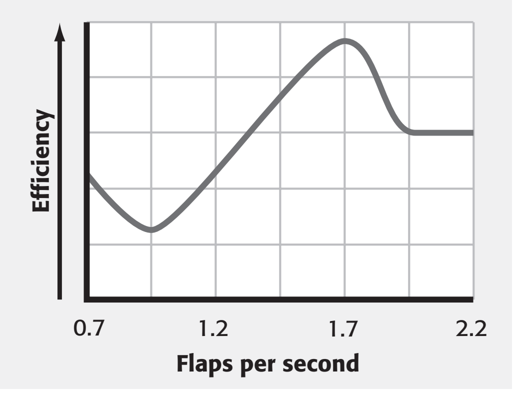
ANALYZING *PROTEUS*

The engineers collected data about the energy used and the speed of each trip. They used the data to calculate *Proteus*'s efficiency. Then, they made a graph of their data, shown below.



This graph shows the efficiency of *Proteus* when the flippers are moving at different rates.

Math Focus

14. Analyze Which flapping rate gave *Proteus* the highest efficiency?

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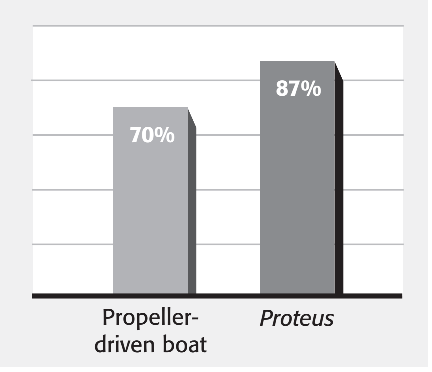
The scientists also used the data to compare the efficiency of *Proteus* with the efficiency of a regular boat. That analysis is shown in the bar graph below.



This graph shows the efficiency of *Proteus* compared with the efficiency of a propeller-driven boat.

Math Focus

15. Compare Which boat was more efficient? How much more efficient was it?

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What Are Conclusions?

At the end of the investigation, you must draw a conclusion. You do this by looking at your analysis. The results tell you whether your hypothesis was correct. If it was, then you can say that your results support your hypothesis. That is your conclusion.

It's also possible that you will come to a different conclusion. You may decide that your results do not support your hypothesis. If so, you can change the procedure, gather more information, or ask new questions. Whether your hypothesis is supported or not, the results are always important.

PROTEUS CONCLUSION

The engineers found that penguin propulsion was more efficient than propeller propulsion. They concluded that the results supported their hypothesis. ☑

The scientists were able to reach this conclusion because they did many tests. They were careful to control all the factors except the variable. They measured everything accurately. This showed that their results were not accidental. Their data showed the same relationship many times. Therefore, their results were probably accurate.

Drawing a conclusion to support your hypothesis usually leads to more questions. More questions lead to more investigations. This is how scientific progress continues.

READING CHECK

16. Explain Why did the engineers think that their hypothesis was correct?

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How Do Scientists Share Results?

Other scientists will want to know your results. Some will want to conduct their own tests based on your results. There are three ways to communicate the results of your investigation to them. You can use any or all of them. ☑

Method of communicating results	Audience
Write a paper for a scientific journal.	scientists and others who read the journal
Give a talk.	scientists and others who attend the talk
Create a Web site.	anyone interested in the work

Sharing your results allows other scientists to continue your work. Sharing also makes it possible for others to do your experiments and support your results.

READING CHECK

17. Identify What are three ways scientists communicate the results of their investigations?

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Name ______________________ Class ______________ Date ____________

Section 2 Review

SECTION VOCABULARY

data any pieces of information acquired through observation or experimentation **hypothesis** a testable idea or explanation that leads to scientific investigation	**observation** the process of obtaining information by using the senses **scientific methods** a series of steps used to solve problems

1. Identify Fill in the missing steps in the table.

Steps in Scientific Methods
Form a hypothesis.
Test the hypothesis.

2. Infer A *synonym* is a word that has the same meaning as another word. What are two synonyms for *hypothesis*?

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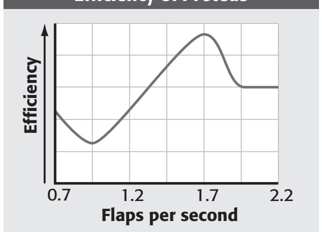
3. Interpret a Graph According to the graph, at what flapping rate was *Proteus* least efficient?

Efficiency of *Proteus*



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4. Define What is a controlled experiment?

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5. Describe How can a scientist do a controlled experiment if it is not possible to use several different groups?

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6. Explain How can a scientist test a hypothesis if it is not possible to do a controlled experiment? Give two ways.

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SECTION 3

Scientific Models

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What are the three types of scientific models?
- How do scientists use models to help them understand scientific information?

What Is a Scientific Model?

The engineers who built the ship *Proteus* wanted to copy the way that a penguin swam. *Proteus* does not have feathers and is not alive. However, the way *Proteus* moves in the water is similar to the way a penguin moves in the water. *Proteus* is a model that helps engineers learn about how objects can move through the water.

A **model** is something that scientists use to represent an object or process. For example, models of human body systems help you learn how the body works. Models can help you learn about the past. They can even help to predict the future! However, a model cannot tell you everything about the thing it represents. This is because the model always has a least a few differences from what it represents.

There are three common kinds of scientific models: physical models, mathematical models, and conceptual models.

STUDY TIP

Compare After you read this section, make a chart comparing scientific theories and scientific laws.

Critical Thinking

1. Compare A globe is a model of the Earth. Give one way that a globe is similar to the Earth and one way that they are different.

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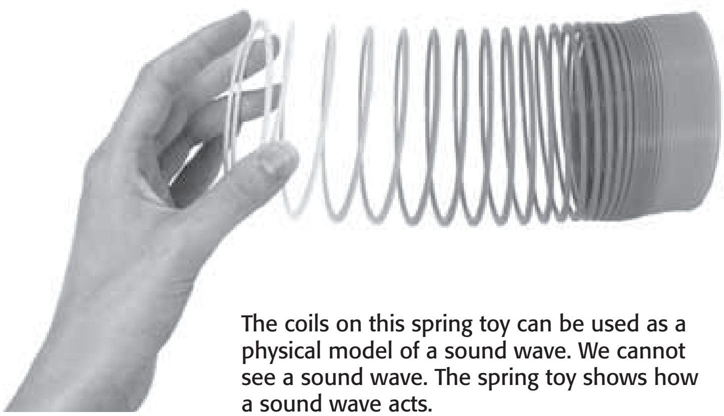

The coils on this spring toy can be used as a physical model of a sound wave. We cannot see a sound wave. The spring toy shows how a sound wave acts.

TAKE A LOOK

2. Infer Why would a scientist use a spring toy to model a sound wave?

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Say It

Brainstorm In a small group, come up with a list of 10 kinds of physical models. Talk about how they are similar to the things they represent and how they are different.

PHYSICAL MODELS

A *physical model* is a model that you can see and touch. Some physical models can help you study things that are too small to see. For example, a ball-and-stick model can show what a molecule is made of. Some physical models show the shape of something that's invisible. For example, you can't see a sound wave. However, a spring toy, such as the one on the previous page, can show you how a sound wave acts.

Other physical models can help you study things that are too large to see all at once. For example, you can't see the whole Earth or all of the solar system. Models help you picture in your mind what they look like.

A physical model can also help you understand a concept. Launching a model of a space shuttle can help you understand how a real space shuttle is launched.

MATHEMATICAL MODELS

A *mathematical model* is made of mathematical equations and data. You can't see a mathematical model the way you can see a physical model. However, you can use it to understand systems and make predictions. Meteorologists put temperature, air pressure, wind speed, and precipitation data into mathematical models to understand weather systems. They also use mathematical models to predict the weather.

Some mathematical models are simple. Others are very difficult and need computers to make them work.

CONCEPTUAL MODELS

Conceptual models are used to help explain ideas. Some conceptual models are systems of many ideas. You may have heard about the big bang theory. It is a conceptual model that explains how the planets and galaxies formed. Most scientists accept the big bang theory, even though some data do not fit the model.

TAKE A LOOK

3. Identify Fill in the blanks in the table to tell whether the example is a physical, mathematical, or conceptual model.

Model	**Type of Model**
The big bang theory	
Ball-and-stick model of a molecule	
Equation that shows how a particle acts in a magnetic field	mathematical
Computer simulation of the path of a tornado	

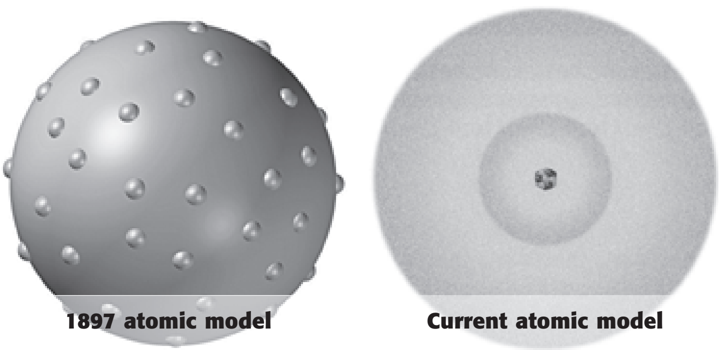
How Do Models Help Build Scientific Knowledge?

Models are used to show ideas and objects in science. They are also used to help scientists learn new things.

SCIENTIFIC THEORIES

Models are often used to help explain scientific theories. In science, a **theory** is an explanation for many hypotheses and observations. Theories are supported by many tests and observations. A theory can explain why something happens and can predict what will happen in the future. ☑

Scientists use models to help them look for new scientific information. The new information can support a theory or show that it is wrong. This is all part of science. As scientists make new observations, new theories are developed over time. New theories replace old theories that are shown to be wrong. The figure below shows an old model of the atom and the new model that replaced it.



These drawings are both models of an average atom. The old model shows what scientists understood about atoms in 1897. The new model replaced the old model as scientists made more observations.

SCIENTIFIC LAWS

When a model correctly predicts the results of many different experiments, a scientific law can be made. In science, a **law** is a summary of many experimental results and observations. It tells you how things work.

A law is different from a theory. A law tells you only what happens, not why it happens. An example of a scientific law is the *law of conservation of mass*. It says that in a chemical change, the total mass doesn't change. The law doesn't explain why this happens or make any predictions. It tells you only what happens during any chemical change.

READING CHECK

4. Define What is a scientific theory?

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TAKE A LOOK

5. Explain Why might scientists come up with a new theory?

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Name ____________________ Class ____________ Date ____________

Section 3 Review

SECTION VOCABULARY

law a descriptive statement or equation that reliably predicts events under certain conditions **model** a pattern, plan, representation, or description designed to show the structure or workings of an object, system, or concept	**theory** a system of ideas that explains many related observations and is supported by a large body of evidence acquired through scientific investigation

1. **Explain** What are some ways that scientists use models?

2. **Identify** What are the three types of models used by scientists?

3. **Identify** A model of a molecule can help you imagine what a molecule looks like. What are two ways that this model is different from the object it represents?

4. **Compare** What is the difference between a scientific theory and a scientific law?

5. **Explain** How can theories change over time?

6. **Explain** Why can't you use a model to learn everything about an object?

SECTION 4

Tools, Measurement, and Safety

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What tools do scientists use to make measurements?
- What is the International System of Units?
- How can you stay safe in science class?

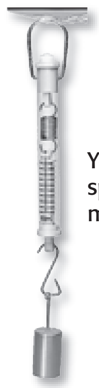
What Kinds Of Tools Do Scientists Use?

A *tool* is anything that helps you do something. Scientists use many tools to help them make observations and do experiments. Some tools are used to take measurements. These include stopwatches, metersticks, thermometers, balances, and spring scales. Making measurements is one way that scientists gather data.

STUDY TIP

Outline As you read, underline the main ideas in each paragraph. When you finish reading, make an outline of the section using the ideas you underlined.

You can use a stopwatch to measure time.



You can use a spring scale to measure force.

TAKE A LOOK

1. Identify What tool can you use to measure time?

____

Tools can also help you analyze the data you have collected. A pencil and graph paper are tools that have been used to graph data for years. A calculator is a tool that can help you do calculations quickly. A graphing calculator can show your data in a graph. A computer can display your data in many ways.

Critical Thinking

2. Predict Consequences What might happen if scientists in different countries used different systems of measurement?

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How Do Scientists Take Measurements?

Many years ago, scientists in different countries used different systems of measurement. They needed a simple measurement system that everyone could use. This would help them share their data more easily.

THE INTERNATIONAL SYSTEM OF UNITS

Over time, the metric system was set up. It is also known as the *International System of Units* (SI). This simple system was one that every country could use to compare measurements. All of the SI units are written in multiples of 10. This makes it easy to change from one unit to another. Some of the units in the SI are shown in the table below. ☑

READING CHECK

3. Explain Why is it easy to change from one SI unit to another?

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Common SI Units		
Length	**meter (m)** kilometer (km) decimeter (dm) centimeter (cm) millimeter (mm) micrometer (µm) nanometer (nm)	1 km = 1,000 m 1 dm = 0.1 m 1 cm = 0.01 m 1 mm = 0.001 m 1 µm = 0.000 001 m 1 nm = 0.000 000 001 m
Area	**square meter (m^2)** square centimeter (cm^2)	1 cm^2 = 0.0001 m^2
Volume	**cubic meter (m^3)** cubic centimeter (cm^3) liter (L) milliliter (mL)	1 cm^3 = 0.000 001 m^3 1 L = 1 dm^3 = 0.001 m^3 1 mL = 0.001 L = 1 cm^3
Mass	**kilogram (kg)** gram (g) milligram (mg)	1 g = 0.001 kg 1 mg = 0.000 001 kg
Temperature	**Kelvin (K)** Celsius (°C)	0°C = 273 K 100°C = 373 K

Math Focus

4. Calculate How many millimeters are in 50 km?

____

LENGTH

The length of an Olympic-sized swimming pool is measured in meters (m). A *meter* is the basic SI unit of length. Other SI units of length are larger or smaller than the meter by multiples of 10. For example, 1 millimeter (mm) is one one-thousandth of a meter. That means that if 1 m is divided into 1,000 equal parts, each part is 1 mm.

MASS

Mass is a measure of how much matter is in an object. The *kilogram* (kg) is the basic SI unit for mass. The kilogram is used to describe the mass of large objects, such as people. *Grams* (g) are used to describe the mass of smaller objects, such as apples. One kilogram equals 1,000 g. ☑

READING CHECK

5. Define What is mass?

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VOLUME

Volume is the amount of space that something fills. Liquid volume is given in *liters* (L). A liter is based on the meter. One *cubic meter* (1 m^3) equals 1,000 L. Therefore, 1,000 L of liquid will fit exactly into a box that is 1 m on each side. ☑

You can find the volume of a box-shaped object by multiplying its length, width, and height together. The volume of a large solid is given in cubic meters (m^3). The volume of a small solid is given in cubic centimeters (cm^3).

READING CHECK

6. Identify What units are used to give the volume of liquids?

____

DENSITY

Density is a measure of how much matter is in a given volume. You cannot measure density directly. It is known as a *derived quantity* because you must calculate it from other, known quantities. You can find the density of an object using the following equation:

$$density = mass \div volume$$

TEMPERATURE

The **temperature** of a substance is the measurement of how hot (or cold) it is. The kelvin (K, without a degree sign) is the SI unit for temperature. Degrees Fahrenheit (°F) and degrees Celsius (°C) are also used. ☑

READING CHECK

7. List Give three units that are used to measure temperature.

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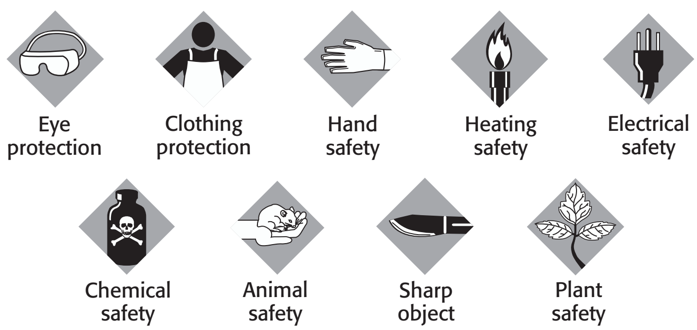
What Are Safety Rules?

Science is exciting and fun, but it can be dangerous. There are many safety rules that you must follow whenever you do an experiment.

- Always listen to your teacher's instructions.
- Don't take shortcuts.
- Read lab directions carefully.
- Pay attention to safety information.

The safety symbols in the figure below are important. Learn them so that you, and others, will be safe in the lab.

Safety Symbols



Name ______________________ Class ______________ Date ______________

Section 4 Review

SECTION VOCABULARY

density the ratio of the mass of a substance to the volume of the substance

mass a measure of the amount of matter in an object

temperature a measure of how hot (or cold) something is; specifically, a measure of the average kinetic energy of the particles in an object

volume a measure of the size of a body or region in three-dimensional space

1. Identify What are two tools that can be used to measure the length of an object?

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2. Compare How is the mass of an object different from its density?

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3. Calculate A ball falls from a height of 25 cm. What is the same distance described in meters? Show your work.

4. Identify What unit is usually used to describe the volume of a liquid? A solid?

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5. Calculate What is the volume of a box that is 3 m long, 0.5 m high, and 2 m wide? Show your work.

6. Analyze What safety symbols would you expect to see for an experiment that asks you to pour acid into a beaker? Give three possibilities.

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CHAPTER 2 The Properties of Matter

SECTION 1

What Is Matter?

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is matter?
- What is volume and mass?
- What are mass and weight?
- What is inertia?

National Science Education Standards

PS 1a, 1c

What Is Matter?

You are made of matter. **Matter** is anything that has mass and takes up space. A toaster, a glass of water, and the air around you are all made of matter.

Matter can be described by its properties. Several properties of matter are volume, mass, and weight. The liter (L) is a scientific unit of volume. The kilogram (kg) is the SI unit for mass, and the newton (N) is the SI unit of weight. ☑

STUDY TIP

Organize Information In your notebook, make a table with three columns. Label the first column Property of Matter, the second column Definition, and the third column Unit of Measure. As you read, fill in the columns.

READING CHECK

1. Identify Give a unit of measure for each of the following properties:

volume: ____________

mass: ____________

weight: ____________

What Is Volume?

All matter takes up space. The amount of space that an object takes up is known as the object's **volume**.

Imagine a car driving into a full swimming pool. Some water would splash out. This happens because the car and the water have volume. Two objects can't occupy the same space at the same time. ☑

READING CHECK

2. Define What is volume?

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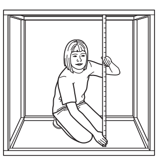
UNITS OF VOLUME

The SI unit of volume is the cubic meter. The figure below shows how big a cubic meter is.

The liter (L) is used more often as the scientific unit for measuring volume. Small volumes of liquid are often given in milliliters (mL). Remember that 1 L equals 1,000 mL. Any volume of liquid can be described in liters or milliliters. For example, the volume of a small can of soda is measured as 0.355 L or 355 mL.



A girl is in a one cubic meter box holding a meter stick.

Math Focus

3. Convert The volume of a one half gallon carton of milk is 1.9 L. How many milliliters is 1.9 L?

____

MEASURING LIQUID VOLUME

At home, you may use a measuring cup to determine a liquid's volume. In class, you may use graduated cylinders to measure volume.

When you measure an amount of liquid, you must be careful. If you look closely, you will see that the surface of water is curved in a glass container. The curve of the surface of a liquid is called a **meniscus**. ☑

READING CHECK

4. Describe What is a meniscus?

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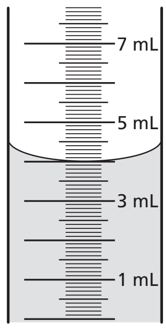
The meniscus may curve only a small amount, and may look flat in a large glass container. The amount of liquid in a container is measured from the lowest point of the meniscus. When you look at the figure below, you can see a meniscus.



To measure volume correctly, read the scale at the lowest point of the meniscus. The volume here equals 4.0 mL.

TAKE A LOOK

5. Draw On the figure, draw a meniscus that would show a volume of 6.0 mL.

VOLUME OF A REGULARLY SHAPED SOLID OBJECT

The volume of any regularly shaped solid object is measured in cubic units. The word *cubic* means that the object is not flat. The volume of an object is calculated by multiplying three measurements: length, width, and height.

It is important to see the difference between cubic measurements, which mean volume, and square measurements, which mean area. The figure below shows the difference between volume and area. ☑

READING CHECK

6. Identify What do cubic measurements measure?

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7. Identify What do square measurements measure?

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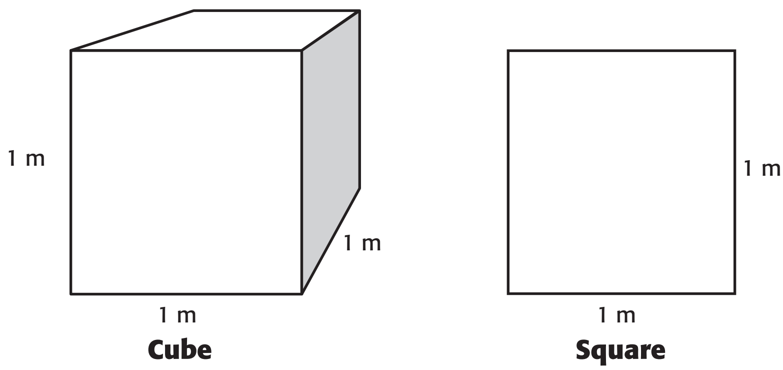
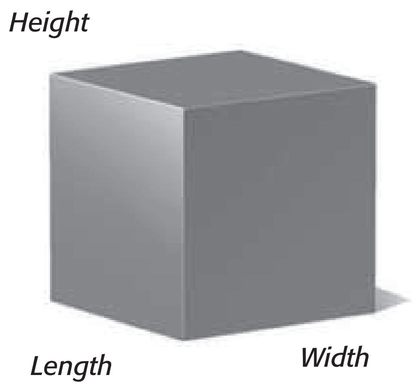


The cube has volume. Each face of the cube has area. The square has only area.

FINDING THE VOLUME OF A REGULARLY SHAPED OBJECT

A formula is used to calculate the volume of a regularly shaped object. An example of a regularly shaped object is a cube.

$$V = 1\text{ m} \times 1\text{ m} \times 1\text{ m} = 1\text{m}^3$$



A cube whose length, width, and height are each 1 m has a volume of one cubic meter (1 m^3).

Critical Thinking

8. Find What is the area of each face of the cube shown in the figure? Remember that area is length multiplied by width.

____

To find the volume (V) of a regularly shaped object, multiply the area (A) and height (h) as shown in the following formula:

$$V = A \times h$$

Let's do a problem. What is the volume of a box that has an area of 400 cm^2 and a height of 10 cm?

$$V = A \times h$$
$$V = 400\text{ cm}^2 \times 10\text{ cm} = 4{,}000\text{ cm}^3$$

VOLUME OF AN IRREGULARLY SHAPED OBJECT

One way to measure the volume of an irregularly shaped object is to put it into a known volume of water. The increase in volume is equal to the volume of the object.

Remember that objects cannot occupy the same space at the same time. The figure below shows how much water is displaced or moved after an object is dropped into it. ☑

READING CHECK

9. Describe You are given a toy metal car and asked to find its volume. Describe how you would do this.

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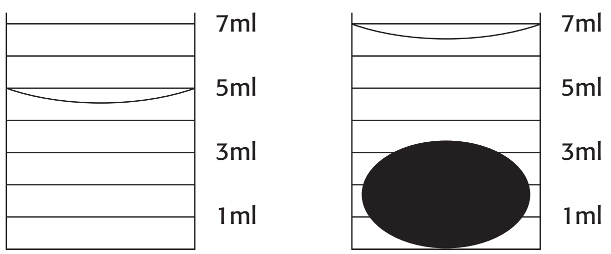


The irregularly shaped solid makes the total volume 2 mL larger. So, its volume is 2 mL.

What Is Mass?

Another property of matter is mass. **Mass** is a measure of the amount of matter that makes up an object. For example, both you and a penny are made of matter. You are made up of more matter than the penny, so you have a greater mass. ☑

The mass of an object does not change when the location of the object changes. The mass of any object changes only when the amount of matter that makes up the object changes.

READING CHECK

10. Describe What does the mass of an object measure?

[2 WORs] [the amount of matter in an object]

DIFFERENCE BETWEEN MASS AND WEIGHT

You may think that the terms mass and weight mean the same thing, but they are very different. **Weight** is the measure of the force of gravity on an object. Earth has a force of gravity that keeps all objects from floating into space. When you step on a scale, you are seeing how much force Earth pulls on you. This is known as your weight. ☑

READING CHECK

11. Identify When you step on a scale, what is being measured?

____

An object's weight can change depending on where the object is located. The mass of the object stays the same. For example, a penny would weigh less on the moon than here on Earth. This happens because the moon has less mass and has a lower force of gravity than Earth does. The mass, or amount of matter in the penny, stays the same. Only the force of gravity changes.

The table below shows how mass and weight differ.

	Mass	**Weight**
How it is measured?	with a balance	with a scale
What is measured?	the amount of matter	the force of gravity
SI measurement units	kilograms	newtons
Changes with the location of the object?		

Say It

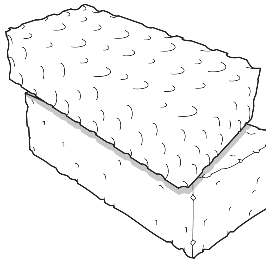
Brainstorm Form a small group. Discuss what it would be like to have a soccer game on the moon. Think about how large the field might be and the weight of the ball.

TAKE A LOOK

12. Completion Fill in the two empty boxes. Write either yes or no.

MEASURING MASS AND WEIGHT

The brick and the sponge in the figure below have the same volume. This is because the brick has larger mass, so Earth pulls on the brick more than it does on the sponge. Therefore, the brick weighs more than the sponge.



The brick and the sponge take up the same amount of space. The brick contains more matter, so its mass—and thus its weight—is greater.

The SI unit for mass is the kilogram (kg). Smaller masses are often measured in grams (g) or milligrams (mg). These units can be used to give the mass of any object. ☑

Weight is a measure of gravitational force. The SI unit of weight is the newton (N). One newton is equal to the weight of an object on Earth with a mass of about 100 g. ☑

READING CHECK

13. Identify Name three mass units.

____

____

READING CHECK

14. Identify What is the SI unit for force and its symbol?

____

What Is Inertia?

Imagine kicking a soccer ball that has the mass of a bowling ball. It would not only be painful but also very difficult to move the ball. The reason is inertia. **Inertia** is the ability of an object to resist a change in its motion. Therefore, an object will stay at rest unless something causes the object to move. Also, a moving object will keep moving unless something causes it to change speed or direction. ☑

The mass of an object tells you how much inertia an object has. An object with a large mass is harder to get moving and harder to stop than an object with less mass. The reason is that the object with the larger mass has more inertia. For example, a truck has more inertia than a bicycle. If you were trying to get a truck moving by pushing on it, you might not be able to get it moving at all. It is much easier to change the motion of a bicycle. ☑

READING CHECK

15. Identify What is inertia?

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READING CHECK

16. Identify What does the mass of an object tell you about its inertia?

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Section 1 Review

NSES **PS 1a, 1c**

SECTION VOCABULARY

inertia the tendency of an object to resist being moved or, if the object is moving, to resist a change in speed or direction until an outside force acts on the object **mass** a measure of the amount of matter in an object **matter** anything that has mass and takes up space	**meniscus** a curve at a liquid's surface by which one measures the volume of a liquid. **volume** a measure of the size of a body or region in three-dimensional space. **weight** a measure of the gravitational force exerted on an object; its value can change with the location of the object in the universe.

1. Describe Why is an apple an example of matter?

____

2. Explain What is the difference between mass and weight?

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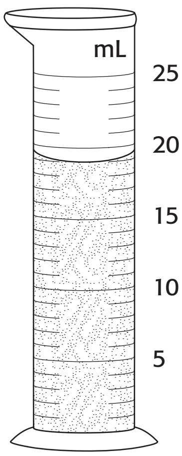
3. Identify In the figure below, what is the volume of water in the graduated cylinder?

____



4. Determine A rock is placed into a graduated cylinder containing 80 mL of water. What is the volume of the rock if the water level rises to the 120 mL mark?

____

5. Calculate One airline limits the size of carry-on luggage to a volume of 40,000 cm^3. A passenger has a carry-on that has an area of 1,960 cm^2 and is 23 cm high. Is the passenger's luggage OK to carry on the airplane? Show work to prove your answer.

____

SECTION 2

Physical Properties

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What are physical properties of matter?
- What is density?
- What is a physical change?
- What makes objects float or sink?

National Science Education Standards
PS 1a, 1b

What Are Physical Properties of Matter?

We use one or more of our senses to identify an object. The properties we are sensing are the physical properties of the object. A **physical property** of matter can be detected and measured without making a new substance. If a new substance is made, a chemical property was measured. Chemical properties will be covered in the next section. ☑

There are many physical properties that can help you identify an object. Some physical properties are color, odor, texture, and shape. How could you identify a fruit as an apple? You would probably first look at its color and shape. Its odor and certainly its taste may confirm that the fruit is an apple.

Other physical properties of an object include its strength, flexibility, ability to conduct electricity, and magnetism. Some important examples of the physical properties of matter can be seen in the table below.

Physical Property	Description
Thermal conductivity	How heat moves through a substance
Ductility	The ability of substance to be pulled into wire
State	The physical form of matter (solid, liquid, or gas)
Malleability	The ability of a substance to be rolled into a shape
Solubility	The ability of a substance to dissolve
Density	How compact a substance is
Compressibility	The ability to be squeezed or pressed together

STUDY TIP

Ask Questions Read this section silently. In your science notebook, write questions that you have about this section. Underline all words you do not understand.

READING CHECK

1. Describe What are physical properties?

____

____

____

Critical Thinking

2. Applying Concepts You are given two balls that are made from the same rubber. They are also the same size and color. One is hollow and one is solid. Give three physical properties that could be used to identify the ball that is solid.

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READING CHECK

3. Describe What is density a measure of?

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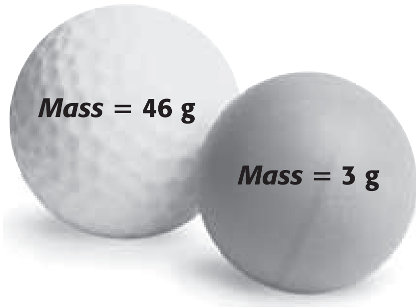
DENSITY

Density is a physical property of matter that describes how its mass and volume are related. **Density** is the amount of matter in a given volume. A golf ball and ping pong ball have similar volumes, so they occupy about the same amount of space. But since the golf ball has more mass, it has a greater density than the ping pong ball does. Take a look at the figure below. ☑



A golf ball is denser than a ping pong ball because the golf ball contains more matter in a similar volume.

Math Focus

4. Determine How much more matter is in a golf ball than a ping pong ball?

____

A formula is used to find the density of an object. To find an object's density (D), you first measure its mass (m) and volume (V). Then use the formula below.

$$D = \frac{m}{V}$$

The units of density are a mass unit (kg or g) divided by a volume unit (L, mL, or cm^3). For example, a density unit could be grams per cubic centimeter (g/cm^3) for solids, and grams per millimeter (g/mL) for liquids. The density of a substance does not depend on how much of the substance you may have. One kilogram of iron has the same density as one gram of iron.

How Is the Density Determined?

When you are given a density problem, follow the following procedure:

Step 1: Write the density equation $D = \frac{m}{V}$

Step 2: Replace m and V with the measurements given in the problem.

Math Focus

5. Calculate What is the density of gold if 28 g (1 oz) of gold has a volume of 1.45 cm^3? Show your work.

Let's try a problem. What is the density of mercury if 270 g of mercury has a volume of 20 mL?

$$D = \frac{m}{V}$$

$$D = \frac{270 \text{ g}}{20 \text{ mL}} = 13.5 \text{ g/mL}$$

USING DENSITY TO IDENTIFY SUBSTANCES

Density is a useful physical property. It can be used to help identify a substance. When measured at the same temperature and pressure, the density of a substance is always the same. The density of some common substances can be seen in the table below. ☑

READING CHECK

6. Describe Under what conditions is the density of a substance always the same?

Densities of Common Substances at 20°C and 1 atm

Substance	Density (g/cm³)	Substance	Density (g/cm³)
Helium (gas)	0.000166	Zinc (solid)	7.13
Oxygen (gas)	0.00133	Silver (solid)	10.5
Water (liquid)	1.00	Lead (solid)	11.4
Pyrite (solid)	5.02	Mercury (liquid)	13.5

STANDARDS CHECK

PS 1a A substance has characteristic properties, such as density, a boiling point, and solubility, all of which are independent of the amount of the sample. A mixture of substances often can be separated into the original substances using one or more of the characteristic properties.

7. Identify You are given a solid found in the table above. The density is about 7 g/cm³. Which solid is it?

DENSITY OF SOLIDS

Would you rather carry around 1 kg of lead or 1 kg of feathers? They both have the same mass. But you know that they are very different. Lead is denser than feathers. It has about the same volume as a stick of butter. The feathers would be about the size of a pillow. This difference in volume makes the lead easier to carry.

DENSITY, FLOATING, AND SINKING

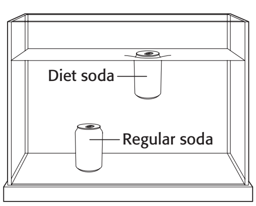
If you know the density of a substance, you can tell if it will float or sink. If the density of an object is lower than the density of water, the object will float. Cork, many types of wood, and some plastics are less dense than water. This is why they will float.

If the density of an object is greater than the density of water, it will sink when submerged. Rock and many types of metal are denser than water, so they sink. ☑

READING CHECK

8. Describe When will an object sink in water?

The figure below shows a can of diet soda and a can of regular soda in a tank of water. You can see that their densities are different.



In a tank of water, a can of diet soda floats, and a can of regular soda sinks.

Critical Thinking

9. Applying Concepts Which can of soda is less dense than water? Explain

LIQUID LAYERS

Take a look at the following figure. It shows different kinds of liquids in a graduated cylinder. Each of the liquids (maple syrup, water, and corn oil) has a different density. When these three items are carefully poured into the cylinder, they will form three different layers. What do you think causes them to look that way?

This happens because their densities are different. The layer with the highest density is on the bottom, and the layer with the lowest density is on the top. ☑

READING CHECK

10. Identify Several liquids are poured into a container. They do not mix or dissolve into each other.

Which liquid will be the top layer?

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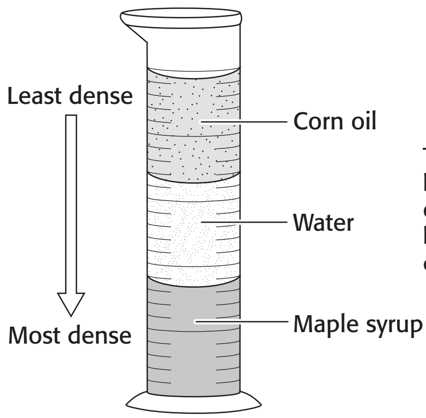
____



This graduated cylinder contains three liquids that form three layers because of the densities of the liquids. The layers are in order of smallest to largest density from top to bottom.

What Is a Physical Change?

Any change that affects the physical properties of a substance is a **physical change**. Imagine that a piece of silver is pounded into a heart-shaped charm. This is a physical change because only the shape of the silver has changed. The piece of silver is still silver. Take a look at the figure below to see some other examples of physical changes. ☑

READING CHECK

11. Describe What is a physical change?

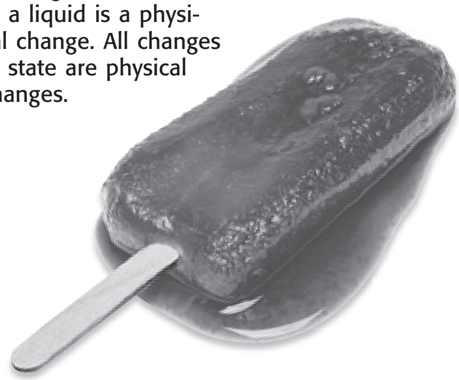
____

____

____

Examples of Physical Change

A change from a solid to a liquid is a physical change. All changes of state are physical changes.



This aluminum can has gone through the physical change of being crushed. The identity of the can has not changed.

TAKE A LOOK

12. Identify Name the physical change that happened to the popsicle.

____

EXAMPLES OF PHYSICAL CHANGES

When a substance changes from a solid to a liquid, it changes state. The three states of matter are solid, liquid, and gas. Any change to a different state of matter is a physical change. See the figure below. ☑

Freezing water to make ice is a physical change. Heating water in a teapot makes steam. This is also a physical change.

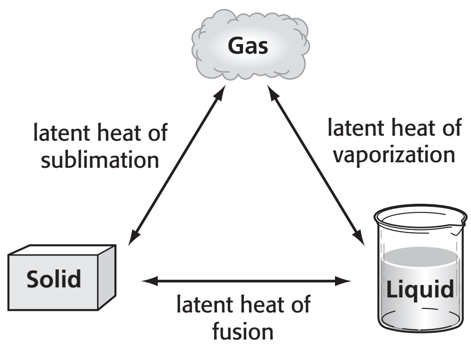
Sugar seems to disappear or dissolve in water. However, if the water evaporates, the sugar reappears. Therefore, dissolving is a physical change.

READING CHECK

13. Identify When a liquid changes into a gas, what kind of physical change has occurred?

____

Changes of State



REVERSIBILITY OF PHYSICAL CHANGES

The figure above shows arrows with two heads. This means that each change can be reversed. For example, a solid can change into a liquid, then back into a solid. ☑

Physical changes are often easy to undo. Suppose that some solid gold is melted and then poured into a bear-shaped mold. When it cools, the gold solidifies, and a bear-shaped charm is formed. These are physical changes because only the state and shape of the gold has changed. The gold charm is still gold.

READING CHECK

14. Identify What change or changes of state can happen to a gas? Looking at the figure may help you with the answer.

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MATTER AND PHYSICAL CHANGES

Physical changes do not change the identity of matter. All of the examples that you have read about are examples of a physical change. Physical changes can often be easily reversed, and the identity of the substance itself never changes. ☑

READING CHECK

15. Identify What happens to the identity of a substance after it has made a physical change?

____

Name ______________________ Class ______________ Date ______________

Section 2 Review

NSES **PS 1a, 1b**

SECTION VOCABULARY

density the ratio of the mass of a substance to the volume of the substance

physical change a change of matter from one form to another without a change in chemical properties

physical property a characteristic of a substance that does not involve a chemical change, such as density, color, or hardness.

1. Describe Write, in words, how to calculate the density of a substance.

____

Interpreting Tables Use the table below to answer questions 2 and 3.

Substance	Density (g/cm^3)
wood (oak)	0.85
water	1.00
ice cube	0.93
aluminum	2.7
lead	11.3
gold	19.3
ethanol	0.94
methanol	0.79

2. Identify Will any substance float in methanol? Why?

____

3. Identify Which substance would have a mass of 135 g when it has a volume of 50 cm^3? Show your work.

____

4. Identify Two balls have the same mass, but one has a larger volume than the other. Which ball has the larger density?

____

5. Explain When water freezes, its density gets lower. The change in density is different than that of most substances. Most substances get denser when they become solid. When a certain mass of water freezes, what property of water changes, causing its density to get lower? How does this property change?

____

Name ______________________________ Class ________________ Date ______________

CHAPTER 2 The Properties of Matter

SECTION 3

Chemical Properties

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What are chemical properties of matter?
- What is a chemical change?
- What is the effect of a chemical change?

National Science Education Standards

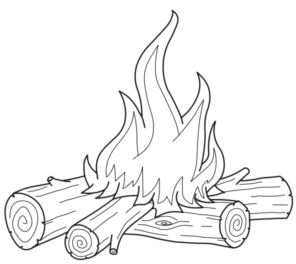
PS 1a

What Are the Chemical Properties of Matter?

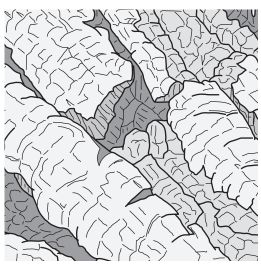
Physical properties are not the only properties that describe matter. **Chemical properties** describe matter based on its ability to change into new matter. One chemical property of matter is reactivity. *Reactivity* is the ability of a substance to change into a new substance.

One kind of reactivity is flammability. *Flammability* is the ability of a substance to burn. For example, wood burns easily. It has the chemical property of flammability. You may have seen wood burning in a fireplace, or in a campfire. ☑

When wood is burned, it becomes several different substances, such as ash and smoke. See the figure below. The properties of these new substances are different than the original properties of the wood. Ash and smoke cannot burn. This is because they have the chemical property of non-flammability.

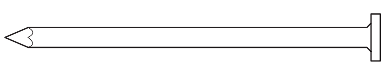


Wood burning in a fire

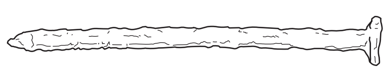


Ashes after the wood has burned

Rusting is another chemical property. Iron is the only substance that can rust. When iron combines with oxygen, it forms a new substance called iron oxide, or rust. ☑



Iron nail with no rust



Iron nail with rust

STUDY TIP

Compare Make a table with two columns, Chemical Property and Physical Property. List the chemical and physical properties that are discussed in this section.

READING CHECK

1. Identify Chemical properties of matter describe matter based on its ability to do what?

____

READING CHECK

2. Identify What metal rusts?

____

Critical Thinking

3. Compare Suppose you observe a physical property and a chemical property of a substance. Describe what happens to the substance when each kind of property is observed.

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COMPARING PHYSICAL AND CHEMICAL PROPERTIES

How can you tell the difference between a physical property and a chemical property? A physical property does not change the identity of a substance. Do you remember the silver and gold charms from the last section? The silver was pounded and the gold was melted to make the charms. After each charm was made, the silver charm was still silver and the gold charm was still gold.

The chemical properties of a substance can't be seen unless you change the identity of the substance. For example, you may not know a liquid is flammable until you try to light it. If it burns, it has the chemical property of flammability. However, the burned liquid has changed into new substances.

A substance always has chemical properties. A piece of wood is flammable even when it is not burning. Iron can form rust even though it has not rusted.

STANDARDS CHECK

PS 1a A substance has characteristic properties, such as density, a boiling point, and solubility, all of which are independent of the amount of the sample. A mixture of substances often can be separated into the original substances using one or more of the characteristic properties.

4. Applying Concepts A scientist measures three properties of a liquid. Its density is 0.8 g/cm^3, it does not mix with water, and its flash point is −35°C. Based on the information in the table, what is the most likely identity of the liquid? Explain your answer.

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CHARACTERISTIC PROPERTIES

The properties that are most useful to identify a substance are called *characteristic properties*. These properties are constant. This means that they do not change. The characteristic properties of a substance can be physical, chemical, or both.

A piece of iron has characteristic properties that help identify it as iron. A good example of this would be density. Iron has a constant density when measured at the same temperature and pressure. Iron also rusts.

Scientists can identify a substance by studying its physical and chemical properties. The table below shows some characteristic properties of several liquids.

Property	**Rubbing alcohol**	**Kerosene**	**Gasoline**
Density (g/cm^3)	0.8	0.8	0.8
Dissolves or mixes with water	yes	no	no
Flash Point (°C) (The higher the flash point, the more flammable the liquid.)	12	40	−40

What Is a Chemical Change?

When substances change into new substances that have different properties, a **chemical change** has happened. Chemical *changes* and chemical *properties* are not the same. The chemical properties of a substance describe which chemical change can happen to the substance. For example, flammability is a chemical property. Burning is the chemical change that shows this property. ☑

READING CHECK

5. Describe What is a chemical change?

____

____

A chemical change causes a substance to change into a new substance. You can learn about a substance's chemical properties by observing what chemical changes happen to that substance.

Chemical changes occur more often than you might think. For example, a chemical change happens every time you use a battery. Chemical changes also take place within your body when the food you eat is digested. The figure below describes other chemical changes.

Soured milk smells bad because bacteria have formed smelly new substances in it.

The **Statue of Liberty** is made of copper, which is orange-brown. But this copper is green because of its interactions with moist air. These interactions are chemical changes that form copper compounds. Over time, the compounds turn the statue green.

TAKE A LOOK

6. Identify What property of the milk told the girl that it had soured?

____

WHAT HAPPENS DURING A CHEMICAL CHANGE?

A fun way to see what happens during a chemical change is to bake a cake. A cake recipe combines different substances. Eggs, cake mix, oil, and water are mixed to form a batter. When the batter is baked, you end up with a substance that is very different from the original batter.

The heat of the oven and the mixture of ingredients cause a chemical change. The result is a cake. The cake has properties that are different than the properties of the raw ingredients alone.

Critical Thinking

7. Applying Concepts How do you know that baking a cake is a chemical change?

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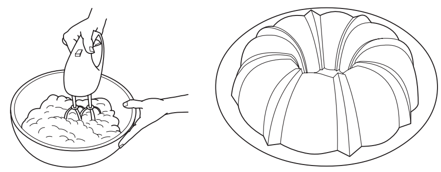

Cake mix batter becomes a cake.

SIGNS OF CHEMICAL CHANGES

A change in color, odor, or texture may show that a chemical change has happened. A chemical change often will produce or absorb heat.

An increase in temperature happens when a chemical change liberates or releases heat. Wood burning is a good example of a chemical change that gives off heat.

Some chemical changes cause a substance to absorb or gain heat. Sugar is broken down into carbon and water by heating. ☑

READING CHECK

8. Identify What are four changes that indicate that a chemical change has occurred?

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____

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MATTER AND CHEMICAL CHANGES

When matter has a chemical change, the identity of the matter changes. Chemical changes can only be reversed by other chemical changes. For example, water can be made by heating a mixture of hydrogen and oxygen. Water can also be broken up into hydrogen and oxygen when an electric current is passed through it. The electric current supplies the energy needed to pull the hydrogen away from the oxygen.

Physical Versus Chemical Changes

Sometimes it is hard to decide whether a physical change or a chemical change has happened to an object. Consider when something new formed as a result of the change.

Physical changes do not change the composition of an object. The *composition* of an object is the type of matter that makes up the object. For example, water is made of two hydrogen atoms and one oxygen atom. Whether water is a solid, liquid, or gas, its composition is the same.

Chemical changes change the composition of matter. For example, through a process called *electrolysis*, water is broken down into hydrogen and oxygen gases. The products of the electrolysis of water are very different from water. ☑

In the figure below, baking soda is ground into a powder. This is a physical change. When vinegar is poured into the baking powder, gas bubbles are produced. This is a chemical change.

READING CHECK

9. Describe How can you tell that a physical rather than a chemical change has occurred?

____

____

Physical and Chemical Changes

Change in Texture Grinding baking soda into a fine, powdery substance is a physical change.

Reactivity with Vinegar Gas bubbles are produced when vinegar is poured into baking soda.

REVERSING CHANGES

Most physical changes can be easily reversed, like freezing, melting, and boiling. Remember that the type or composition of matter does not change.

This is very different from a chemical change. During a chemical change the type or composition of matter does change. Many chemical changes cannot be easily reversed. Ash cannot be turned back into wood. The explosion of a firework cannot be reversed. ☑

READING CHECK

10. Identify Which kind of changes cannot be easily reversed?

____

Section 3 Review

NSES PS 1a

SECTION VOCABULARY

chemical change a change that occurs when one or more substances change into entirely new substances with new chemical properties	**chemical property** a property of matter that describes a substance's ability to participate in chemical reactions

1. Describe How is a chemical property different than a chemical change?

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____

2. Explain Why is reactivity not a physical property?

____

____

3. Identify What can be absorbed or released as the result of a chemical reaction?

____

4. Complete Fill in the type of change in the table below.

Type of Change	Description of Change
	rusting
	boiling
	freezing
	burning

5. Identify What are four things that indicate that a chemical change may have taken place?

____

____

6. Identify and Explain Originally, the Statue of Liberty was copper-colored. After many years, it turned green. What kind of change happened? Explain.

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7. Identify You see a burning candle. You feel heat above the flame, you see black smoke rising from the wick, and wax melts. List each of the changes that occurred and tell the type of change that caused it.

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SECTION 1
Three States of Matter

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is matter made of?
- What are the three most common states of matter?
- How do particles behave in each state of matter?

National Science Education Standards
PS 1a

What Are the Three States of Matter?

Have you ever had a steaming hot bowl of soup and an ice cold drink for lunch? The three most common states of matter are found in this lunch. The soup and the drink are made of water. However, the water exists in three different forms. The soup and the drink are liquids. The ice is a solid. The steam from the soup is a gas.

The substance is the same whether it is a solid, a liquid, or a gas. The substance is just in a different form, or state. The **states of matter** are the physical forms of a substance. The three well-known states of matter are solid, liquid, and gas. ☑

Matter is made up of very tiny particles. These particles are called *atoms* and *molecules*. Atoms and molecules act differently in each state of matter. We cannot see atoms and molecules, but they are always moving. How fast they move depends on the state they are in. The figure below describes the three states of matter and how particles act in each state.

STUDY TIP
Describe Write a short description of a solid, a liquid, and a gas. Include the motions of the particles and how the motion affects volume and shape.

READING CHECK
1. Define What are states of matter?

____

____

Models of a Solid, a Liquid, and a Gas

Particles of a solid have a strong attraction between them. The particles are closely locked in position and only vibrate.

Particles of a liquid are more loosely connected than those of a solid and can move past one another.

Particles of a gas move fast enough that they overcome the attractions between them. The particles move independently and collide frequently.

TAKE A LOOK
2. Identify In which state do the particles move about the most? In which state do they move about the least?

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____

What Are the Properties of Solids?

Any solid material, such as a penny, a rock, or a marble, has a specific shape and volume. For example, if you place a solid marble into a bottle, the marble's shape and volume stay the same. It keeps its original shape and volume no matter where it is placed. A **solid** is the state of matter that has a specific shape and volume.

The particles of a solid are very close to each other. They have a strong attraction for each other. Therefore, the particles of a solid are locked into place. However, they do make small movements called vibrations. Remember, the particles of any substance are always in motion. ☑

READING CHECK

3. Describe How do the particles of a solid move?

____

What Are the Properties of Liquids?

Ice cubes and liquid water are made of the same material, but they are physically very different. In solids, such as ice cubes, particles are closely locked together and vibrate in place. In liquids, such as liquid water, particles are able to move more freely.

A **liquid** is a substance that has a specific volume, but doesn't have a particular shape. For example, a liter of milk takes the shape of its container. The same liter of milk will take the shape of a bowl it is poured into. The shape of the milk changes. The volume of the milk stays the same. This is seen in the figure below with the juice.

In a liquid, the particles move fast enough to overcome their attraction to each other. As a result, they can move or slide past each other, even though they always stay close together. In liquids, we know that the particles can move past each other because liquids can change shape.

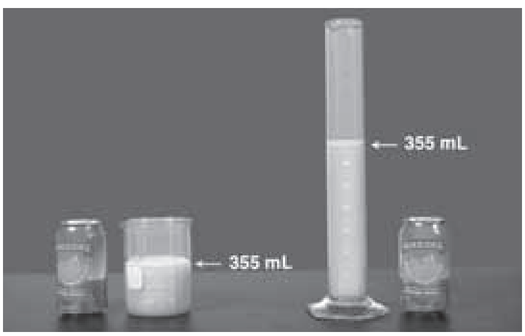
STANDARDS CHECK

PS 1a A substance has characteristic properties, such as density, a boiling point, and solubility, all of which are independent of the amount of the sample. A mixture of substances often can be separated into the original substances using one or more of the characteristic properties.

4. Identify How are the particles in a liquid different from the particles in a solid?

____

____



Although their shapes are different, the beaker and the graduated cylinder each contain 355 mL of juice.

THE UNIQUE PROPERTIES OF LIQUIDS

Liquids have special properties that the other states of matter do not have. One special property of liquids is surface tension. **Surface tension** is a force that acts on the particles at the surface of a liquid. Water has a high surface tension, causing it to form spherical or oval-shaped drops. You may have seen beads of water on an object. Each liquid has a different amount of surface tension. Gasoline has a low surface tension and forms flat drops. ☑

Another special property of liquids is viscosity. **Viscosity** is a liquid's resistance to flow. Liquids that are "sticky" usually have a high viscosity. The particles in these liquids have a strong attraction for each other. For example, honey flows more slowly than water. So the viscosity of honey is greater than that of water.

READING CHECK

5. Describe What is surface tension?

____

____

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What Are the Properties of Gases?

The properties of a gas are different from the properties of other states of matter. A **gas** has no specific shape or volume. All gases take on the shape of the container they are put in. This is because their particles have little attraction for each other.

A gas that you might know about is helium. Helium is the gas that is used to fill birthday balloons. When the helium is in the tank, the particles are close to each other. As the helium particles fill a balloon, they spread out. So the amount of space between the helium particles in the balloon increases.

Critical Thinking

6. Apply Concepts Put the following in order from lowest to highest viscosity: syrup, water, and cream.

____

Many balloons can be filled from one tank of helium because the particles of helium gas in a balloon are far apart.

TAKE A LOOK

7. Describe What happens to the space between particles when helium moves from the tank into the balloon?

____

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Name ______________________ Class ______________ Date ______________

Section 1 Review

NSES PS 1a

SECTION VOCABULARY

gas a form of matter that does not have a definite volume or shape

liquid the state of matter that has a definite volume but not a definite shape

solid the state of matter in which the volume and shape of a substance are fixed

states of matter the physical forms of matter, which include solid, liquid, and gas

surface tension the force that acts on the surface of a liquid and that tends to minimize the area of the surface

viscosity the resistance of a gas or liquid to flow

1. Identify Name the three states of matter and give an example of each.

____

____

____

2. Identify What is one property that all particles of matter have in common?

____

____

3. Compare How are the particles of a liquid different from the particles of a solid?

____

____

____

4. Compare How are the particles of a liquid different from the particles of a gas?

____

____

____

5. Identify What property of water causes it to form beads on the leaves of the plants?

____

6. Describe Indicate how the shape and volume of each state of matter are different.

State of matter	Definite shape	Definite volume
solid		
liquid	no	
gas		no

SECTION 2

Behavior of Gases

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What affects how a gas behaves?
- What are the gas laws?

National Science Education Standards
PS 1a

What Affects the Behavior of a Gas?

Gases behave differently than solids or liquids. Gas particles have a large amount of space between them. The space that the gas particles take up is the gas's volume. Its volume depends on its temperature and pressure.

STUDY TIP
Brainstorm With a partner, describe situations where Boyle's Law and Charles's Law apply.

TEMPERATURE

Helium is a gas that is used to fill balloons. The amount of helium needed to fill a balloon depends on the temperature. **Temperature** is a measure of how fast the particles of an object are moving. ☑

When it is hot, the helium particles have more energy. They move faster and bump into the walls of the balloon more often than they do when it is cool. This causes the gas particles to move apart and take up a larger volume. Therefore, less helium is needed to fill the balloons on a hot day. If the balloon is heated too much, it might burst.

When the temperature is cooler, the helium has less energy. The particles do not hit the walls of the balloon as hard or as often. The helium doesn't take up as much volume. Therefore, more helium is needed to fill the balloons when the temperature is lower. ☑

The following table describes what happens to gas particles at different temperatures.

READING CHECK
1. Describe What is temperature?

____
____
____

READING CHECK
2. Identify Does a helium balloon have a larger volume when it is heated or cooled?

____
____

Temperature of gas particles	**Energy of gas particles**	**Volume of gas particles**
1. 20°C	particles have the smallest amount of energy	volume is smallest
2. 50°C	particles have ________ energy than 20°C, but not as much as 80°C	volume is ________ than 20°C but smaller than 80°C
3. 80°C	particles have the ________ amount of energy	volume is ________

TAKE A LOOK
3. Complete Fill in the missing words in the table.

VOLUME

The **volume** of an object is how much space it takes up. Gas particles do not stick together. They spread out. Therefore, the volume of a gas always depends on the container the gas is in.

For example, what happens when you gently squeeze a balloon? The balloon does not usually break unless a lot of pressure is put on the balloon. When you squeeze the balloon, you change the volume of the gas inside of it. The particles of the gas are being forced into a smaller volume.

PRESSURE

The amount of force that is put on an area is called **pressure**. You can think about pressure as the number of times the particles of a gas hit the inside of their container. ☑

The figure below shows two different kinds of balls: a basketball and a beach ball. They are both the same size and hold the same volume of air, which is a gas. There are more particles of gas in the basketball than in the beach ball. This means there are more particles that are hitting the inside of the basketball. There is greater pressure in the basketball. This makes the basketball feel harder than the beach ball.

READING CHECK

4. Describe What is pressure?

____

____

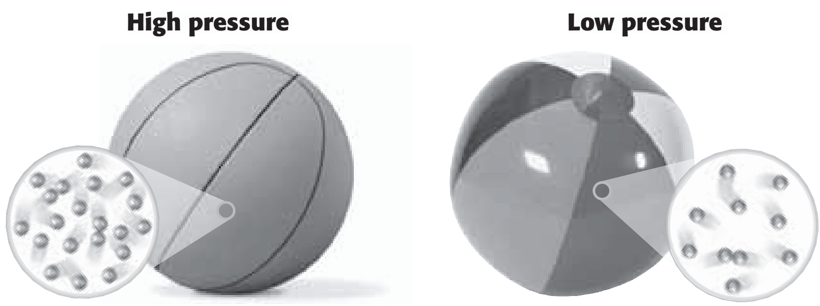
STANDARDS CHECK

PS 1a A substance has characteristic properties, such as density, a boiling point, and solubility, all of which are independent of the amount of the sample. A mixture of substances often can be separated into the original substances using one or more of the characteristic properties.

5. Identify What two factors influence the volume of a gas?

____

Gas and Pressure



The basketball has a higher pressure because there are more particles of gas in it, and they are closer together. The particles collide with the inside of the ball at a faster rate.

The beach ball has a lower pressure because there are fewer particles of gas, and they are farther apart. The particles in the beach ball collide with the inside of the ball at a slower rate.

What Are the Gas Laws?

The temperature, pressure, and volume of a gas are linked to each other. When one of these changes, the other two change. The gas laws describe how the temperature, pressure, and volume of a gas are related to each other.

1. BOYLE'S LAW

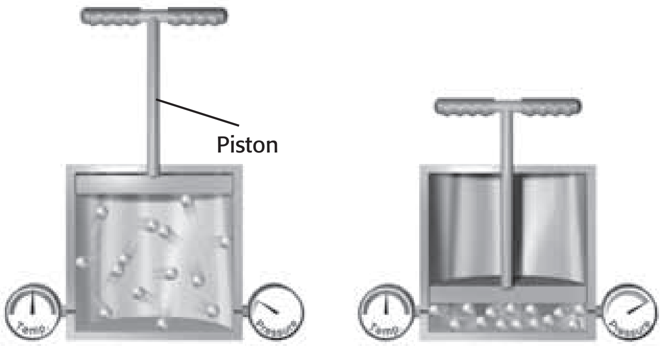
Boyle's law says that the volume of a gas is inversely related to its pressure when temperature stays the same. This means that when the pressure of a gas increases, its volume will decrease. For example, if the pressure of a gas doubles, the volume will be cut in half. This is seen in the figure below.

Math Focus

6. Determine If the pressure of a gas is tripled and its temperature remains constant, what happens to its volume?

____

Boyle's Law



Lifting the piston lets the particles of gas spread far apart. The volume of the gas increases as the pressure decreases.

Pushing the piston forces the gas particles close together. The volume of the gas decreases as the pressure increases.

2. CHARLES'S LAW

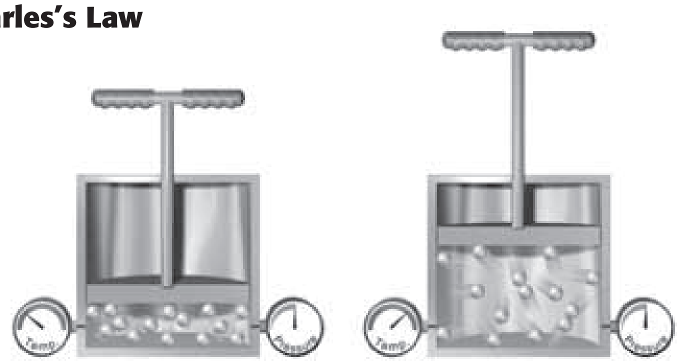
Charles's law says that the volume of a gas is directly related to its Kelvin temperature when pressure stays the same. Therefore, if the Kelvin temperature of a gas increases, the volume of a gas will increase. For example, if the Kelvin temperature of a gas doubles, the volume doubles.

Math Focus

7. Determine If the Kelvin temperature of a gas is cut in half and its pressure remains constant, what happens to its volume?

____

Charles's Law



Decreasing the temperature of a gas makes the particles move more slowly. The gas particles hit the piston less often and with less force. Therefore, the volume of the gas decreases.

Increasing the temperature of a gas makes the particles move more quickly. The gas particles hit the piston more often and with more force. Therefore, the volume of the gas increases.

Section 2 Review

NSES PS 1a

SECTION VOCABULARY

Boyle's Law the law that states that the volume of a gas is inversely proportional to the pressure of a gas when temperature is constant **Charles's Law** the law that states that the volume of a gas is directly proportional to the temperature of a gas when pressure is constant **pressure** the amount of force exerted per unit area of a surface	**temperature** a measure of how hot (or cold) something is; specifically, a measure of the average kinetic energy of the particles in an object **volume** a measure of the size of a body or region in three-dimensional space

1. **Identify** Name the three factors that affect how a gas behaves.

____

2. **Describe** What happens to the temperature and volume of a balloon if it is taken outside on a cold winter day?

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____

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3. **Calculate** You have three liters of gas at a certain Kelvin temperature and a certain pressure. The Kelvin temperature triples and the pressure stays the same. What is the gas volume? Explain your answer.

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4. **Analyze** The pressure of the gas is cut in half and the temperature stays the same? What happens to the gas volume? Explain your answer.

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____

5. **Explain** When scientists record a gas's volume, they also record its temperature and pressure. Why?

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SECTION 3
Changes of State

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is a change of state?
- What happens during a change of state?
- What can happen when a substance loses or gains energy?

National Science Education Standards
PS 1a, 3a

How Are Changes of State and Energy Related?

It can be tricky to eat a frozen juice bar outside on a hot day. In just minutes, the juice bar begins to melt. As it melts, the juice bar changes its state from a solid to a liquid. A **change of state** happens when matter changes from one physical form to another. A change of state is always a physical change. Remember that in a physical change, the substance does not change into a new substance.

STUDY TIP

Compare As you read the chapter, complete a table with the following headings:
- name of change
- states that are changing
- energy (added or removed).

Energy must be added or removed in order for a substance to change its physical state. It is important to remember that the particles of every substance move differently. This movement of particles depends on the state of the substance (solid, liquid, or gas). ☑

READING CHECK

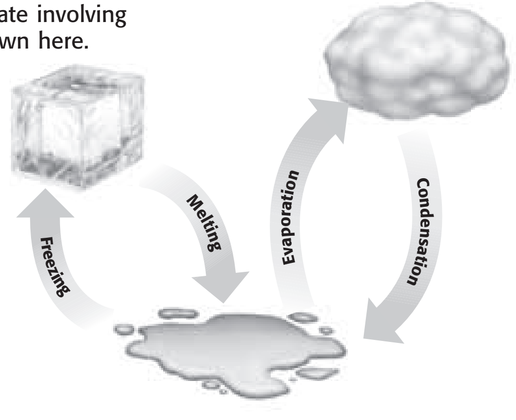
1. Identify What must be added or removed when a substance changes state?

____

For example, the particles in frozen water or ice (a solid) only vibrate. The particles in liquid water move faster and have more energy than particles in ice. To change ice into liquid water, energy must be added. To change liquid water into ice, energy must be removed.

The figure below shows changes of state that water can undergo.

Changes of state involving water are shown here.



TAKE A LOOK

2. Describe What happens to water in a puddle before it forms droplets of liquid water in a cloud?

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STANDARDS CHECK

PS 3a Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.

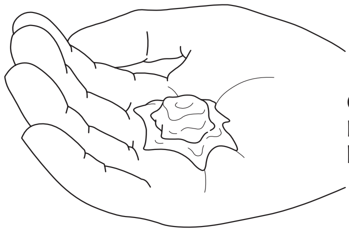
Word Help: chemical
of or having to do with the properties or actions of substances

3. Identify What must be added to melt a substance?

____

What Is Melting?

When energy is added to a solid, it can melt. **Melting** is the change of state from a solid to a liquid. For example, an ice cube in a glass of lemonade melts as it absorbs heat from the lemonade.



Gallium is a metal that can melt in your hand. Even though gallium is a metal, it would not be very useful as jewelry!

MELTING POINT AND ENERGY

The *melting point* of the substance is the temperature in which it changes from a solid to a liquid. As the temperature of the solid becomes greater, its particles move faster. When a certain temperature is reached, the solid will melt. The melting point of a substance is a physical property of the substance. ☑

READING CHECK

4. Describe What is the melting point of a substance?

____

____

____

Melting point depends on the composition of, or material that makes up, the substance. It can be used to help identify a substance. For example, copper has a melting point of 420.7°C. Other substances may look like copper, but they will likely have different melting points.

For a solid to melt, particles must absorb energy. The energy makes the particles move faster and have less attraction to each other. This allows the particles to move past each other. The solid melts and becomes a liquid.

What Are Freezing and Freezing Point?

The *freezing point* is the temperature at which a substance changes from a liquid to a solid state. When a liquid freezes, its particles have less energy and become closely locked in position. Energy is removed from the substance during freezing.

Freezing is the exact opposite of melting. The freezing point of a substance is exactly the same as the melting point of the substance. They both happen at the same temperature. For example, liquid water freezes and becomes solid ice at temperatures below 0°C. Solid ice melts and becomes liquid water at temperatures above 0°C. ☑

READING CHECK

5. Identify If the freezing point of a substance is 68°C, what is its melting point?

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What Is the Process of Evaporation?

When you get out of a swimming pool on a windy day, your body sometimes feels cold. Why? The water on your skin is evaporating. **Evaporation** is the change of state from the liquid state to the gas state. The reason you feel cold is because evaporation requires energy. The energy in this case goes from your body into the liquid water. The liquid water changes state to a gas called *water vapor*.

This change of state also happens when you sweat. Sweat is mostly water. When sweat appears on your skin, the water absorbs heat (energy) from your skin. This causes the water to evaporate, and you feel cooler. ☑

Say It

Investigate People usually feel warmer on a warm, humid day than on a warm, dry day. Investigate why most people feel warmer on humid days and report to the class.

READING CHECK

6. Describe Why does sweating help cool your body?

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EVAPORATION AND BOILING

Evaporation can occur at low temperatures. Water can evaporate at temperatures near 0°C, but it will evaporate very slowly. For water to evaporate quickly in an open container, it must be heated. If the water is heated to a high enough temperature, it will boil.

Boiling occurs when a liquid evaporates quickly. The particles leave the liquid state and change to vapor (gas) particles. This change creates a vapor pressure. A liquid boils when the vapor pressure equals the air pressure in the room. The temperature at which boiling occurs is known as the *boiling point* of the substance. ☑

READING CHECK

7. Identify When the vapor pressure of a liquid equals the air pressure in the room, what will the liquid do?

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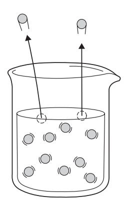
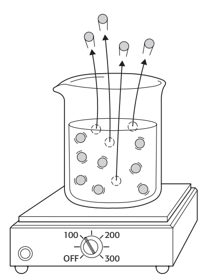
Like melting point, boiling point can help identify a substance. For example, the normal boiling point of water is about 100°C. Many liquids that look like water boil at different temperatures.

The figure below shows water evaporating at room temperature and water boiling.



Evaporation can happen in a liquid below its boiling point. Some particles at the surface of the liquid move fast enough to break away from the particles around them. When they break away, they become a gas (or vapor).



Boiling happens in a liquid at its boiling point. As energy is added to the liquid, particles throughout the liquid move faster. When they move fast enough to break away from other particles, they evaporate. The bubbles you see when water boils contain water vapor.

TAKE A LOOK

8. Identify Are there more water vapor molecules above a beaker of water at room temperature or a beaker of water at its boiling point?

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What Is the Process of Condensation?

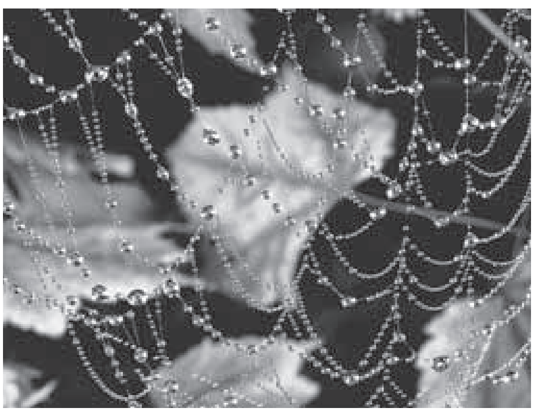
On a hot day in the summer, a glass of ice water might look like it is sweating. The water drops on the outside of the glass have formed because of condensation. **Condensation** is the change of state from a gas to a liquid. The water vapor in the air (sometimes called humidity) hits the cold glass. The particles of water vapor lose energy and change into the liquid state.

Condensation happens when a gas is cooled. When the gas cools, the particles lose energy, move slower, and have a greater attraction for each other. The particles begin to clump together. Condensation and evaporation are the opposites of each other. When condensation happens, the particles of gas lose energy and move more slowly. For evaporation to occur, the particles of a liquid must gain energy, and move faster. ☑

The *condensation point* of a substance is the temperature at which a gas becomes a liquid. Under most conditions, the condensation point of a substance is the same temperature as the boiling point of the substance. Condensation can occur when the temperature of a surface is below the condensation point of the gas.

For example, water drops form a haze on a bathroom mirror when you take a shower. The water drops condense from the water vapor in the air. The mirror is at a temperature well below water vapor's condensation point, 100°C.

Take a close look at the spider web in the figure below. Notice the beads of water that have formed on it. This happens because water vapor (a gas) has condensed to form liquid water.



Beads of water form when water vapor in the air contacts a cool surface, such as this spider web.

Critical Thinking

9. Describe How does water from a lake become part of a cloud in the sky?

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READING CHECK

10. Identify Which process requires energy, condensation or evaporation?

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Critical Thinking

11. Explain As the day gets warmer, the water droplets on a spider web are no longer seen. Why?

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What Is the Process of Sublimation?

The electric company in your community sometimes hands out dry ice when a storm knocks out power. Dry ice keeps groceries cold, but does not melt like ice. Dry ice can change directly from a solid state to a gas state. This process in known as **sublimation**. ☑

Dry ice is frozen carbon dioxide. Its temperature is −78.5°C or lower. When it sublimes, it pulls energy from substances around it. This makes substances around it become cold. The energy it pulls weakens the attraction of the particles in the solid dry ice. When the attraction weakens enough, the solid changes into a gas. It does not melt into a liquid.

READING CHECK

12. Describe What occurs when a substance sublimes?

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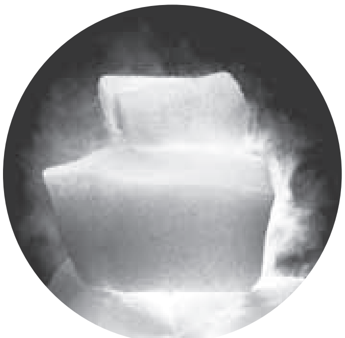


Dry ice is a substance that will change directly from a solid to a gas at atmospheric pressure.

How Are Changes of State and Temperature Related?

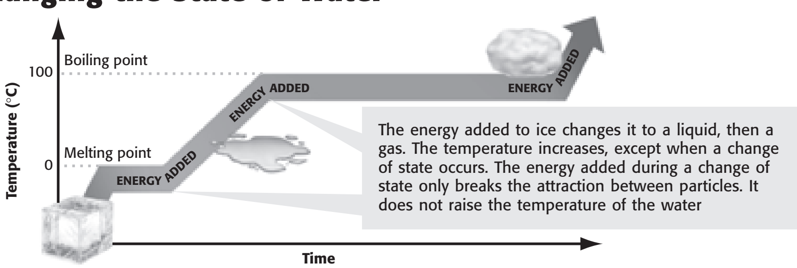
Two things can happen to a substance when it gains or loses energy. Either the temperature of the substance changes, or the state of the substance changes. During a change of state, the temperature of a substance will not change until the change of state is complete.

Take a close look at the figure below. The figure shows the effects and state changes that happen when energy is added to ice.

Say It

Demonstrate Put an ice cube in the freezer compartment of a refrigerator. Allow it to sit, undisturbed, for about two weeks. Report to the class on how its size changed.

Changing the State of Water



TAKE A LOOK

13. Describe What is the shape of the graph at the melting and freezing points of water? What does this shape tell you about the temperature?

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Name ______________________ Class ______________ Date ____________

Section 3 Review

NSES PS 1a, 3a

SECTION VOCABULARY

boiling the conversion of a liquid to a vapor when the vapor pressure of the liquid equals the atmospheric pressure

change of state the change of a substance from one physical state to another

condensation the change of state from a gas to a liquid

evaporation the change of state from a liquid to a gas

melting the change of state by which a solid becomes a liquid by adding heat

sublimation the process in which a solid changes directly into a gas

1. **Describe** How do the motions of the particles differ between the states of matter?

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2. **Describe** What happens to energy during a change of state? Why is it a physical change?

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3. **Describe** What are the differences between freezing and melting? How are they similar?

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4. **Explain** How are evaporation and boiling the same? How do they differ?

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5. **Describe and Compare** What is needed for a solid to sublime and what change of state occurs? How does sublimation differ from condensation?

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6. **Complete** Fill in the missing boxes in the table below.

Property	Solid	Liquid	Gas
attraction between particles		weaker than in a solid	
distance between particles	close	close	
movement of particles		they can move past each other	

SECTION 1
Elements

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is an element?
- How do elements differ from other materials?
- How are elements classified?

National Science Education Standards
PS 1a, 1c

What Are Elements?

Many materials can be broken down into simpler materials. For example, some rocks contain copper. When they are heated in a large furnace, the copper separates from the rest of the rock. Another example is breaking down water by passing electricity through it. The electric current causes hydrogen gas and oxygen gas to form.

Some materials cannot be separated or broken down into other materials. An **element** is a pure substance that cannot be separated into simpler substances by chemical or physical methods. This is how elements are different from all other materials.

A **pure substance** is a material in which all the basic particles are the same. For example, table salt contains particles of sodium chloride. Table salt from anywhere is the same. All pure substances, except for elements, can be broken down into simpler substances. ☑

The basic particles of an element are called *atoms*. Copper is an example of an element. All of the atoms in a piece of pure copper are alike. As shown in the figure below, iron is also an element.

STUDY TIP
Graphic Organizer In your notebook, make a Concept Map by using the terms element, substance, metal, nonmetal, and metalloid.

READING CHECK
1. Compare How does an element differ from other pure substances?

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The iron atoms in the meteorite from space are the same as the iron atoms in a steel spoon. There are also iron atoms in the cereal, in the boy's braces, and even in his blood.

TAKE A LOOK
2. Identify Look at the illustration and identify one source of iron that comes to Earth from somewhere else.

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How Can Elements Be Classified?

Elements can be classified based on their properties. There are two types of properties, chemical and physical. Physical properties include hardness, melting point, and density. Chemical properties include reactivity and flammability.

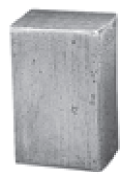
We can use properties to tell elements apart. For example, the elements helium and krypton are both colorless, odorless, unreactive gases. However, the elements have different densities (mass per unit volume). Helium is less dense than air, so a helium balloon floats upward. Krypton is denser than air. A krypton-filled balloon, on the other hand, will sink to the floor.

The Unique Properties of Elements

Cobalt

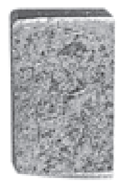
- Melting point: 1,495°C
- Density: 8.9 g/cm^3
- Conducts electricity and heat
- Reactivity: unreactive with oxygen in the air

Iron



- Melting point: 1,535°C
- Density: 7.9 g/cm^3
- Conducts electricity and heat
- Reactivity: reacts by combining with oxygen in the air to form rust.

Nickel



- Melting point: 1,455°C
- Density: 8.9 g/cm^3
- Conducts electricity and heat
- Reactivity: unreactive with oxygen in the air

The figure above shows some of the properties of three different elements. The physical properties shown are melting point, electrical and thermal conductivities, and density. Each element has other physical properties, including color, hardness, and texture. The figure also includes a chemical property: the reactivity of the element with oxygen in the air.

If you had a piece of metal, you could use these properties to determine which element it is. Iron has different physical and chemical properties than the other two elements. The density of iron is much less than cobalt or nickel, and it reacts with oxygen in the air.

We can also use properties to tell nickel and cobalt apart. They have the same density and reactivity, but the melting points of these two elements differ by 40°C. This property can be used to tell them apart. ☑

STANDARDS CHECK

PS 1a A substance has characteristic properties, such as density, a boiling point, and solubility, all of which are independent of the amount of the sample. A mixture of substances often can be separated into the original substances using one or more of the characteristic properties.

3. List What are five physical properties that are characteristics of an element?

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Critical Thinking

4. Infer Compare the properties of iron with those of cobalt and nickel. How do you think cobalt and nickel are used in manufactured products?

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READING CHECK

5. Explain Why can't you use density or reactivity to determine whether a sample is cobalt or nickel?

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How Can Elements Be Sorted?

Think about all the different types of dogs that you have seen. Dogs can be classified based on different properties. These include their size, the shape of the ears, or the length of their coat. You can often determine a dog's breed just with a quick glance. The figure below shows three kinds of terriers. They are not exactly alike, but they share certain features.

Even though these dogs are different breeds, they have enough in common to be classified as terriers.

TAKE A LOOK

6. Describe What are some of the physical properties that describe terriers?

____

____

The elements can be classified based on properties, just like the dogs in the image. There are three major categories of elements: metals, nonmetals, and metalloids. The elements iron, cobalt, and nickel are all metals. They are not exactly alike, but they have similar properties. ☑

READING CHECK

7. Identify What are the three main categories of elements?

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Metals tend to be shiny solids (except mercury, which is a shiny liquid). Metals conduct electric current and heat well. **Nonmetals** do not conduct heat or electric current very well. Many nonmetals are gases. The solid nonmetals have a dull appearance. **Metalloids** have some of the properties of metals and some of the properties of nonmetals. Metalloids are important in electronics because their electrical conductivity can vary with conditions.

Say It

Explore Applications The properties of metals make them very useful in everyday things. In groups of three or four, make a list of things that you use for cooking that are made of metal. Make another list of things used for cooking that are never made of metal. Discuss why the properties of metal determined which things are in which group.

Three Major Categories of Elements

Property	Metals	Nonmetals	Metalloids
Appearance	shiny	dull	some are shiny
Conductivity of heat and electricity	good	poor	some do
Malleable—can be hammered into sheets	yes	no	some are somewhat malleable
Ductile—can be made into wires	yes	no	some are somewhat ductile
Brittle	no	yes	some are

Name ______________________ Class ______________ Date ______________

Section 1 Review

NSES PS 1a, 1c

SECTION VOCABULARY

element a substance that cannot be separated or broken down into simpler substances by chemical means

metal an element that is shiny and conducts heat and electricity well

metalloid an element that has properties of both metals and nonmetals

nonmetal an element that conducts heat and electricity poorly

pure substance a sample of matter, either a single element or a single compound that has definite chemical and physical properties

1. **Compare** How does the ability to conduct heat differ between metals and nonmetals?

____

2. **Classify** Fill in each blank to complete the table.

Element	Property	Classification
Copper	shiny solid	
Oxygen	gas	
Silicon	electrical conductivity varies depending on conditions	

3. **Evaluate Assumptions** Your friend tells you that all of the electric wires in your home are metals. From what you know about elements, explain whether or not this statement is true.

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4. **Apply Concepts** Several elements are placed between panes of glass in double windows to block heat flow. Should these elements be metals or nonmetals? Why?

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5. **Calculate** Two elements, hydrogen and helium, make up most of the atoms in the universe. 92.7% of atoms are hydrogen and 6.9% of atoms are helium. What percentage of atoms are neither hydrogen nor helium? Show your work.

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SECTION 2
Compounds

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What are compounds?
- What is a chemical reaction?
- How are compounds used in everyday life?

National Science Education Standards
PS 1a, 1c

What Are Compounds?

Look around the classroom. Most of the things you see are not made of just one element. Instead, they are made of elements combined with other elements. A **compound** is a pure substance composed of two or more elements that are joined by chemical bonds. The figure below shows some compounds that you might find in your kitchen and what elements make up the compounds. ☑

STUDY TIP

Asking Questions Read this section silently. In your notebook, write down questions that you have about this section. Discuss your questions in a small group.

READING CHECK

1. Describe What is a compound?

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Familiar Compounds

Compound	Elements in the compound
Table salt	sodium and chlorine
Water	hydrogen and oxygen
Sugar	hydrogen, carbon, and oxygen
Carbon dioxide	carbon and oxygen
Baking soda	sodium, hydrogen, carbon, and oxygen

RATIO OF ELEMENTS IN A COMPOUND

Elements join in a specific ratio according to their masses to form a compound. For example, in 18 g of water, there are 2 g of hydrogen and 16 g of oxygen. The mass ratio of oxygen to hydrogen is $\frac{2\cancel{g}}{16\cancel{g}}$ or $\frac{1}{8}$. The mass ratio is written as 1 to 8 or 1:8. Every sample of water has a 1:8 mass ratio of hydrogen to oxygen. What happens if a compound has a different mass ratio of hydrogen to water? The compound cannot be water.

Sometimes the same two elements can join in different ratios. However, two different compounds are formed. For example, carbon and oxygen can join to form carbon monoxide, CO, and can also form carbon dioxide, CO_2. Carbon dioxide forms when there is lots of oxygen present.

Math Focus

2. Determine A compound has 40 g of calcium and 160 g of bromine. What is the mass ratio of calcium to bromine in the compound?

____

What Properties Do Compounds Have?

Compounds, just like elements, have physical and chemical properties. Some physical properties of compounds are melting point, boiling point, density, and color. The table below shows some of the physical properties of three colorless liquids. These properties can be used to tell them apart, even though the three compounds look alike in a container.

Critical Thinking

3. Analyze Data How can you tell from the table that all of the compounds listed are liquids at room temperature?

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Physical Properties

	Melting point (°C)	Boiling point (°C)	Odor	Density (g/mL)
Chloroform	−64	61	strong	1.48
Ethanol	−114	75	mild	0.79
Water	0	100	none	1.00

Chemical properties can also be used to identify compounds. Compounds may change when they are exposed to other chemicals or to heat or light. These are chemical properties. The table below shows how the chemical properties of three common white solids differ.

TAKE A LOOK

4. Identify What element is part of both of the compounds on the table that are not flammable?

____

Chemical Properties

	Reacts with acid	Flammable
Sodium chloride (salt)	no	no
Sucrose (sugar)	no	yes
Sodium bicarbonate (baking soda)	yes	no

The properties of a compound differ from those of its elements. Sodium chloride is made of two very reactive and toxic elements—sodium and chlorine. Sodium is a metal that reacts violently with water and can cause damage if it touches skin. Chlorine is a poisonous gas. The combination of the two elements makes sodium chloride. Sodium chloride, or table salt, is safe to eat. ☑

READING CHECK

5. Identify How do the properties of a compound compare to the properties of its elements?

____

How Can Compounds Be Broken Down?

Some compounds can be broken down into their elements by applying heat or using electricity. In the figure below, mercury oxide breaks down to form mercury and oxygen.

When mercury oxide is heated, it undergoes a chemical change in which it separates into the elements mercury and oxygen.

TAKE A LOOK

6. Identify What is used to break down the mercury oxide into mercury and oxygen?

____

What Are Some Important Compounds?

You are surrounded by compounds. Compounds make up the food you eat, the school supplies you use, and the clothes you wear.

COMPOUNDS IN INDUSTRY

Aluminum is an element used in making cans and airplanes. However, aluminum is not found in nature. Aluminum is produced by breaking down the compound aluminum oxide that is found in nature.

Ammonia is another important compound used in industry. It is used to make fertilizers. Ammonia is made by combining nitrogen and hydrogen.

COMPOUNDS IN NATURE

Proteins are compounds found in all living things. The element nitrogen is needed to make proteins. Plants get the nitrogen they need from the soil. Animals get the nitrogen they need by eating plants or other animals that eat plants. The proteins in food are broken down as an animal digests the food. The simpler compounds formed are used by the animal's cells to make the proteins needed by the animal.

Another compound that is important for life is carbon dioxide. You exhale carbon dioxide that was made in your body. Plants take in carbon dioxide, which is used in photosynthesis. Plants use photosynthesis to make compounds called carbohydrates. These carbohydrates can then be broken down for energy by plants and animals.

STANDARDS CHECK

PS 1c Chemical elements do not break down during normal laboratory reactions involving such treatments as heating, exposure to electric current, or reaction with acids. There are more than 100 known elements that combine in a multitude of ways to produce compounds, which account for the living and nonliving substances that we encounter.

7. Identify What are two types of compounds found in nature?

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Name ______________________ Class ______________ Date ____________

Section 2 Review

NSES PS 1a, 1c

SECTION VOCABULARY

compound a substance made up of atoms of two or more different elements joined by chemical bonds	

1. **Explain** How do the particles of a compound differ from the particles of an element?

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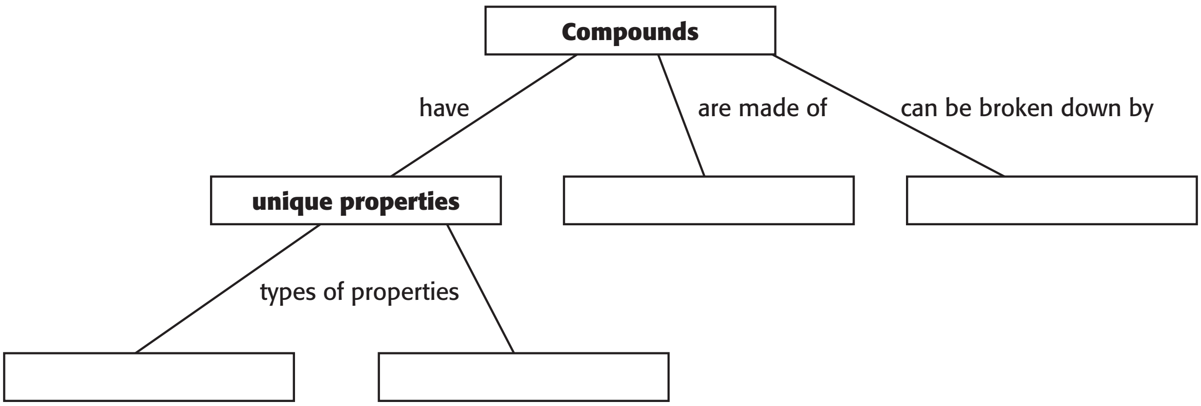
2. **Organize** Fill in the knowledge web below with words from this section.



3. **Draw Conclusions** A label for a plant is made of copper. When it is first put in a garden, it is bright and shiny. After a few months, the label has a dull, greenish color. When you rub your finger over the surface, some soft material rubs off. What happened to the copper?

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4. **Identify** What are two types of energy used to break down compounds?

____

5. **Determine** A compound has 39 g of potassium and 78 g of selenium. What is the mass ratio of potassium to selenium in the compound?

____

SECTION 3

Mixtures

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- How do mixtures differ from elements and compounds?
- How can mixtures be separated?
- What are solutions?

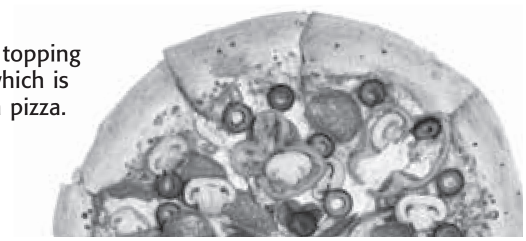
What Are the Properties of Mixtures?

The figure below shows a familiar mixture—a pizza. When you pick up a piece of pizza, you can see different parts of it that have different properties. A **mixture** is a combination of two or more substances that are not chemically combined.

STUDY TIP

Brainstorming The main idea of this section is mixtures of substances. Brainstorm words and phrases related to mixtures. Record your work in your notebook.

You can see each topping on this mixture, which is better known as a pizza.



Chemicals can form mixtures, but no chemical change happens when a mixture is made. That means that each chemical keeps its original identity. The pepperoni and olives on the pizza don't change when they are mixed. Making a mixture is a physical change. ☑

Sometimes, you can see the components of the mixture. For example, if you mix sugar and sand together, you can see the different crystals in the mixture. In other mixtures, such as saltwater, you cannot see the individual parts. Even so, the salt and the water are not changed by making the mixture.

READING CHECK

1. Identify What kind of change occurs when a mixture forms?

____

Because the components of a mixture are not changed, they can often be separated easily. The olives and the pepperoni can easily be picked off the pizza. Iron particles can be pulled out of a mixture with sand using a magnet. ☑

READING CHECK

2. Explain Why can some mixtures be separated easily?

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Other mixtures are not separated so easily. Salt can't simply be picked out of saltwater. Salt can be separated from the water by letting the water evaporate. Heating the saltwater in a container speeds up the process.

How Can Mixtures Be Separated?

The figure below shows three methods of separating the parts of a mixture.

TAKE A LOOK

3. Identify Distillation always requires the addition of energy to convert a substance to a gas. What is the source of energy in the illustration?

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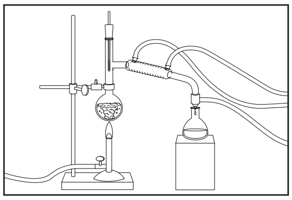
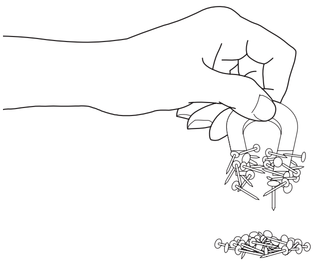


Distillation is the process that separates a mixture based on boiling points. Water in this mixture evaporates and then condenses as pure water.



A **magnet** can be used to separate a mixture of the elements iron and aluminum. Iron is attracted to the magnet, but the aluminum is not.

Critical Thinking

4. Infer How does separating blood into several layers in a centrifuge show that blood is a mixture instead of a pure substance?

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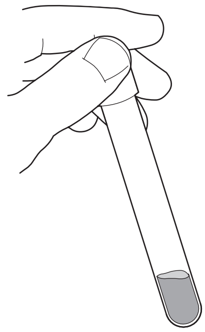

Blood is separated into its parts by a machine called a **centrifuge**. In the test tube of blood above, a layer of plasma rests atop a layer of red blood cells. A centrifuge separates mixtures by the densities of the components.

Another method of separating the parts of a mixture is to dissolve one of the substances in water. Then you filter the mixture and evaporate the water. This is shown in a diagram called a *flow chart*.

TAKE A LOOK

5. Identify What substance is not collected in the process shown by the flow chart?

____

Dissolving In the first step, water is added, and the mixture is stirred. Salt dissolves in water. Sulfur does not. →	**Filtering** In the second step, the mixture is poured through a filter. The filter traps the solid sulfur. →	**Evaporating** In the third step, the water is evaporated. The salt is left in the evaporating dish on the hot plate.

Do Mixtures Have Fixed Ratios?

A compound is made of elements in a fixed, or specified, ratio. For example, water is always two parts hydrogen and one part oxygen.

A mixture, however, does not have a fixed ratio of components. A mixture of salt and water can have a little salt or a lot of salt. Either way, you make a mixture. The figure below compares mixtures and compounds. ☑

READING CHECK

6. Compare How is the ratio of components in a mixture different from the ratio of elements in a compound?

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Mixtures and Compounds

Mixtures	Compounds
Made of elements, compounds, or both	Made of elements
No change in original properties of the components	Change in original properties of the components
Heat or electricity not required for separating components	Heat or electricity required for separating components
Made using any ratio of components	Made using a fixed ratio of components

What Is a Solution?

Saltwater is an example of a solution. A **solution** is a *homogeneous* mixture. This means that a solution appears to be a single substance. The particles of the substances in a solution are evenly spread out. The appearance and properties are the same throughout the solution.

Particles of substances separate and spread evenly throughout a mixture. This process is known as *dissolving*. In a solution, the component that is present in the largest amount is called the **solvent**. Substances present in a solution in smaller amounts are called **solutes**. ☑

Say It

Discuss Read "What Is a Solution?" In small groups, discuss what the solvent is and the solutes are in soft drinks.

READING CHECK

7. Identify In a solution, what component is present in the largest amount?

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WATER AS A SOLVENT

Water is a very common solvent. In a saltwater solution, water is the solvent and salt is the solute. Water is the solvent of many of the solutions that you come across in daily life. In fact, your body contains many solutions in water; blood plasma, saliva, and tears are all solutions. Reactions in cells take place in water solutions. So many different substances dissolve in water that it is sometimes called the "universal solvent." ☑

READING CHECK

8. Identify What is called the universal solvent?

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TYPES OF SOLUTIONS

Water is not the only solvent, though. Many other liquids dissolve substances, some of which do not dissolve in water. *Hydrocarbon solvents*, such as turpentine, are used to dissolve grease and other substances that don't dissolve in water.

In fact, solvents do not have to be liquids. Gases, or even solids, are able to become solvents by dissolving other substances. The air around you is a solution of oxygen and other gases in nitrogen. Many familiar metals are *alloys*. Alloys, such as bronze, are solid solutions in which a metal, copper, is the solvent. Other metal or nonmetal elements are solutes.

The table below shows some examples of solutions. In a solution, the particles of the components are evenly spread throughout the solution.

Critical Thinking

9. Applying Ideas If you look at the side of a quarter, you can see layers of different metals. Is the coin a solid solution? Explain.

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Examples of Solutions in Various States of Matter

State of matter	Example
Gas in a gas	dry air (oxygen in nitrogen)
Gas in a liquid	carbonated water (carbon dioxide in water)
Liquid in a liquid	antifreeze (an alcohol in water)
Solid in a liquid	saltwater (salt in water)
Solid in a solid	brass (zinc in copper)

TAKE A LOOK

10. Identify What is the solute in each of the example solutions? Circle the name of each solute.

How Much Solute Can Be Added to a Solvent?

The amount of solute in a given amount of solvent is called the **concentration**. The concentration of a solution gives the mass of solute in a volume of solution. The units of concentration are grams of solute per milliliter of solvent (g/mL). As more solute is added, the concentration of the solution increases. ☑

Solutions are often described as being concentrated or dilute. A dilute solution is one that has a small amount of solute dissolved in the solvent. A concentrated solution has more solute in solution. These terms do not tell you the actual concentration of the solution, but rather a relative concentration.

READING CHECK

11. Define What two things do you need to know in order to calculate concentration?

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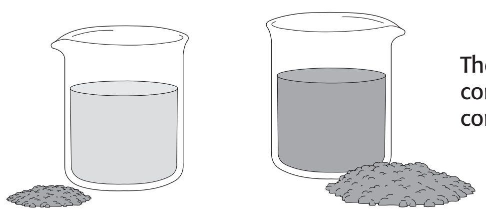

The dilute solution (left) contains less solute than the concentrated solution (right).

SOLUBILITY

Is there a limit to the amount of solute that can be added to a solution? The answer is yes. Think about how you add sugar to lemonade. As you add some sugar to the lemonade and stir it, the sugar dissolves. If you add more sugar, you make a more concentrated solution. Eventually, no matter how much you stir, some sugar remains as a solid at the bottom of the glass.

Suppose you want find the maximum amount of sugar that you could add to the lemonade. You need to know the solubility of sugar in water. **Solubility** is how much solute dissolves in a certain amount of solvent at a certain temperature.

For most solids, the solubility of the solid in water increases as temperature rises. This is shown on the graph below as a line that slopes upward to the right. However, there are some exceptions to this rule. Notice that the line for cerium sulfate slopes downward to the right. This means that as temperature increases, cerium sulfate gets less soluble.

Critical Thinking

12. Infer If you keep adding sugar to lemonade, why does it eventually stop dissolving?

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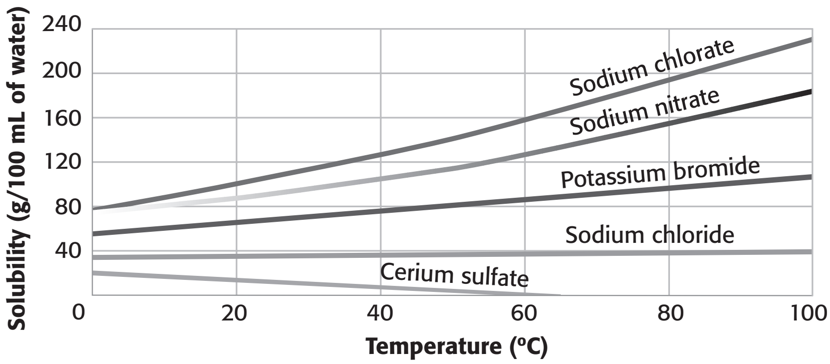
Solubility of Different Solids in Water



Math Focus

13. Read a Graph What is the solubility of sodium chlorate at 60°C?

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CALCULATING CONCENTRATION

The equation for calculating concentration is $concentration = \dfrac{grams\ of\ solute}{milliliters\ of\ solvent}$. Let's try a problem. What is the concentration of a solution that has 35 g of salt dissolved in 175 mL of water?

Step 1: write the equation

$$concentration = \frac{grams\ of\ solute}{milliliters\ of\ solvent}$$

Step 2: substitute values

$$concentration = \frac{35\text{ g}}{175\text{ mL}} = 0.2\text{ g/mL}$$

Math Focus

14. Calculate What is the concentration of a solution if it has 55 g of sugar dissolved in 500 mL of water? Show your work.

DISSOLVING GASES IN LIQUIDS

Most solids are more soluble in liquids at higher temperatures. However, gas becomes less soluble in liquids as the temperature is raised. A soft drink goes flat faster when warm than when cool. The gas that is dissolved in the soft drink cannot stay dissolved when the temperature increases. Therefore, the gas escapes, and the soft drink becomes "flat". ☑

READING CHECK

15. Identify Are gases more soluble at high or low temperatures?

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DISSOLVING SOLIDS FASTER IN LIQUIDS

Several things affect how fast a solid will dissolve. Look at the figure below to see three ways to make a solid dissolve faster. You will enjoy a glass of lemonade sooner if you stir sugar into the lemonade before adding ice.

How to Dissolve Solids Faster

Mixing by stirring or shaking causes the solute particles to separate from one another and spread out more quickly among the solvent particles.

Heating causes particles to move more quickly. The solvent particles can separate the solute particles and spread them out more quickly.

Crushing the solute increases the amount of contact it has with the solvent. The particles of the crushed solute mix with the solvent more quickly.

TAKE A LOOK

16. Identify What are three ways to make a solid dissolve faster?

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What Are Suspensions?

Have you ever shaken a snow globe? If so, you have seen the solid snow particles mix with the water, as shown in the figure below. When you stop shaking the globe, the snow settles to the bottom. This mixture is called a suspension. A **suspension** is a mixture in which the particles of a material are large enough to settle out. ☑

The particles in a suspension are large enough to scatter or block light. The particles are too large to stay mixed without being shaken or stirred.

A suspension can be separated by passing it through a filter. The solid particles get trapped by the filter. The liquid or gas part of the suspension passes through the filter. ☑

READING CHECK

17. Describe What is a suspension?

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READING CHECK

18. Describe How can a suspension be separated?

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What Are Colloids?

Some mixtures have properties between those of solutions and suspensions. A **colloid** is a mixture in which the particles are spread throughout but are not large enough to settle out. The particles of a colloid are not as small as those of a solution. However, they are smaller than those of a suspension. You might be surprised at the number of colloids you see each day. Milk, mayonnaise, gelatin, and whipped cream are all colloids. ☑

The particles of a colloid are large enough to scatter light. An example of this is the headlights of a car that is traveling through fog. However, a colloid cannot be separated by a filter. The particles of the colloid are small enough to pass through the filter.

READING CHECK

19. Describe What is a colloid?

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Properties of Suspensions and Colloids

Suspension This snow globe contains solid particles that will mix with the clear liquid when you shake it up. But the particles will soon fall to the bottom when the globe is at rest.

Colloid This dessert includes two tasty examples of colloids—fruity gelatin and whipped cream.

Name ______________________ Class ______________ Date ______________

Section 3 Review

SECTION VOCABULARY

colloid a mixture consisting of tiny particles that are intermediate in size between those in solutions and those in suspensions and that are suspended in a liquid, solid, or gas

concentration the amount of a particular substance in a given quantity of a mixture, solution, or ore

mixture a combination of two or more substances that are not chemically combined

solubility the ability of one substance to dissolve in another at a given temperature and pressure

solute in a solution, the substance that dissolves the solute

solution a homogeneous mixture throughout which two or more substances are uniformly dispersed

solvent in a solution, the substance in which the solute dissolves

suspension a mixture in which particles of a material are more or less evenly dispersed throughout a liquid or gas

1. **Identify** What are the solvent and solute in a solution containing 100 grams of ethanol and 3 grams of sucrose?

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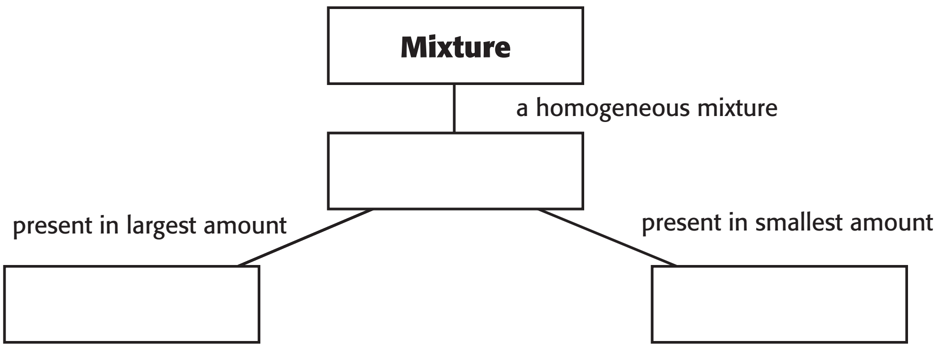
2. **Organize** Complete the Concept Map for a mixture shown below.



3. **Calculate** What is the concentration of a solution if it has 25 g of salt dissolved in 400 mL of water? Show your work.

4. **Apply Concepts** Suppose you add a cup of sugar to hot water and all of the sugar dissolves. Then the water cools and some of the sugar is seen as a solid on the bottom of the beaker. Explain why this happened.

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Name ______________________ Class ______________ Date ______________

CHAPTER 5 | Matter in Motion

SECTION 1

Measuring Motion

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is motion?
- How is motion shown by a graph?
- What are speed and velocity?
- What is acceleration?

National Science Education Standards
PS 2a

What Is Motion?

Look around the room for a moment. What objects are in motion? Are students writing with pencils in their notebooks? Is the teacher writing on the board? Motion is all around you, even when you can't see it. Blood is circulating throughout your body. Earth orbits around the sun. Air particles shift in the wind.

When you watch an object move, you are watching it in relation to what is around it. Sometimes the objects around the object you are watching are at rest. An object that seems to stay in one place is called a *reference point*. When an object changes position over time in relation to a reference point, the object is in **motion**. ☑

You can use *standard reference directions* (such as north, south, east, west, right, and left) to describe an object's motion. You can also use features on Earth's surface, such as buildings or trees, as reference points. The figure below shows how a mountain can be used as a reference point to show the motion of a hot-air balloon.

The hot-air balloon changed position relative to a reference point.

STUDY TIP

Describe Study each graph carefully. In the margin next to the graph, write a sentence or two explaining what the graph shows.

READING CHECK

1. Describe What is the purpose of a reference point?

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TAKE A LOOK

2. Identify What is the fixed reference point in the photos?

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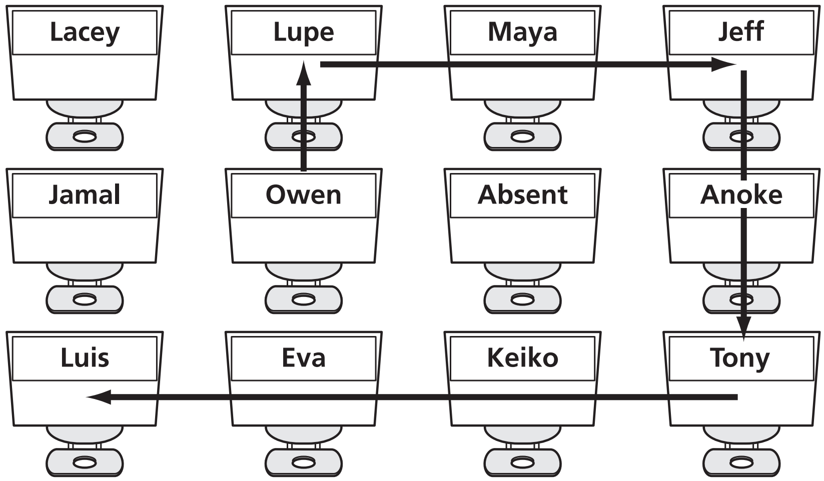
How Can Motion Be Shown?

In the figure below, a sign-up sheet is being passed around a classroom. You can follow its path. The paper begins its journey at the reference point, the origin.



The path taken by a field trip sign-up sheet.

TAKE A LOOK

3. Identify What is the origin, or reference point, of the paper?

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The figure below shows a graph of the position of the sign-up sheet as it is passed around the class. The paper moves in this order:

1. One positive unit on the y-axis
2. Two positive units on the x-axis
3. Two negative units on the y-axis
4. Three negative units on the x-axis

The graph provides a method of using standard reference directions to show motion.

STANDARDS CHECK

PS 2a The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph.

4. Identify What is the shortest path that the paper could take to return to Owen's desk? The paper cannot move diagonally.

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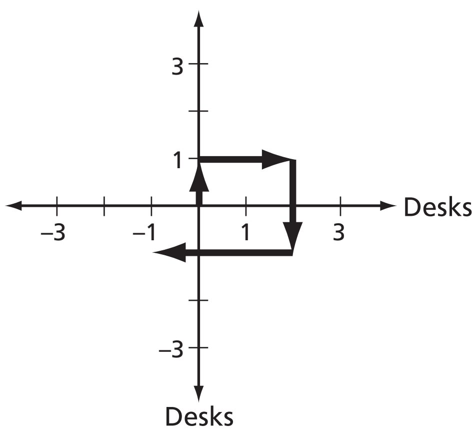


The position of the sign-up sheet as it moves through the classroom.

What Is Speed?

Speed is the rate at which an object moves. It is the distance traveled divided by the time taken to travel that distance. Most of the time, objects do not travel at a constant speed. For example, when running a race, you might begin slowly but then sprint across the finish line.

So, it is useful to calculate *average speed*. We use the following equation:

$$\textit{average speed} = \frac{\textit{total distance}}{\textit{total time}}$$

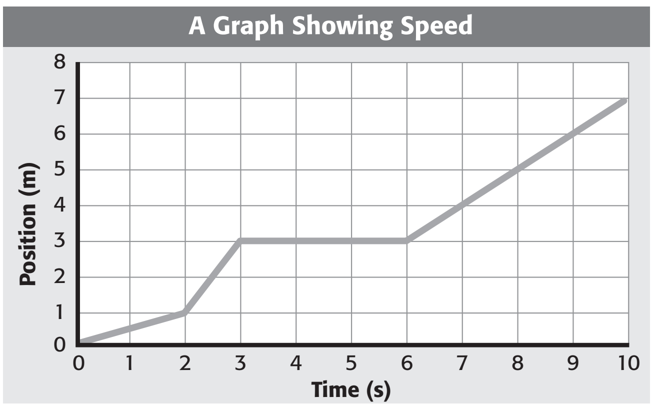
Suppose that it takes you 2 s to walk 4 m down a hallway. You can use the equation above to find your average speed:

$$\textit{average speed} = \frac{4\text{ m}}{2\text{ s}} = 2\text{ m/s}$$

Your speed is 2 m/s. Units for speed include meters per second (m/s), kilometers per hour (km/h), feet per second (ft/s), and miles per hour (mi/h).

How Can You Show Speed on a Graph?

You can show speed on a graph by showing how the position of an object changes over time. The x-axis shows the time it takes to move from place to place. The y-axis shows distance from the reference point.



A graph of position versus time also shows the dog's speed during his walk. The more slanted the line, the faster the dog walked.

Suppose you watched a dog walk beside a fence. The graph above shows the total distance the dog walked in 10 s. The line is not straight because the dog did not walk the same distance in each second. The dog walked slowly for 2 s and then quickly for 1 s. From 3 s to 5 s, the dog did not move.

Critical Thinking

5. Explain The average flight speed of a bald eagle is about 50 km/h. A scientist has measured an eagle flying 80 km/h. How is this possible?

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Math Focus

6. Calculate Suppose you walk 10 m down a hallway in 2.5 s. What is your average speed? Show your work.

TAKE A LOOK

7. Apply Concepts Suppose the dog walks at a constant speed the whole way. On the graph, draw a line showing that the dog walks at a constant speed during the walk.

The average speed of the dog is:

$$\textit{average speed} = \frac{\textit{total distance walked}}{\textit{total time}} = \frac{7\text{ m}}{10\text{ s}} = .07\text{ m/s}$$

What Is Velocity?

Suppose that two birds leave the same tree at the same time. They both fly at 10 km/h for 5 min, then 5 km/h for 10 min. However, they don't end up in the same place. Why not?

The birds did not end up in the same place because they flew in different directions. Their speeds were the same, but because they flew in different directions, their velocities were different. **Velocity** is the speed of an object and its direction. ☑

The velocity of an object is constant as long as both speed and direction are constant. If a bus driving at 15 m/s south speeds up to 20 m/s south, its velocity changes. If the bus keeps moving at the same speed but changes direction from south to east, its velocity also changes. If the bus brakes to a stop, the velocity of the bus changes again.

The table below shows that velocity is a combination of both the speed of an object and its direction.

Speed	Direction	Velocity
15 m/s	south	15 m/s south
20 m/s	south	20 m/s south
20 m/s	east	20 m/s east
0 m/s	east	0 m/s east

Velocity changes when the speed changes, when the direction changes, or when both speed and direction change. The table below describes various situations in which the velocity changes.

Situation	What changes
Raindrop falling faster and faster	
Runner going around a turn on a track	direction
Car taking an exit off a highway	speed and direction
Train arriving at a station	speed
Baseball being caught by a catcher	speed
Baseball hit by a batter	
	speed and direction

READING CHECK

8. Analyze Someone tells you that the velocity of a car is 55 mi/h. Is this correct? Explain your answer.

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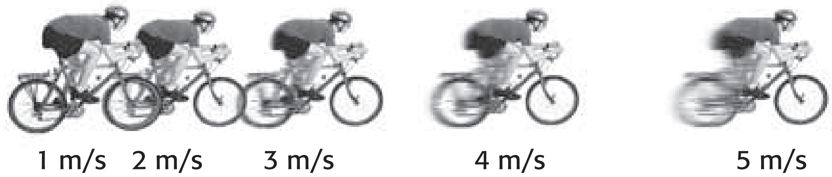
Say It

Share Experiences Have you ever experienced a change in velocity on an amusement park ride? In pairs, share an experience. Explain how the velocity changed—was it a change in speed, direction, or both?

TAKE A LOOK

9. Identify Fill in the empty boxes in the table.



This cyclist moves faster and faster as he peddles his bike south.

TAKE A LOOK

10. Identify Is the cyclist accelerating? How do you know?

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What Is Acceleration?

Acceleration is how quickly velocity changes. An object accelerates if its speed changes, its direction changes, or both its speed and direction change.

The units for acceleration are the units for velocity divided by a unit for time. The resulting unit is often meters per second per second (m/s/s or m/s^2).

Looking at the figure above, you can see that the speed increases by 1 m/s during each second. This means that the cyclist is accelerating at 1 m/s^2.

An increase in speed is referred to as *positive acceleration*. A decrease in speed is referred to as *negative acceleration* or *deceleration*. ☑

READING CHECK

11. Explain What happens to an object when it has negative acceleration?

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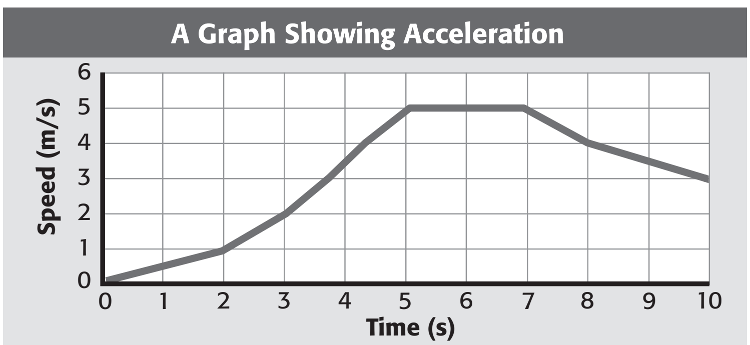
Acceleration can be shown on a graph of speed versus time. Suppose you are operating a remote control car. You push the lever on the remote to move the car forward. The graph below shows the car's acceleration as the car moves east. For the first 5 s, the car increases in speed. The car's acceleration is positive because the speed increases as time passes.

For the next 2 s, the speed of the car is constant. This means the car is no longer accelerating. Then the speed of the car begins to decrease. The car's acceleration is then negative because the speed decreases over time.



The graph of speed versus time also shows that the acceleration of the car was positive and negative. Between 5 s and 7 s, it had no acceleration.

Math Focus

12. Interpret Graphs Is the slope positive or negative when the car's speed increases? Is the slope positive or negative when the car's speed decreases?

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Name ______________________ Class ______________ Date ______________

Section 1 Review

NSES PS 2a

SECTION VOCABULARY

acceleration the rate at which the velocity changes over time; an object accelerates if its speed, direction, or both change

speed the distance traveled divided by the time interval during which the motion occurred

motion an object's change in position relative to a reference point

velocity the speed of an object in a particular direction

1. Identify What is the difference between speed and velocity?

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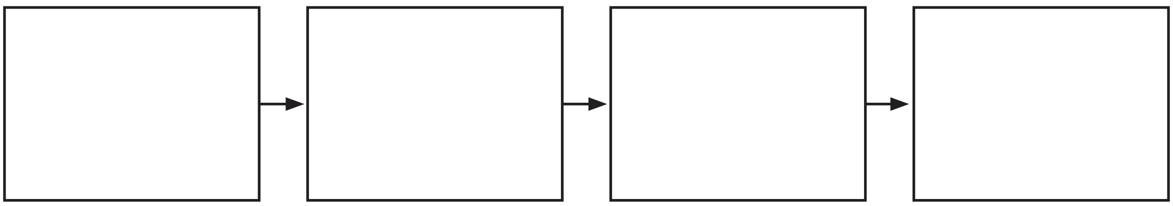
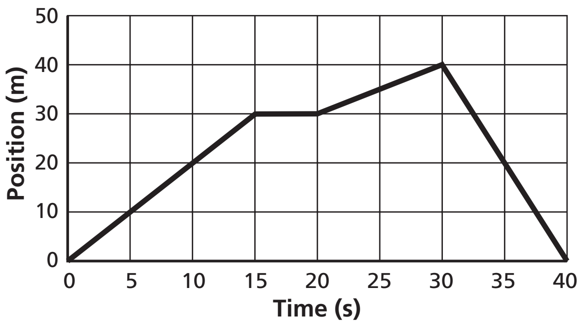
2. Complete a Graphic Organizer Fill in the graphic organizer for a car that starts from one stop sign and approaches the next stop sign. Use the following terms: constant *velocity*, *positive acceleration*, *deceleration*, and *at rest*.



3. Interpret a Graph Describe the motion of the skateboard using the graph below. Write what the skateboard does from time = 0 s to time = 40 s.

Position Verses Time for a Skateboard



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4. Calculate The graph above shows that the skateboard went a total distance of 80 m. What was the average speed of the skateboard? Show your work.

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CHAPTER 5 Matter in Motion

SECTION 2

What Is a Force?

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is a force?
- How do forces combine?
- What is a balanced force?
- What is an unbalanced force?

National Science Education Standards

PS 2b, PS 2c

What Is a Force?

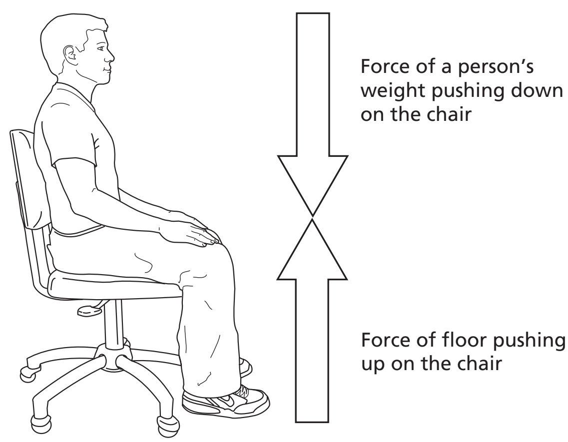
You probably hear people talk about force often. You may hear someone say, "That storm had a lot of force" or "Mrs. Larsen is the force behind the school dance." But what exactly is a force in science?

In science, a **force** is a push or a pull. All forces have two properties: direction and size. A **newton** (N) is the unit that describes the size of a force. ☑

Forces act on the objects around us in ways that we can see. If you kick a ball, the ball receives a push from you. If you drag your backpack across the floor, the backpack is pulled by you.

Forces also act on objects around us in ways that we cannot see. For example, in the figure below, a student is sitting on a chair. What are the forces acting on the chair?

The student is pushing down on the chair, but the chair does not move. Why? The floor is balancing the force by pushing up on the chair. When the forces on an object are *balanced*, the object does not move.



A person sitting on a chair.

STUDY TIP

Brainstorm As you read, think about objects you see every day. What kinds of forces are affecting them? How do the forces affect them?

READING CHECK

1. List What two properties do all forces have?

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TAKE A LOOK

2. Explain Since the chair is not moving, what kind of forces are acting on it?

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How Do Forces Combine?

As you saw in the previous example, more than one force often acts on an object. When all of the forces acting on an object are added together, you determine the **net force** on the object. An object with a net force more than 0 N acting on it will change its state of motion.

TAKE A LOOK

3. Identify On the figure, draw an arrow showing the direction and size of the net force on the piano. The length of the arrow should represent the size of the force.

FORCES IN THE SAME DIRECTION

Suppose your music teacher asks you and a friend to move a piano, as shown in the figure above. You push the piano from one end and your friend pulls the piano from the other end. You and your friend are applying forces in the same direction. Adding the two forces gives you the size of the net force. The direction of the net force is the same as the direction of the forces.

$$125\text{ N} + 120\text{ N} = 245\text{ N}$$
$$\textit{net force} = 245\text{ N to the right}$$

FORCES IN DIFFERENT DIRECTIONS

Critical Thinking

4. Predict What would happen if both dogs pulled the rope with a force of 85 N?

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Suppose two dogs are playing tug of war, as shown above. Each dog is exerting a force on the rope. Here, the forces are in opposite directions. Which dog will win the tug of war?

You can find the size of the net force by subtracting the smaller force from the bigger force. The direction of the net force is the same as that of the larger force:

$$120\text{ N} - 80\text{ N} = 40\text{ N}$$
$$\textit{net force} = 40\text{ N to the right}$$

What Happens When Forces Are Balanced or Unbalanced?

Knowing the net force on an object lets you determine its effect on the motion of the object. Why? The net force tells you whether the forces on the object are balanced or unbalanced.

BALANCED FORCES

When the forces on an object produce a net force of 0 N, the forces are *balanced*. There is no change in the motion of the object. For example, a light hanging from the ceiling does not move. This is because the force of gravity pulls down on the light while the force of the cord pulls upward. ☑

READING CHECK

5. Describe What happens to the motion of an object if the net force acting on it is 0 N?

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The soccer ball moves because the players exert an unbalanced force on the ball each time they kick it.

UNBALANCED FORCES

When the net force on an object is not 0 N, the forces on the object are *unbalanced*. Unbalanced forces produce a change in motion of an object. Think about a soccer game. Players kick the ball to each other. When a player kicks the ball, the kick is an unbalanced force. It sends the ball in a new direction with a new speed.

An object can continue to move when the unbalanced forces are removed. For example, when it is kicked, a soccer ball receives an unbalanced force. The ball continues to roll on the ground after the ball was kicked until an unbalanced force changes its motion.

STANDARDS CHECK

PS 2c If more than one force acts on an object along a straight line, then the forces reinforce or cancel one another, depending on their direction and magnitude. Unbalanced forces will cause changes in the speed or direction of an object's motion.

6. Describe What will happen to an object that has an unbalanced force acting on it?

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Name ______________________ Class ______________ Date ______________

Section 2 Review

NSES PS 2b, PS 2c

SECTION VOCABULARY

force a push or a pull exerted on an object in order to change the motion of the object; force has size and direction **net force** the combination of all the forces acting on an object	**newton** the SI unit for force (symbol, N)

1. Explain If there are many forces acting on an object, how can the net force be 0?

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2. Apply Concepts Identify three forces acting on a bicycle when you ride it.

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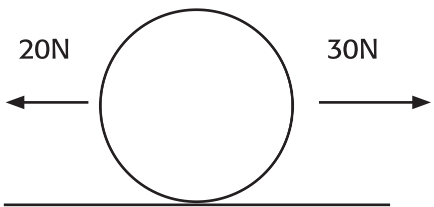
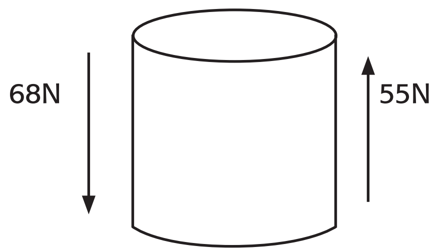
3. Calculate Determine the net force on each of the objects shown below. Don't forget to give the direction of the force.





net force = ______________ *net force* = ______________

4. Explain How will the net force affect the motion of each object shown above?

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5. Describe What is the difference between balanced and unbalanced forces?

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SECTION 3

Friction: A Force That Opposes Motion

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is friction?
- How does friction affect motion?
- What are the types of friction?
- How can friction be changed?

National Science Education Standards
PS 2c

What Causes Friction?

Suppose you are playing soccer and you kick the ball far from you. You know that the ball will slow down and eventually stop. This means that the velocity of the ball will decrease to 0. You also know that an unbalanced force is needed to change the velocity of objects. So, what force is stopping the ball?

Friction is the force that opposes the motion between two surfaces that touch. Friction causes the ball to slow down and then stop. ☑

What causes friction? The surface of any object is rough. Even an object that feels smooth is covered with very tiny hills and valleys. When two surfaces touch, the hills and valleys of one surface stick to the hills and valleys of the other. This contact between surfaces causes friction.

If a force pushes two surfaces together even harder, the hills and valleys come closer together. This increases the friction between the surfaces.

STUDY TIP

Imagine As you read, think about the ways that friction affects your life. Make a list of things that might happen, or not happen, if friction did not exist.

READING CHECK

1. Describe What is friction?

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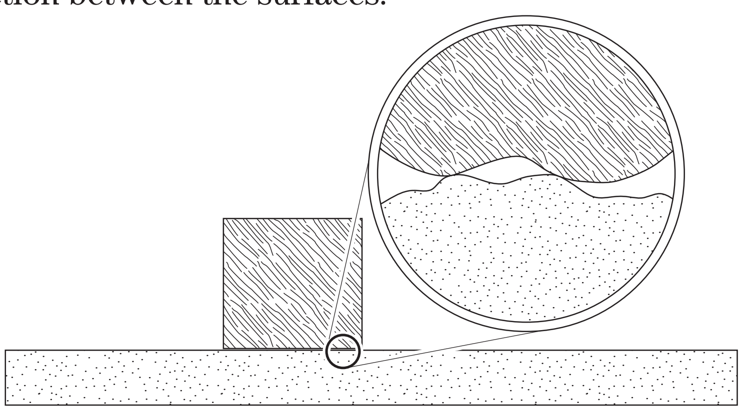

When the hills and valleys of one surface stick to the hills and valleys of another surface, friction is created.

TAKE A LOOK

2. Explain Why can't you see the hills and valleys without a close-up view of the objects?

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STANDARDS CHECK

PS 2c If more than one force acts on an object along a straight line, then the forces reinforce or cancel one another, depending on their direction and magnitude. Unbalanced forces will cause changes in the speed or direction of an object's motion.

3. Identify Two identical balls begin rolling next to each other at the same velocity. One is on a smooth surface and one is on a rough surface. Which ball will stop first? Why?

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What Affects the Amount of Friction?

Imagine that a ball is rolled over a carpeted floor and another ball is rolled over a wood floor. Which surface affects a ball more?

The smoothness of the surfaces of the objects affects how much friction exists. Friction is usually greater between materials that have rough surfaces than materials that have smooth surfaces. The carpet has greater friction than the wood floor, so the ball on the carpet stops first.

What Types of Friction Exist?

There are two types of friction: kinetic friction and static friction. *Kinetic friction* occurs when force is applied to an object and the object moves. When a cat slides along a countertop, the friction between the cat and the countertop is kinetic friction. The word kinetic means "moving."

The amount of kinetic friction between moving surfaces depends partly on how the surfaces move. In some cases, the surfaces slide past each other like pushing a box on the floor. In others, one surface rolls over another like a moving car on a road. There is usually less friction between surfaces that roll than between surfaces that slide.

Static friction occurs when force applied to an object does not cause the object to move. When you try to push a piece of furniture that will not move, the friction observed is static friction.

TAKE A LOOK

4. Describe When does static friction become kinetic friction?

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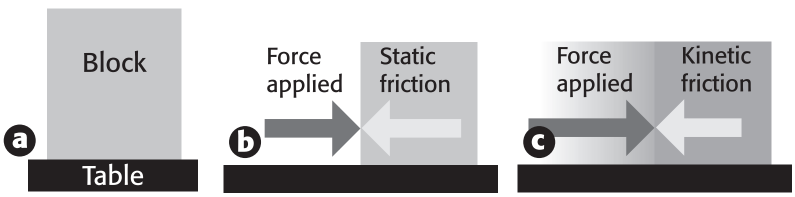

a: There is no friction between the block and the table when no force is applied to the block.

b: If a small force (dark gray arrow) is applied to the block, the block does not move. The force of static friction (light gray arrow) balances the force applied.

c: When the force applied to the block is greater than the force of static friction, the block starts moving. When the block starts moving, kinetic friction (light gray arrow) replaces all of the static friction and opposes the force applied.

How Can Friction Be Decreased?

To reduce the amount of friction, you can apply a lubricant between two surfaces. A *lubricant* is a substance that reduces the friction between surfaces. Motor oil, wax, and grease are examples of lubricants.

You can also reduce friction by rolling, rather than sliding, an object. A refrigerator on rollers is much easier to move than one that just slides.

Another way of reducing friction is to smooth the surfaces that rub against each other. Skiers have their skis sanded down to make them smoother. This makes it easier for the skis to slide over the snow.

Critical Thinking

5. Infer How does a lubricant reduce the amount of friction?

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If you work on a bicycle, you may get dirty from the chain oil. This lubricant reduces friction between sections of the chain.

TAKE A LOOK

6. Identify Why is it important to put oil on a bicycle chain?

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How Can Friction Be Increased?

Increasing the amount of friction between surfaces can be very important. For example, when the tires of a car grip the road better, the car stops and turns corners much better. Friction causes the tires to grip the road. Without friction, a car could not start moving or stop.

On icy roads, sand can be used to make the road surface rougher. Friction increases as surfaces are made rougher.

You can also increase friction by increasing the force between the two objects. Have you ever cleaned a dirty pan in the kitchen sink? You may have found that cleaning the pan with more force allows you to increase the amount of friction. This makes it easier to clean the pan. ☑

READING CHECK

7. Identify Name two things that can be done to increase the friction between surfaces.

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Name ______________________ Class ______________ Date ______________

Section 3 Review

NSES PS 2c

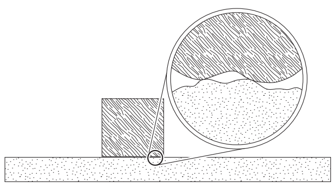
SECTION VOCABULARY

friction a force that opposes the motion between two surfaces that are in contact	

1. **Describe** What effect does friction have when you are trying to move an object at rest?

2. **Compare** Explain the difference between static friction and kinetic friction. Give an example of each.

3. **Compare** The figure on the left shows two surfaces up close. On the right, draw a sketch. Show what the surfaces of two objects that have less friction between them might look like.



4. **Analyze** Name three common lubricants and describe why they are used.

5. **Analyze** In what direction does friction always act?

6. **Identify** A car is driving on a flat road. When the driver hits the brakes, the car slows down and stops. What would happen if there were no friction between the tires and the road? Explain your answer.

SECTION 4

Gravity: A Force of Attraction

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is gravity?
- How are weight and mass different?

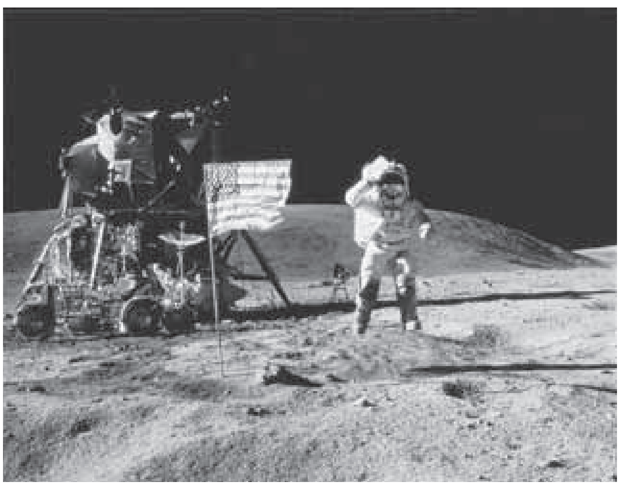
National Science Education Standards
PS 2c

How Does Gravity Affect Matter?

Have you ever seen a video of astronauts on the moon? The astronauts bounce around like beach balls even though the space suits weighed 180 pounds on Earth. See the figure below. Why is it easier for a person to move on the moon than on Earth? The reason is that the moon has less gravity than Earth. **Gravity** is a force of attraction, or a pull, between objects. It is caused by their masses. ☑

All matter has mass. Gravity is a result of mass. Therefore all matter has gravity. This means that all objects attract all other objects in the universe! The force of gravity pulls objects toward each other. For example, gravity between the objects in the solar system holds the solar system together. Gravity holds you to Earth.

Small objects also have gravity. You have gravity. This book has gravity. Why don't you notice the book pulling on you or you pulling on the book? The reason is that the book's mass and your mass are both small. The force of gravity caused by small mass is not large enough to move either you or the book.



Because the moon has less gravity than Earth does, walking on the moon's surface was a very bouncy experience for the Apollo astronauts.

STUDY TIP

Discuss Ideas Take turns reading this section out loud with a partner. Stop to discuss ideas that seem confusing.

READING CHECK

1. Describe What is gravity?

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Critical Thinking

2. Infer Why can't you see two soccer balls attracting each other?

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What Is the Law of Universal Gravitation?

According to a story, Sir Isaac Newton, while sitting under an apple tree, watched an apple fall. This gave him a bright idea. Newton realized that an unbalanced force on the apple made it fall.

He then thought about the moon's orbit. Like many others, Newton had wondered what kept the planets in the sky. He realized that an unbalanced force on the moon kept it moving around Earth. Newton said that these forces are both gravity.

Newton's ideas are known as the *law of universal gravitation*. Newton said that all objects in the universe attract each other because of gravitational force. ☑

This law says that gravitational force depends on two things:

1. the masses of the objects
2. the distance between the objects

The word "universal" means that the law applies to all objects. See the figure below. ☑

Sir Isaac Newton said that the same unbalanced force caused the motions of the apple and the moon.

READING CHECK

3. Describe What is the law of universal gravitation?

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READING CHECK

4. Identify What two things determine gravitational force?

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STANDARDS CHECK

PS 2c If more than one force acts on an object along a straight line, then the forces reinforce or cancel one another, depending on their direction and magnitude. Unbalanced forces will cause changes in the speed or direction of an object's motion.

5. Identify What is the unbalanced force that affects the motions of a falling apple and the moon?

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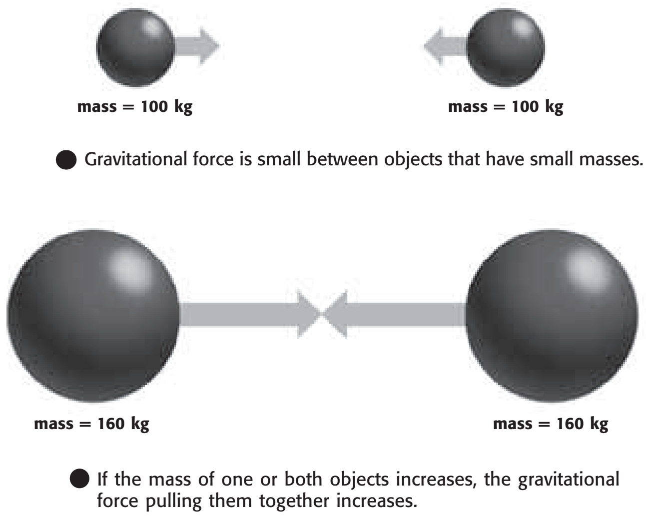
How Does Mass Affect Gravity?

Imagine an elephant and a cat. Because the elephant has a larger mass than the cat does, gravity between the elephant and Earth is larger. So, the cat is much easier to pick up than the elephant. The gravitational force between objects depends on the masses of the objects. See the figure below.



The arrows indicate the gravitational force between two objects. The length of the arrows indicates the magnitude of the force.

TAKE A LOOK

6. Compare Is there more gravitational force between objects with small masses or objects with large masses?

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Mass also explains why an astronaut on the moon can jump around so easily. The moon has less mass than Earth does. This gives the moon a weaker pull on objects than the pull of Earth. The astronaut is not being pulled toward the moon as much as he is by Earth. So the astronaut can jump higher and more easily on the moon.

The universal law of gravitation can let us predict what happens to gravity when mass changes. According to the universal law of gravitation, suppose there is a 5 N force of gravity between two objects. If the mass of one object doubles and the other stays the same, the force of gravity also doubles.

Let's try a problem. The force due to gravity between two objects is 3 N. If the mass of one object triples and the other stays the same, what is the new force of gravity?

Solution: Since the mass of one object tripled and the other stayed the same, the force of gravity also triples. It is 9 N.

Math Focus

7. Infer Two objects of equal mass have a force of gravity of 6 N between them. Imagine the mass of one is cut in half and the other stays the same, what is the force due to gravity?

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How Does Distance Affect Gravity?

The mass of the sun is 300,000 times bigger than that of Earth. However, if you jump up, you return to Earth every time you jump rather than flying toward the sun. If the sun has more mass, then why doesn't it have a larger gravitational pull on you?

This is because the gravitational force also depends on the distance between the objects. As the distance between two objects gets larger, the force of gravity gets much smaller. And as the distance between objects gets smaller, the force of gravity gets much bigger. This is shown in the figure below.

Although the sun has tremendous mass, it is also very far away. This means that it has very little gravitational force on your body or on small objects around you. The sun does have a large gravitational force on planets because the masses of planets are very large.

Critical Thinking

8. Analyze The sun is much more massive than Earth. Why is the force of gravity between you and the sun so much less than Earth's gravity and you?

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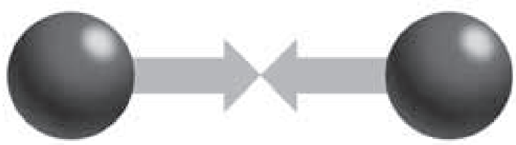

● Gravitational force is large when the distance between two objects is small.

TAKE A LOOK

9. Describe Use the diagram to describe the effect of distance on gravitational force.

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● If the distance between two objects increases, the gravitational force pulling them together decreases rapidly.

The length of the arrows indicates the magnitude of the gravitational force between two objects.

What Is the Difference Between Mass and Weight?

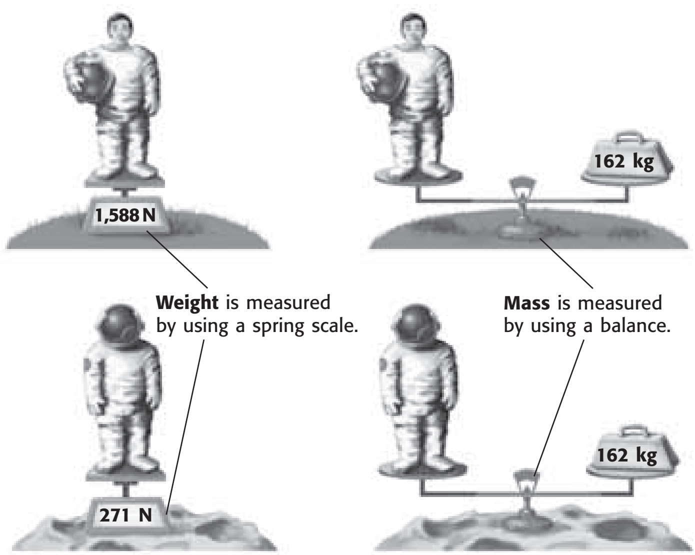
You have learned that gravity is a force of attraction between objects. **Weight** is a measure of the gravitational force on an object. The SI unit for weight is the newton (N).

Mass is a measure of the amount of matter in an object. This seems similar to weight, but it is not the same. An object's mass does not change when gravitational forces change, but its weight does. Mass is usually expressed in kilograms (kg) or grams (g). ☑

In the figure below, you can see the difference between mass and weight. Compare the astronaut's mass and weight on Earth to his mass and weight on the moon.

READING CHECK

10. Contrast How is mass different from weight?



TAKE A LOOK

11. Identify What is the weight of the astronaut on Earth? What is the weight of the astronaut on the moon?

Gravity can cause objects to move because it is a type of force. But gravity also acts on objects that are not moving, or *static*. Earth's gravity pulls objects downward. However, not all objects move downward. Suppose a framed picture hangs from a wire. Gravity pulls the picture downward, but tension (the force in the wire) pulls the picture upward. The forces are balanced so that framed picture does not move.

Critical Thinking

12. Contrast What forces act on a framed picture on a shelf?

Name ____________________ Class ____________ Date ____________

Section 4 Review

NSES PS 2c

SECTION VOCABULARY

gravity a force of attraction between objects that is due to their masses

mass a measure of the amount of matter in an object

weight a measure of the gravitational force exerted on an object; its value can change with the location of the object in the universe

1. **Identify** What is gravity? What determines the gravitational force between objects?

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2. **Describe** A spacecraft is moving toward Mars. Its rocket engines are turned off. As the spacecraft nears the planet, what will happen to the pull of Mars's gravity?

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3. **Summarize** An astronaut travels from Earth to the moon. How does his mass change? How does his weight change? Explain.

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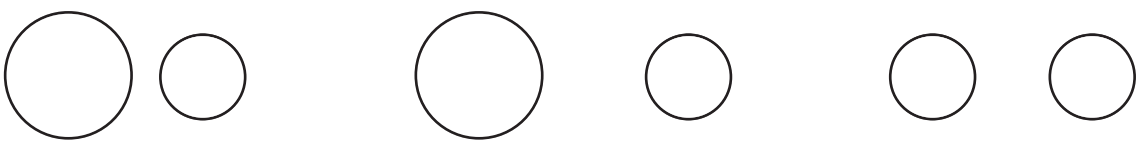
4. **Applying Concepts** An astronaut visits Planet X. Planet X has the same radius as Earth but has twice the mass of Earth. Fill in the table below to show the astronaut's mass and weight on Planet X. (Hint: Newton's law of universal gravitation says that when the mass of one object doubles, the force due to gravity also doubles.)

	Earth	**Planet X**
Mass of astronaut	80 kg	
Weight of astronaut	784 N	

5. **Select** Each of the spheres shown below is made of iron. Circle the pair of spheres that would have the greatest gravitational force between them. Below the spheres, explain the reason for your choice.



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Name ______________________ Class ______________ Date ____________

CHAPTER 6 Forces and Motion

SECTION 1

Gravity and Motion

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

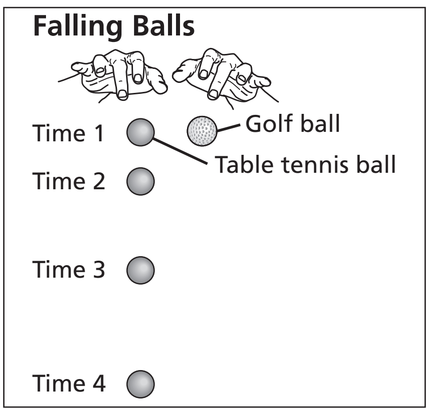
- How does gravity affect objects?
- How does air resistance affect falling objects?
- What is free fall?
- Why does an object that is thrown horizontally follow a curved path?

How Does Gravity Affect Falling Objects?

In ancient Greece, a great thinker named Aristotle said that heavy objects fall faster than light objects. For almost 2,000 years, people thought this was true. Then, in the late 1500s, an Italian scientist named Galileo Galilei proved that heavy and light objects actually fall at the same rate.

It has been said that Galileo proved this by dropping two cannonballs from the top of a tower at the same time. The cannonballs were the same size, but one was much heavier than the other. The people watching saw both cannonballs hit the ground at the same time. ☑

Why don't heavy objects fall faster than light objects? Gravity pulls on heavy objects more than it pulls on light objects. However, heavy objects are harder to move than light objects. So, the extra force from gravity on the heavy object is balanced by how much harder it is to move.



STUDY TIP

Practice After every page, stop reading and think about what you've read. Try to think of examples from everyday life. Don't go on to the next section until you think you understand.

READING CHECK

1. Describe What did the people watching the cannonballs see that told them the cannonballs fell at the same rate?

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TAKE A LOOK

2. Predict The golf ball is heavier than the table tennis ball. On the figure, draw three circles to show where the golf ball will be at times 2, 3, and 4.

How Much Acceleration Does Gravity Cause?

Because of gravity, all objects accelerate, or speed up, toward Earth at a rate of 9.8 meters per second per second. This is written as 9.8 m/s/s or 9.8 m/s^2. So, for every second an object falls, its velocity (speed) increases by 9.8 m/s. This is shown in the figure below.

Math Focus

3. Calculate How fast is the ball moving at the end of the third second? Explain your answer.

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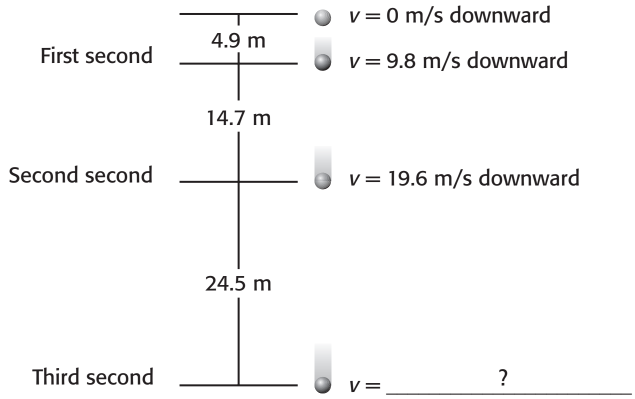


A falling object accelerates at a constant rate. The object falls faster and farther each second than it did the second before.

What Is the Velocity of a Falling Object?

Suppose you drop a rock from a cliff. How fast is it going when it reaches the bottom? If you have a stopwatch, you can calculate its final velocity.

If an object starts from rest and you know how long it falls, you can calculate its final velocity by using this equation:

$$v_{\text{final}} = g \times t$$

In the equation, v_{final} stands for final velocity in meters per second, g stands for the acceleration due to gravity (9.8 m/s^2), and t stands for the time the object has been falling (in seconds).

If the rock took 4 s to hit the ground, how fast was it falling when it hit the ground?

Math Focus

4. Calculate A penny is dropped from the top of a tall stairwell. What is the velocity of the penny after it has fallen for 2 s? Show your work.

Step 1: Write the equation.

$$v_{\text{final}} = g \times t$$

Step 2: Place values into the equation, and solve for the answer.

$$v_{\text{final}} = 9.8\ \frac{\text{m/s}}{\cancel{\text{s}}} \times 4\ \cancel{\text{s}} = 39.2\ \text{m/s}$$

The velocity of the rock was 39.2 m/s when it hit the ground.

How Can You Calculate How Long an Object Was Falling?

Suppose some workers are building a bridge. One of them drops a metal bolt from the top of the bridge. When the bolt hits the ground, it is moving 49 m/s. How long does it take the bolt to fall to the ground?

Step 1: Write the equation.

$$t = \frac{v_{\text{final}}}{g}$$

Step 2: Place values into the equation, and solve for the answer.

$$t = \frac{49 \cancel{\text{m/s}}}{9.8 \frac{\cancel{\text{m/s}}}{\text{s}}} = 5 \text{ s}$$

The bolt fell for 5 s before it hit the ground.

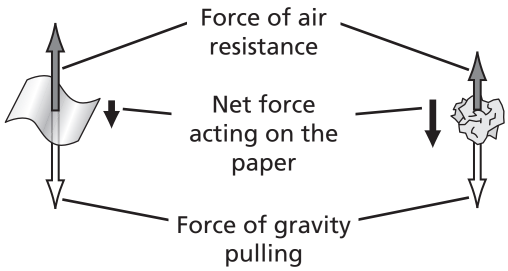
How Does Air Resistance Affect Falling Objects?

Try dropping a pencil and a piece of paper from the same height. What happens? Does this simple experiment show what you just learned about falling objects? Now crumple the paper into a tight ball. Drop the crumpled paper and the pencil from the same height.

What happens? The flat paper falls more slowly than the crumpled paper because of air resistance. *Air resistance* is the force that opposes the motion of falling objects. ☑

How much air resistance will affect an object depends on the size, shape, and speed of the object. The flat paper has more surface area than the crumpled sheet. This causes the flat paper to fall more slowly.

How Air Resistance Affects Velocity



Math Focus

5. Calculate A rock falls from a cliff and hits the ground with a velocity of 98 m/s. How long does the rock fall? Show your work.

READING CHECK

6. Identify Which has more air resistance, the flat paper or the crumpled paper?

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TAKE A LOOK

7. Explain Why does the crumpled paper fall faster than the flat paper?

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What Is Terminal Velocity?

As the speed of a falling body increases, air resistance also increases. The upward force of air resistance keeps increasing until it is equal to the downward force of gravity. At this point, the total force on the object is zero, so the object stops accelerating.

When the object stops accelerating, it does not stop moving. It falls without speeding up or slowing down. It falls at a constant velocity called the terminal velocity. **Terminal velocity** is the speed of an object when the force of air resistance equals the force of gravity. ☑

Air resistance causes the terminal velocity of hailstones to be between 5 m/s and 40 m/s. Without air resistance, they could reach the ground at a velocity of 350 m/s! Air resistance also slows sky divers to a safe landing velocity.

READING CHECK

8. Describe When does an object reach its terminal velocity?

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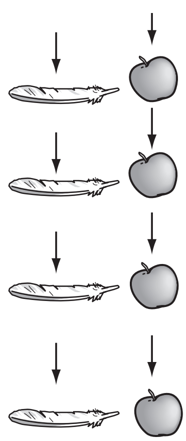
TAKE A LOOK

9. Identify A sky diver is falling at terminal velocity. Draw and label an arrow showing the direction and size of the force due to gravity on the sky diver. Draw and label a second arrow showing the direction and size of the force of air resistance on the sky diver.

The parachute increases the air resistance of this sky diver and slows him to a safe terminal velocity.

What Is Free Fall?

Free fall is the motion of an object when gravity is the only force acting on the object. The figure below shows a feather and an apple falling in a vacuum, a place without any air. Without air resistance, they fall at the same rate.



Air resistance usually causes a feather to fall more slowly than an apple falls. But in a vacuum, a feather and an apple fall with the same acceleration because both are in free fall.

TAKE A LOOK

10. Predict When air resistance acts on the apple and the feather, which falls faster?

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Orbiting Objects Are in Free Fall

Satellites and the space shuttle orbit Earth. You may have seen that astronauts inside the shuttle float unless they are belted to a seat. They seem weightless. In fact, they are not weightless, because they still have mass.

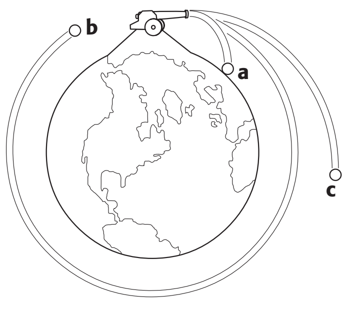
Weight is a measure of the pull of gravity on an object. Gravity acts between any two objects in the universe. Every object in the universe pulls on every other object. Every object with mass has weight. ☑

The force of gravity between two objects depends on the masses of the objects and how far apart they are. The more massive the objects are, the greater the force is. The closer the objects, the greater the force.

Your weight is determined mostly by the mass of Earth because it is so big and so close to you. If you were to move away from Earth, you would weigh less. However, you would always be attracted to Earth and to other objects, so you would always have weight.

Astronauts float in the shuttle because the shuttle is in free fall. That's right—the shuttle is always falling. Because the astronauts are in the shuttle, they are also falling. The astronauts and the shuttle are falling at the same rate. That is why the astronauts seem to float inside the shuttle. ☑

Isaac Newton first predicted this kind of free fall in the late 17th century. He reasoned that if a cannon were placed on a mountain and fired, the cannon ball would fall to Earth. Yet, if the cannon ball were shot with enough force, it would fall at the same rate that Earth's surface curves away. The cannon ball would never hit the ground, so it would orbit Earth. The figure below shows this "thought experiment."



Newton's cannon is a "thought experiment." Newton reasoned that a cannon ball shot hard enough from a mountain top would orbit Earth.

READING CHECK

11. Explain When will an object have no weight? Explain your answer.

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READING CHECK

12. Explain Why don't the astronauts in the orbiting shuttle fall to the floor?

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Critical Thinking

13. Infer Compared with cannon ball **b**, what do you think cannon ball **c** would do?

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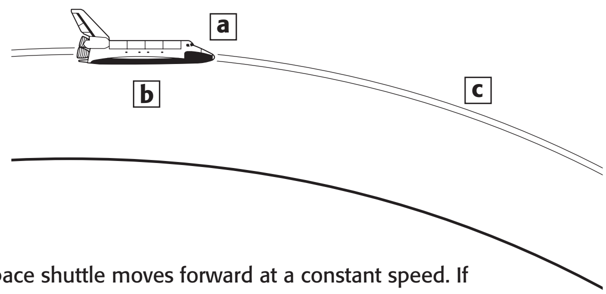
What Motions Combine to Make an Object Orbit?

An object is in orbit (is orbiting) when it is going around another object in space. When the space shuttle orbits Earth, it is moving forward. Yet, the shuttle is also in free fall. The figure below shows how these two motions combine to cause orbiting.



a. The space shuttle moves forward at a constant speed. If there were no gravity, the space shuttle would continue to move in a straight line.
b. The space shuttle is in free fall because gravity pulls it toward Earth. The space shuttle would move straight down if it were not traveling forward.
c. The path of the space shuttle follows the curve of Earth's surface. This path is known as an orbit.

TAKE A LOOK
14. Identify On the figure, draw a line showing the path that the space shuttle would take if gravity were not acting on it.

What Force Keeps an Object in Orbit?

Many objects in space are orbiting other objects. The moon orbits Earth, while Earth and the other planets orbit the sun. These objects all follow nearly circular paths. An object that travels in a circle is always changing direction.

If all the forces acting on an object balance each other out, the object will move in the same direction at the same speed forever. So, objects cannot orbit unless there is an unbalanced force acting on them. *Centripetal force* is the force that keeps an object moving in a circular path. Centripetal force pulls the object toward the center of the circle. The centripetal force of a body orbiting in space comes from gravity. ☑

READING CHECK
15. Identify What must be applied to an object to change its direction?

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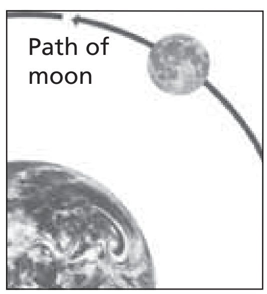


The moon stays in orbit around Earth because Earth's gravity provides a centripetal force on the moon.

TAKE A LOOK
16. Identify Draw an arrow on the figure to show the direction that centripetal force acts on the moon.

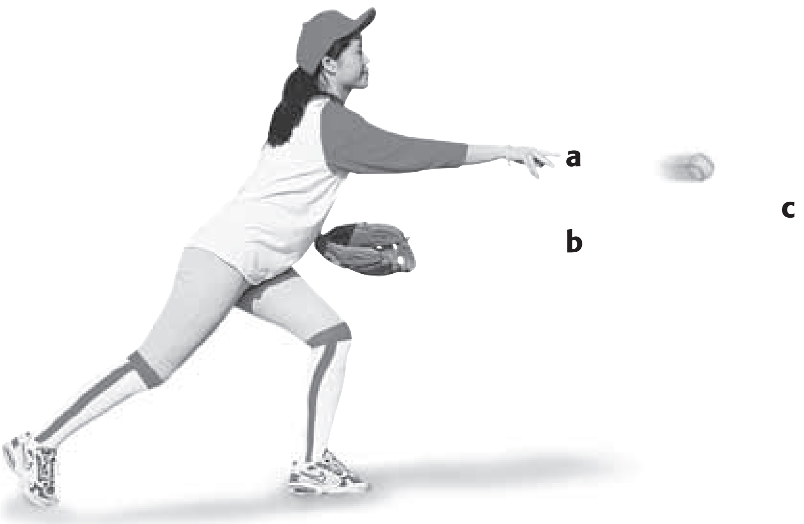
What Is Projectile Motion?

Projectile motion is the curved path an object follows when it is thrown near the Earth's surface. The motion of a ball that has been thrown forward is an example of projectile motion.

Projectile motion is made up of two parts: horizontal motion and vertical motion. Horizontal motion is motion that is parallel to the ground. Vertical motion is motion that is perpendicular to the ground. The two motions do not affect each other. Instead, they combine to form the curved path we call projectile motion. ☑

When you throw a ball forward, your hand pushes the ball to make it move forward. This force gives the ball its horizontal motion. After the ball leaves your hand, no horizontal forces act on the ball (if we forget air resistance for now). So the ball's horizontal velocity does not change after it leaves your hand.

However, gravity affects the vertical part of projectile motion. Gravity pulls the ball straight down. All objects that are thrown accelerate downward because of gravity.



a After the ball leaves the pitcher's hand, the ball's ____________ velocity is constant.

b The ball's vertical velocity increases because ____________ causes it to accelerate downward.

c The two motions combine to form a ____________ path.

READING CHECK

17. List What two motions combine to make projectile motion?

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Critical Thinking

18. Infer If you are playing darts and you want to hit the bulls-eye, where should you aim?

____

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TAKE A LOOK

19. List On the figure, fill in the three blanks with the correct words.

20. Apply Concepts If there were no air resistance, how fast would the ball's downward velocity be changing? Explain your answer.

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Name ______________________ Class ______________ Date ______________

Section 1 Review

SECTION VOCABULARY

free fall the motion of a body when only the force of gravity is acting on the body **projectile motion** the curved path that an object follows when thrown, launched, or otherwise projected near the surface of Earth	**terminal velocity** the constant velocity of a falling object when the force of air resistance is equal in magnitude and opposite in direction to the force of gravity

1. **Explain** Is a parachutist in free fall? Why or why not?

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2. **Identify Cause and Effect** Complete the table below to show how forces affect objects.

Cause	Effect
Gravity acts on a falling object.	
	The falling object reaches terminal velocity.

3. **Calculate** A rock at rest falls off a cliff and hits the ground after 3.5 s. What is the rock's velocity just before it hits the ground? Show your work.

4. **Identify** What force must be applied to an object to keep it moving in a circular path?

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5. **Explain** Which part of projectile motion is affected by gravity? Explain how it is affected.

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SECTION 2
Newton's Laws of Motion

BEFORE YOU READ

After you read this section, you should, be able to answer these questions:

- What is net force?
- What happens to objects that have no net force acting on them?
- How are mass, force, and acceleration related?
- How are force pairs related by Newton's third law of motion?

National Science Education Standards
PS 2b, 2c

What Is a Net Force?

A *force* is a push or a pull. It is something that causes an object to change speed or direction. There are forces acting on all objects every second of the day. They are acting in all directions.

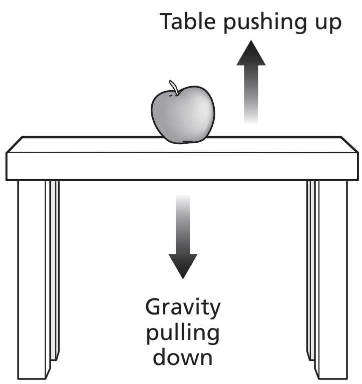
At first, this might not make sense. After all, there are many objects that are not moving. Are forces acting on an apple sitting on a desk? The answer is yes. Gravity is pulling the apple down. The desk is pushing the apple up.

In the figure below, the arrows represent the size and direction of the forces on the apple.

STUDY TIP

Summarize in Pairs Read each of Newton's laws silently to yourself. After reading each law, talk about what you read with a partner. Together, try to figure out any ideas that you didn't understand.

Forces Acting on an Apple



TAKE A LOOK

1. Compare What is the size of the force pulling the apple down compared with the size of the force pushing it up?

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So, why doesn't the apple move? The apple is staying where it is because all the forces balance out. There are no unbalanced forces. That is, there is no net force on the apple. *Net force* is the total force acting on an object. If the net force on an object is zero, the object will not change speed or direction. ☑

READING CHECK

2. Explain What will not happen to an object if the net force acting on it is zero?

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What Is Newton's First Law of Motion?

Newton's first law of motion describes objects that have no unbalanced forces, or no net force, acting on them. It has two parts:

1. An object at rest will remain at rest.
2. An object moving at a constant velocity will continue to move at a constant velocity. ☑

READING CHECK

3. Identify What will happen to an object at rest if no unbalanced forces act on it?

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4. Identify What will happen to an object moving at constant velocity?

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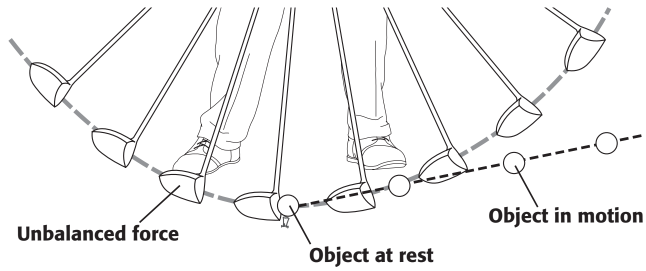
PART 1: OBJECTS AT REST

An object that is not moving is said to be at rest. A golf ball on a tee is an example of an object at rest. An object at rest will not move unless an unbalanced force is applied to it. The golf ball will keep sitting on the tee until it is struck by a golf club.



A golf ball will remain at rest on a tee until it is acted on by the unbalanced force of a moving club.

TAKE A LOOK

5. Predict What would happen to the distances between the moving-ball images if the unbalanced force were greater?

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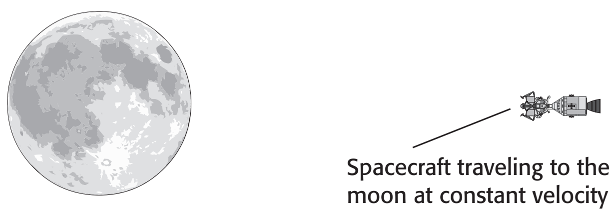
PART 2: OBJECTS IN MOTION

The second part of Newton's first law can be hard to picture. On Earth, all objects that are moving eventually slow down and stop, even if we are no longer touching them. This is because there is always a net force acting on these objects. We will talk about this force later.

However, in outer space, Newton's first law can be seen easily. During the Apollo missions to the moon, the spacecraft turned off its engine when it was in space. It then drifted thousands of miles to the moon. It could keep moving forward without turning on its engines because there was no unbalanced force to slow it down.



TAKE A LOOK

6. Apply Concepts What must the spacecraft do to land softly on the moon?

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How Does Friction Affect Newton's First Law?

On Earth, friction makes observing Newton's first law difficult. If there were no friction, a ball would roll forever until something got in its way. Instead, it stops quickly because of friction.

Friction is a force that is produced whenever two surfaces touch each other. Friction always works against motion. ☑

Friction makes a rolling ball slow down and stop. It also makes a car slow down when its driver lets up on the gas pedal.

READING CHECK

7. Describe How does friction affect the forward motion of an object?

____

What Is Inertia?

Newton's first law is often called the *law of inertia*. **Inertia** is the ability of an object to resist any change in motion. In order to change an object's motion, a force has to overcome the object's inertia. So, in order to move an object that is not moving, you have to apply a force to it. Likewise, in order to change the motion of an object that is moving, you have to apply a force to it. The greater the object's inertia, the harder it is to change its motion.

STANDARDS CHECK

PS 2b An object that is not subjected to a force will continue to move at constant speed and in a straight line.

Word Help: constant
a quantity whose value does not change

8. Explain When a moving car stops suddenly, why does a bag of groceries on the passenger seat fly forward into the dashboard?

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How Are Mass and Inertia Related?

An object that has a small mass has less inertia than an object with a large mass. Imagine a golf ball and a bowling ball. Which one is easier to move?

The golf ball has much less mass than the bowling ball. The golf ball also has much less inertia. This means that a golf ball will be much easier to move than a bowling ball. ☑

READING CHECK

9. Explain Why is a golf ball easier to throw than a bowling ball?

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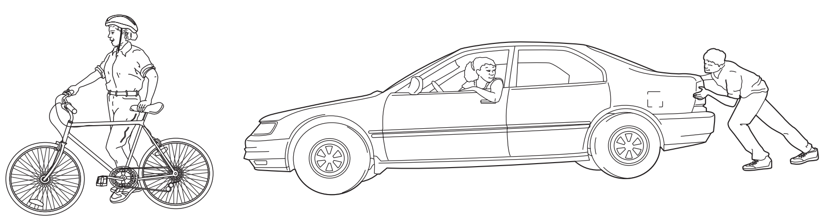


Inertia makes it harder to accelerate a car than to accelerate a bicycle. Inertia also makes it easier to stop a moving bicycle than a car moving at the same speed.

What Is Newton's Second Law of Motion?

Newton's second law of motion describes how an object moves when an unbalanced force acts on it. The second law has two parts:

1. The acceleration of an object depends on the mass of the object. If two objects are pushed or pulled by the same force, the object with the smaller mass will accelerate more. ☑
2. The acceleration of an object depends on the force applied to the object. If two objects have the same mass, the one you push harder will accelerate more.

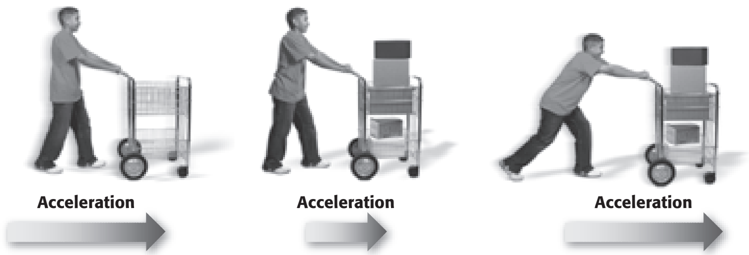
READING CHECK

10. Apply Concepts Which object will accelerate more if the same force is applied to both: a pickup truck or a tractor-trailer truck?

____

TAKE A LOOK

11. Compare On the figure, draw arrows showing the size and direction of the force that the person is applying to the cart in each picture.



If the force applied to the carts is the same, the acceleration of the empty cart is greater than the acceleration of the loaded cart.

Acceleration increases when a larger force is exerted.

How Is Newton's Second Law Written as an Equation?

Newton's second law can be written as an equation. The equation shows how acceleration, mass, and net force are related to each other:

$$a = \frac{F}{m}, \text{ or } F = m \times a$$

In the equation, a is acceleration (in meters per second squared), m is mass (in kilograms), and F is net force (in newtons, N). One newton is equal to one kilogram multiplied by one meter per second squared. ☑

READING CHECK

12. Identify What are the units of force?

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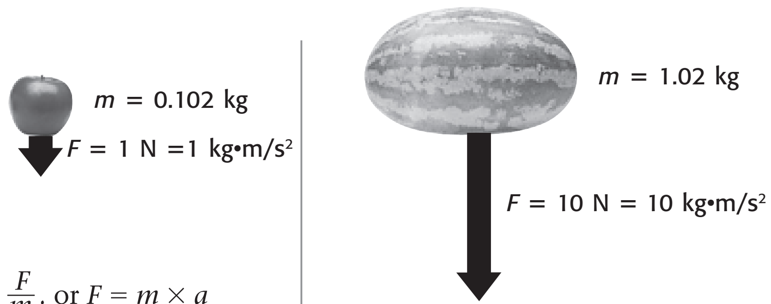
Newton's second law explains why all objects fall to Earth with the same acceleration. In the figure on the top of the next page, you can see how the larger force of gravity on the watermelon is balanced by its large mass.



$a = \frac{F}{m}$, or $F = m \times a$

$$a = \frac{1\ \cancel{kg}\bullet m/s^2}{0.102\ \cancel{kg}} = 9.8\ m/s^2$$

$a = \frac{F}{m}$, or $F = m \times a$

$$a = \frac{\boxed{}\ kg\bullet m/s^2}{\boxed{}\ kg} = \boxed{}\ m/s^2$$

The apple has less mass than the watermelon does. So, less force is needed to give the apple the same acceleration that the watermelon has.

Math Focus

13. Calculate In the figure, fill in the boxes with the correct numbers to calculate the acceleration of the watermelon.

How Can You Solve Problems Using Newton's Second Law?

You can use the equation $F = ma$ to calculate how much force you need to make a certain object accelerate a certain amount. Or you can use the equation $a = \frac{F}{m}$ to calculate how much an object will accelerate if a certain net force acts on it.

For example, what is the acceleration of a 3 kg mass if a force of 14.4 N is used to move the mass?

Step 1: Write the equation that you will use.

$$a = \frac{F}{m}$$

Step 2: Replace the letters in the equation with the values from the problem.

$$a = \frac{14.4\ N}{3\ kg} = \frac{14.4\ \cancel{kg}\bullet m/s^2}{3\ \cancel{kg}} = 4.8\ m/s^2$$

Math Focus

14. Calculate What force is needed to accelerate a 1,250 kg car at a rate of 40 m/s²? Show your work in the space below.

What Is Newton's Third Law of Motion?

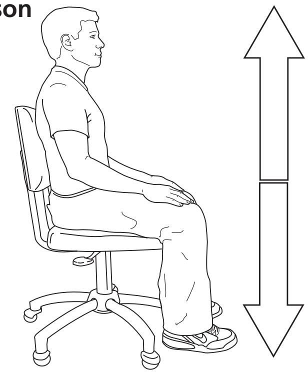
All forces act in pairs. Whenever one object exerts a force on a second object, the second object exerts a force on the first object. The forces are always equal in size and opposite in direction.

For example, when you sit on a chair, the force of your weight pushes down on the chair. At the same time, the chair pushes up on you with a force equal to your weight.

ACTION AND REACTION FORCES

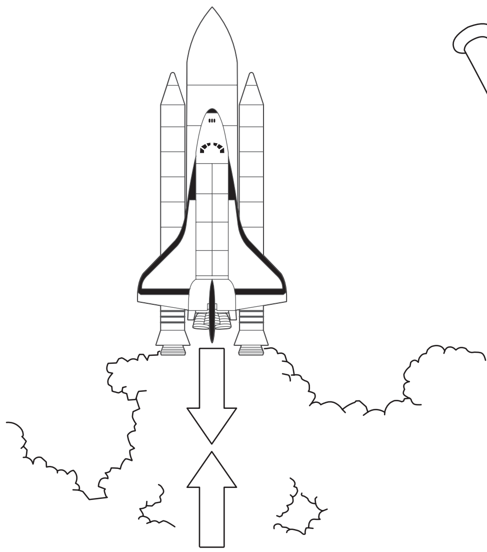
The figure below shows two forces acting on a person sitting in a chair. The *action force* is the person's weight pushing down on the chair. The *reaction force* is the chair pushing back up on the person. These two forces together are known as a *force pair*.

Forces on a Person in a Chair

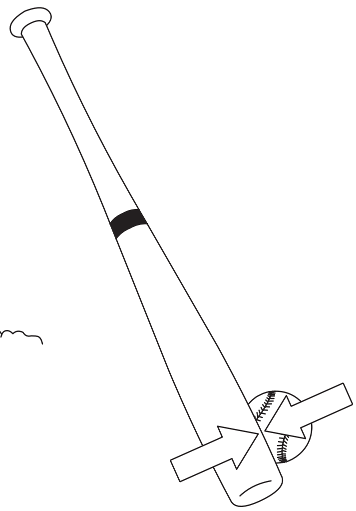


TAKE A LOOK
15. Identify On the figure, label the action force and the reaction force.

Action and reaction forces are also present when there is motion. The figures below show some more examples of action and reaction forces.



The space shuttle's thrusters push gases downward. The gases push the space shuttle upward with equal force.



The bat exerts a force on the ball and sends the ball flying. The ball exerts an equal force on the bat.

TAKE A LOOK
16. Describe How big is the reaction force compared with the action force in each picture?

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Critical Thinking
17. Apply Concepts If the ball exerts a force on the bat, why doesn't the bat move backward?

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The action force and reaction force always act on different objects. For example, when you sit in a chair, the action force (your weight) acts on the chair. However, the reaction force (the chair pushing up on you) acts on you.

HARD-TO-SEE REACTION FORCES

In the figure below, a ball is falling toward the Earth's surface. The action force is the Earth's gravity pulling down on the ball. What is the reaction force?

The force of gravity between Earth and a falling object is a force pair.

TAKE A LOOK

18. Identify On the figure, draw and label arrows showing the size and direction of the action force and the reaction force for the ball falling to the Earth.

Believe it or not, the reaction force is the ball pulling up on Earth. Have you ever felt this reaction force when you have dropped a ball? Of course not. However, both forces are present. So, why don't you see or feel Earth rise?

To answer this question, recall Newton's second law. Acceleration depends on the mass and the force on an object. The force acting on Earth is the same as the force acting on the ball. However, Earth has a very, very large mass. Because it has such a large mass, its acceleration is too small to see or feel. ☑

You can easily see the ball's acceleration because its mass is small compared with Earth's mass. Most of the objects that fall toward Earth's surface are much less massive than Earth. This means that you will probably never feel the effects of the reaction force when an object falls to Earth.

READING CHECK

19. Explain Why can't you feel the effect of the reaction force when an object falls to Earth?

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Name ______________________ Class ______________ Date ______________

Section 2 Review

NSES PS 2b, 2c

SECTION VOCABULARY

inertia the tendency of an object to resist being moved or, if the object is moving, to resist a change in speed or direction until an outside force acts on the object	

1. **Explain** How are inertia and mass related?

____

2. **Use Graphics** The hockey puck shown below is moving on the ice at a constant velocity. The arrow represents the constant velocity. In the box, draw the arrow that represents the velocity of the puck if no unbalanced forces act on the puck.

3. **Use Graphics** The ball shown below has two forces acting on it. The arrows represent the size and direction of the forces. In the box, draw the arrow that represents the net force on the ball.

4. **Identify** Describe two things you can do to increase the acceleration of an object.

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5. **Identify** Identify the action and reaction forces when you kick a soccer ball.

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6. **Calculate** What force is needed to accelerate a 40 kg person at a rate of 4.5 m/s^2? Show your work.

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SECTION 3

Momentum

BEFORE YOU READ

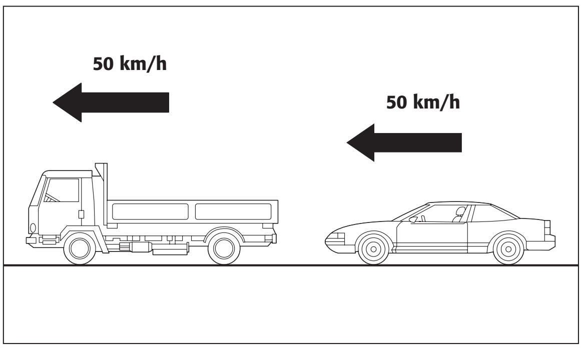
After you read this section, you should be able to answer these questions:

- What is momentum?
- How is momentum calculated?
- What is the law of conservation of momentum?

What Is Momentum?

Picture a compact car and a large truck moving at the same velocity. The drivers of both vehicles put on the brakes at the same time. Which vehicle will stop first? You most likely know that it will be the car. But why? The answer is momentum.

The momentum of an object depends on the object's mass and velocity. **Momentum** is the product of the mass and velocity of an object. In the figure below, a car and a truck are shown moving at the same velocity. Because the truck has a larger mass, it has a larger momentum. A greater force will be needed to stop the truck. ☑



A truck and car traveling with the same velocity do not have the same momentum.

Object	Momentum
A train moving at 30 km/h	
A bird sitting on a branch high in a tree	
A truck moving at 30 km/h	
A rock sitting on a beach	

STUDY TIP

Visualize As you read, try to picture in your head the events that are described. If you have trouble imagining, draw a sketch to illustrate the event.

READING CHECK

1. Identify What is the momentum of an object?

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TAKE A LOOK

2. Predict How could the momentum of the car be increased?

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Critical Thinking

3. Apply Concepts Fill in the chart to the left to show which object has the most momentum, which object has a smaller amount of momentum, and which objects have no momentum.

How Can You Calculate Momentum?

If you know what an object's mass is and how fast it is going, you can calculate its momentum. The equation for momentum is

$$p = m \times v$$

In this equation, p is momentum (in kilograms multiplied by meters per second), m is the mass of the object (in kilograms), and v is the velocity of the object (in meters per second). ☑

Like velocity, momentum has direction. The direction of an object's momentum is always the same as the direction of the object's velocity.

Use the following procedure to solve momentum problems:

Step 1: Write the momentum equation.

Step 2: Replace the letters in the equation with the values from the problem.

Let's try a problem. A 120 kg ostrich is running with a velocity of 16 m/s north. What is the momentum of the ostrich?

Step 1: The equation is $p = m \times v$.

Step 2: m is 120 kg and v is 16 m/s north. So,

$$p = (120 \text{ kg}) \times (16 \text{ m/s north}) = 1{,}920 \text{ kg} \bullet \text{m/s north}$$

READING CHECK

4. Identify What do you need to know in order to calculate an object's momentum?

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Math Focus

5. Calculate A 6 kg bowling ball is moving at 10 m/s down the alley toward the pins. What is the momentum of the bowling ball? Show your work.

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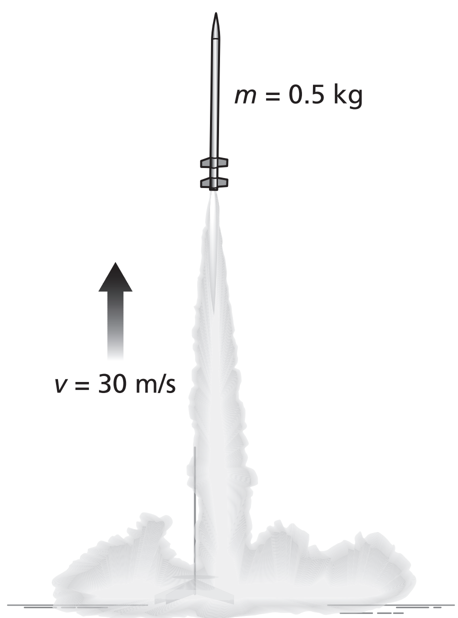
TAKE A LOOK

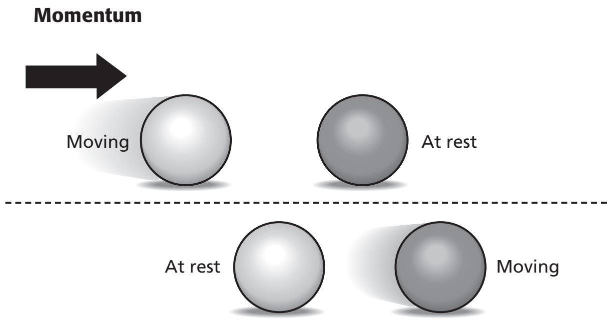
6. Describe Use a metric ruler to draw an arrow next to the rocket to show its momentum. The size of the rocket's momentum is 15 kg•m/s. The scale for the arrow should be 1 cm = 10 kg•m/s.

Model Rocket Launch



What Is the Law of Conservation of Momentum?

When a moving object hits an object at rest, some or all of the momentum of the first object is transferred to the second object. This means that the object at rest gains all or some of the moving object's momentum. During a collision, the total momentum of the two objects remains the same. Total momentum doesn't change. This is called the *law of conservation of momentum.*



The momentum before a collision is equal to the momentum after the collision.

TAKE A LOOK

7. Identify Draw an arrow showing the size and direction of the darker ball's momentum after its collision with the lighter ball.

The law of conservation of momentum is true for any colliding objects as long as there are no outside forces. For example, if someone holds down the darker ball in the collision shown above, it will not move. In that case, the momentum of the lighter ball would be transferred to the person holding the ball. The person is exerting an outside force. ☑

The law of conservation of momentum is true for objects that either stick together or bounce off each other during a collision. In both cases, the velocities of the objects will change so that their total momentum stays the same.

READING CHECK

8. Identify When is the law of conservation of momentum not true for two objects that are interacting?

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When football players tackle another player, they stick together. The velocity of each player changes after the collision because of conservation of momentum.

Although the bowling ball and bowling pins bounce off each other and move in different directions after a collision, momentum is neither gained nor lost.

Say It

Explain Words In a group, discuss how the everyday use of the word *momentum* differs from its use in science.

Name ______________________ Class ______________ Date ______________

Section 3 Review

SECTION VOCABULARY

momentum a quantity defined as the product of the mass and velocity of an object	

1. **Explain** A car and a train are moving at the same velocity. Do the two objects have the same momentum? Explain your answer.

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2. **Show Relationships** Put the following objects in order of increasing momentum: a parked car, a train moving at 50 km/h, a train moving at 80 km/h, a car moving at 50 km/h.

[ ] < [ ] < [ ] < [ ]

3. **Calculate** A 2.5 kg puppy is running with a velocity of 4.8 m/s south. What is the momentum of the puppy? Show your work.

4. **Explain** What is the law of conservation of momentum?

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5. **Calculate** A ball has a momentum of 1 kg•m/s north. It hits another ball of equal mass that is at rest. If the first ball stops, what is the momentum of the other ball after the collision? (Assume there are no outside forces.) Explain your answer.

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SECTION 1 Fluids and Pressure

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What are fluids?
- What is atmospheric pressure?
- What is water pressure?
- What causes fluids to flow?

What Are Fluids?

You have something in common with a dog, a sea gull, and a dolphin. You and all these other animals spend a lifetime moving through fluids. A **fluid** is any material that can flow and that takes the shape of its container. Fluids have these properties because their particles can easily move past each other. Liquids and gases are fluids. ☑

Fluids produce pressure. **Pressure** is the force exerted on a given area. The motions of the particles in a fluid are what produce pressure. For example, when you pump up a bicycle tire, you push air into the tire. Air is made up of tiny particles that are always moving. When air particles bump into the inside surface of the tire, the particles produce a force on the tire. The force exerted on the area of the tire creates air pressure inside the tire.

STUDY TIP

Explain As you read this section, study each figure. In your notebook, describe what each figure tells you about pressure.

READING CHECK

1. Identify What is a fluid?

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The air particles inside the tire hit the walls of the tire with a force. This force produces a pressure inside the tire. The pressure keeps the tire inflated.

TAKE A LOOK

2. Define What is pressure?

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PRESSURE AND BUBBLES

Why are bubbles round? It's because fluids (such as the gas inside the bubbles) exert the same pressure in all directions. This gives the bubbles their round shape.

CALCULATING PRESSURE

Remember that pressure is a force exerted on an area. You can use this equation to calculate pressure:

$$pressure = \frac{force}{area}$$

The SI unit of force is the pascal. One **pascal** (Pa) is equal to a force of one newton pushing on an area of one square meter (1 N/m^2). 1 Pa of pressure is very small. A stack of 120 sheets of notebook paper exerts a pressure of about 1 Pa on a table top. Therefore, scientists usually give pressure in kilopascals (kPa). 1 kPa equals 1,000 Pa.

Let's calculate a pressure. What is the pressure produced by a book that has an area of 0.2 m^2 and a weight of 10 N? Solve pressure problems using the following procedure:

Step 1: Write the equation. $pressure = \frac{force}{area}$

Step 2: Substitute and solve. $= \frac{10\text{ N}}{0.2\text{ m}^2} = 50\ \frac{\text{N}}{\text{m}^2} = 50\text{ Pa}$

Math Focus

3. Calculate What pressure is exerted by a crate with a weight of 3,000 N on an area of 2 m^2? Show your work.

What Is Atmospheric Pressure?

The *atmosphere* is the layer of gases that surrounds Earth. Gravity holds the atmosphere in place. The pull of gravity gives air weight. The pressure caused by the weight of the atmosphere is called **atmospheric pressure**.

Atmospheric pressure is exerted on everything on Earth, including you. At sea level, the pressure is about 101,300 Pa (101.3 kPa). This means that every square centimeter of your body has about 10 N (2 lbs) of force pushing on it.

Why doesn't your body collapse under this pressure? Like the air in a balloon, the fluids inside your body exert pressure. This pressure inside your body acts against the atmospheric pressure.

TAKE A LOOK

4. Describe What would be the length of the arrows if the balloon were inflated more? Explain your answer.

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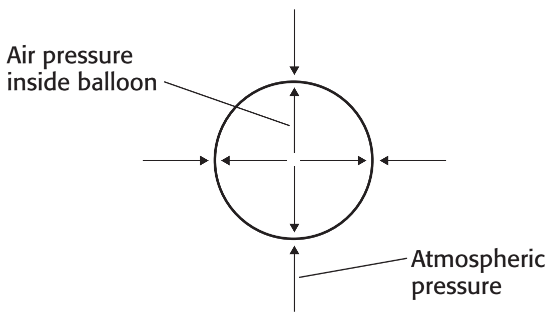

The air inside the balloon produces a pressure inside the balloon. The pressure inside the balloon equals the atmospheric pressure outside the balloon. Therefore, the balloon stays inflated.

PRESSURE, ALTITUDE, AND DEPTH

It is very difficult to climb Mount Everest. One reason is that there is not very much air at the top of Mount Everest. The atmospheric pressure on top of Mount Everest is only about one-third of that at sea level. As you climb higher, the pressure gets lower and lower. At the top of the atmosphere, the pressure is almost 0 Pa. ☑

READING CHECK

5. Describe As altitude increases, what happens to atmospheric pressure?

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Increasing altitude ↑

12,000 m above sea level	Airplanes fly at about 12,000 m above sea level. Atmospheric pressure there is about 20 kPa.
9,000 m above sea level	The top of Mount Everest is about 9,000 m above sea level. Atmospheric pressure there is about 30 kPa.
4,000 m above sea level	La Paz, the capital of Bolivia, is about 4,000 m above sea level. Atmospheric pressure in La Paz is about 51 kPa.
0 m above sea level	At sea level, atmospheric pressure is about 101 kPa.

Math Focus

6. Calculate About what fraction of atmospheric pressure at sea level is atmospheric pressure at La Paz?

____

Air pressure is greatest at Earth's surface because the entire weight of the atmosphere is pushing down there. This is true for all fluids. As you get deeper in a fluid, the pressure gets higher. You can think of being at sea level as being "deep" in the atmosphere. ☑

READING CHECK

7. Explain Why is atmospheric pressure greatest at the surface of Earth?

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PRESSURE CHANGES AND YOUR BODY

What happens to your body when atmospheric pressure changes? You may have felt your ears "popping" when you were in an airplane or in a car climbing a mountain. Air chambers behind your ears help to keep the pressure in your ears equal to air pressure. The "pop" happens because the pressure inside your ears changes as air pressure changes.

What Affects Water Pressure?

Water is a fluid. Therefore, it exerts a pressure. Like air pressure, water pressure increases as depth increases, as shown in the figure below. The pressure increases as the diver gets deeper because more and more water is pushing on her. In addition, the atmosphere pushes down on the water. Therefore, the total pressure on the diver is the sum of the water pressure and the atmospheric pressure. ☑

READING CHECK

8. Explain Why does pressure increase as depth increases?

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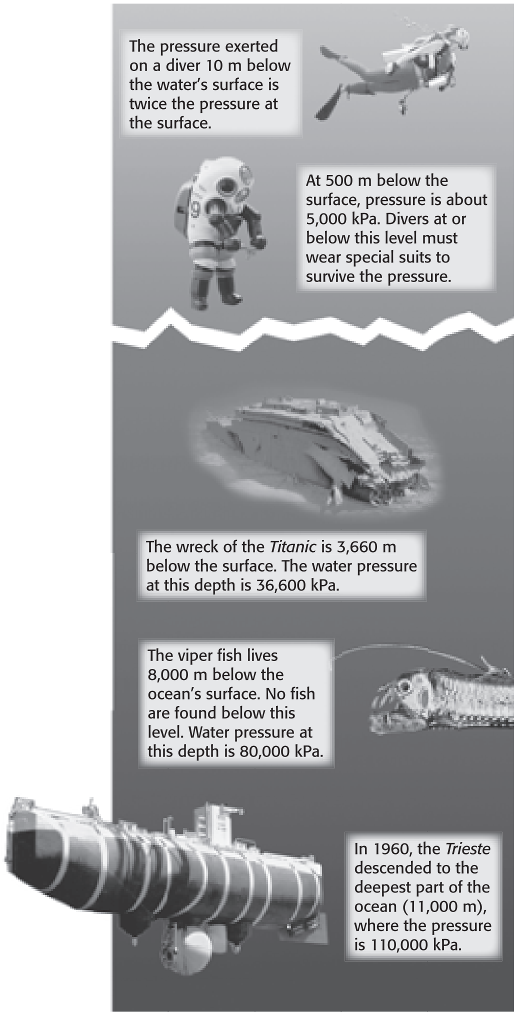

Say It

Discuss In a small group, talk about the kinds of adaptations that deep-water organisms, such as the viper fish, may have to help them survive at very high water pressures.

DENSITY EFFECTS ON WATER PRESSURE

Density is a measure of how closely packed the particles in a substance are. It is a ratio of the mass of an object to its volume. Water is about 1,000 times denser than air. Water has more mass (and weighs more) than the same volume of air. Therefore, water exerts more pressure than air. The pressure exerted by 10 m of water is 100 kPa. This is almost the same as the pressure exerted by the whole atmosphere.

Critical Thinking

9. Infer What is the total pressure in kPA 10 m below the water? Hint: the total pressure is the sum of the atmospheric pressure and the water pressure.

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What Causes Fluids to Flow?

All fluids flow from areas of high pressure to areas of low pressure. Imagine a straw in a glass of water. Before you suck on the straw, the air pressure inside the straw is equal to the air pressure on the water. When you suck on the straw, the air pressure inside the straw decreases. However, the pressure on the water outside the straw stays the same. The pressure difference forces water up the straw and into your mouth.

Critical Thinking

10. Apply Concepts Why does the air pressure inside a straw go down when you suck on the straw?

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PRESSURE DIFFERENCE AND BREATHING

The flow of air from high pressure to low pressure is also what allows you to breathe. In order to inhale, a muscle in your chest moves down. This makes the volume of your chest bigger, so your lungs have more room to expand. As your lungs expand, the pressure inside them goes down. Atmospheric pressure is now higher than the pressure inside your lungs, so air flows into your lungs. The reverse of this process happens when you exhale, as shown in the figure below.

When you exhale, a muscle in your chest moves upward. The volume of your chest decreases.

As the volume of your chest decreases, the pressure in your lungs increases. The pressure in your lungs becomes greater than the pressure outside your lungs. Therefore, the air flows out of your lungs (higher pressure) into the air (lower pressure).

TAKE A LOOK

11. Explain Why does air flow out of your lungs when you exhale?

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PRESSURE DIFFERENCES AND TORNADOES

During a tornado, wind speeds can reach 300 miles per hour or more! Some of the damaging winds caused by a tornado are due to pressure differences. The air pressure inside a tornado is very low. Because the air pressure outside the tornado is high, the air rushes into the tornado and produces strong winds. The winds cause the tornado to act as a giant vacuum cleaner. Objects are pulled in and lifted up by these winds.

Name ______________________ Class ______________ Date ____________

Section 1 Review

SECTION VOCABULARY

atmospheric pressure the pressure caused by the weight of the atmosphere **fluid** a nonsolid state of matter in which the atoms or molecules are free to move past each other, as in a gas or liquid	**pascal** the SI unit of pressure (symbol, Pa) **pressure** the amount of force exerted per unit area of a surface

1. Describe How do fluids exert pressure on a container?

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2. Evaluate Define density in terms of mass and volume. How does density affect pressure?

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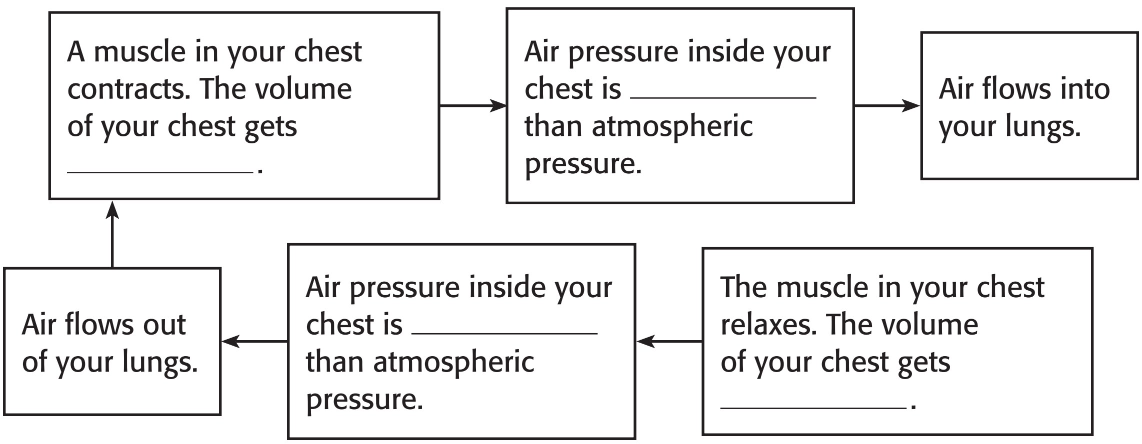
3. Calculate The water in a glass has a weight of 2.5 N. The bottom of the glass has an area of 0.012 m^2. What is the pressure exerted by the water on the bottom of the glass? Show your work.

4. Describe Fill in the blank spaces in the chart below to show how air moves in and out of your lungs when you breathe.



Name ______________________ Class ______________ Date ____________

CHAPTER 7 Forces in Fluids

SECTION 2

Buoyant Force

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is buoyant force?
- What makes objects sink or float?
- How can we change an object's density?

National Science Education Standards
PS 1a, 2c

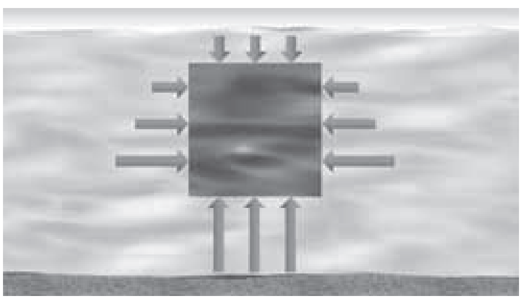
What Is Buoyant Force and Fluid Pressure?

Why does an ice cube that has been pushed under the water pop back up? A force called buoyant force pushes the ice cube up to the water's surface. **Buoyant force** is the upward force that a fluid exerts on all objects in the fluid. If an object is buoyant, that means it will float on water like a raft. Or rise in the air like a helium-filled balloon.

Look at the figure below. Water exerts a pressure on all sides of the object in the water. The water produces the same amount of horizontal force on both sides of the object. These equal forces balance one another.

However, the vertical forces are not equal. Remember that fluid pressure increases with depth. There is more pressure on the bottom of the object than on the top. ☑

The longer arrows in the figure below show the larger pressures. You can see that the arrows are longest underneath the object. This shows that the water applies a net upward force on the object. This upward force is buoyant force. It is what makes the object float.



There is more pressure at the bottom of an object because pressure increases with depth. The differences in pressure produce an upward buoyant force on the object.

Buoyant force is what makes you feel lighter when you float in a pool of water. The buoyant force of the water pushes up on your body and reduces your weight.

STUDY TIP

Learn New Words As you read, underline words you don't understand. When you figure out what they mean, write the words and their definitions in your notebook.

READING CHECK

1. Identify Why is the force on the bottom of an object in a fluid larger than the force on the top?

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TAKE A LOOK

2. Identify What produces buoyant force?

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Math Focus

3. Calculate A can of soda displaces about 360 mL of water when it is put in a tank of water. The weight of 360 mL of water is about 3.6 N. What is the buoyant force on the can of soda?

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DETERMINING BUOYANT FORCE

Archimedes, a Greek mathematician who lived in the third century BCE, discovered how to find buoyant force. Archimedes found that objects in water *displace*, or take the place of, water. The weight of the displaced water equals the buoyant force of the water. This is now known as **Archimedes' principle**.

You can find buoyant force by measuring the weight of the water that an object displaces. Suppose a block of ice displaces 250 mL of water. The weight of 250 mL of water is about 2.5 N. The weight of the displaced water equals the buoyant force. Therefore, the buoyant force on the block is 2.5 N.

Notice that only the weight of the displaced fluid determines the buoyant force on an object. The weight of the object does not affect buoyant force.

What Makes Objects Float or Sink?

An object in a fluid will sink if its weight is greater than the buoyant force. An object floats only when the buoyant force is equal to or less than the object's weight. ☑

READING CHECK

4. Identify Will an object sink or float if its weight is less than the buoyant force?

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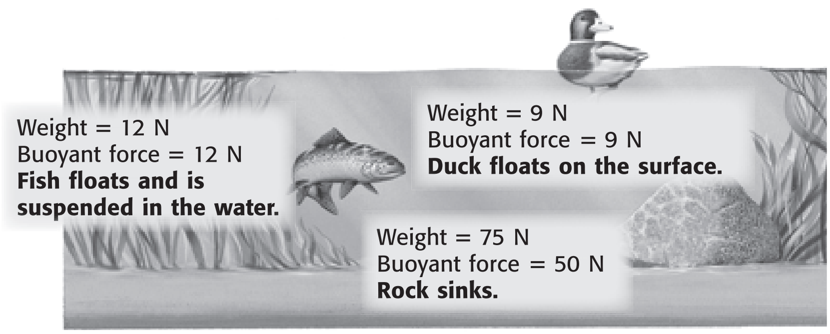

TAKE A LOOK

5. Explain Why does the fish float in the middle of the water?

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SINKING

The rock in the figure above weighs 75 N. It displaces 5 L, or about 50 N, of water. According to Archimedes' principle, the buoyant force is about 50 N. Since the weight of the rock is greater than the buoyant force, the rock sinks.

Critical Thinking

6. Apply Concepts If the duck in the figure weighed 10 N, would more or less of the duck be underwater?

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FLOATING

The fish in the figure weighs 12 N. It displaces a volume of water that weighs 12 N. The buoyant force and the fish's weight are equal, so the fish floats in the water. It does not sink to the bottom or rise to the surface—it is *suspended* in the water.

BUOYING UP

If the duck dove underwater, it would displace more than 9 N of water. As a result, the buoyant force on the duck would be greater than the duck's weight. When the buoyant force on an object is greater than the object's weight, the object is *buoyed up*, or pushed up in the water.

An object is buoyed up until the part underwater displaces an amount of water that equals the object's weight. Therefore, the part of the duck that is underwater displaces 9 N of water.

How Does Density Affect Floating?

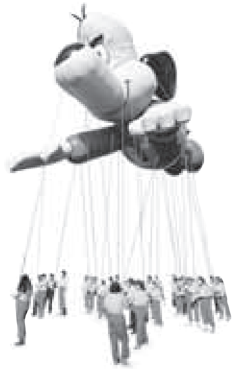
Remember that *density* is the mass of an object divided by its volume. How does the density of the rock compare to the density of water? The volume of the rock is 5 L, and it displaces 5 L of water. The weight of the rock is 75 N, and the weight of 5 L of water is 50 N. The weight of an object is a measure of its mass. In the same volume, the rock has more mass than water. Therefore, the rock is more dense than water. ☑

The rock sinks because it is denser than water. The duck floats because it is less dense than water. The fish floats suspended in the water because it has the same density as the water. ☑

MORE DENSE OR LESS DENSE THAN AIR

Why does an ice cube float on water but not in air? An ice cube floats in water because it is less dense than water. However, most substances are more dense than air. The ice cube is more dense than air, so it does not float in air.

One substance that is less dense than air is helium, a gas. When a balloon is filled with helium, the filled balloon becomes less dense than air. Therefore, the balloon floats in air, like the one in the picture below.



This balloon floats because the helium in it is less dense than air.

STANDARDS CHECK

PS 2c If more than one force acts on an object along a straight line, then the forces will reinforce or cancel one another, depending on their direction and magnitude. Unbalanced forces will cause changes in the speed or direction of an object's motion.

7. Explain If a log floating on the water is pushed underwater, why will it pop back up?

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READING CHECK

8. Define What is density?

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READING CHECK

9. Explain How does an object's density determine whether it floats or sinks?

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TAKE A LOOK

10. Infer The balloon in the picture is filled with about 420,000 L of helium. Does 420,000 L of air have a greater or smaller mass than the 420,000 L of helium in the balloon? Explain your answer.

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What Affects an Object's Density?

The total density of an object can change if its mass or volume changes. If volume increases and mass stays the same, density decreases. If mass increases and volume stays the same, density increases.

TAKE A LOOK

11. Compare What is the volume of the ship compared to the volume of the steel used to make the ship?

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A block of steel is denser than water, so it sinks. If that block is shaped into a hollow form, the overall density of the form is less than water. Therefore, the ship floats.

CHANGING SHAPE

Steel is almost eight times denser than water. Yet huge steel ships cruise the oceans with ease. If steel is more dense than water, how can these ships float? The reason a steel ship floats has to do with its shape. If the ship were just a big block of steel, it would sink very quickly. However, ships are built with a hollow shape. The hollow shape increases the volume that the steel takes up without increasing the mass of the steel.

Increasing the volume of the steel produces a decrease in its density. When the volume of the ship becomes large enough, the overall density of the ship becomes less than water. Therefore, the ship floats. ☑

READING CHECK

12. Explain How can changing the shape of an object lower its overall density?

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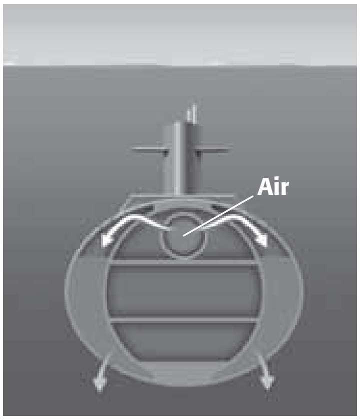
Most ships are built to displace more water than is necessary for the ship to float. These ships are made this way so that they won't sink when people and cargo are loaded onto the ship.

CHANGING MASS

A submarine is a ship that can travel both on the surface of the water and underwater. Submarines have *ballast tanks* that can open to let seawater flow in. When seawater flows in, the mass of the submarine increases. Therefore, its overall density increases. When seawater is pushed out, the overall density of the submarine decreases and it rises to the surface.

Water flows into the ballast tanks. The submarine becomes more dense and sinks.



Compressed air forces water out of the ballast tanks. The submarine becomes less dense and floats to the surface.

TAKE A LOOK

13. Describe How does a submarine increase its density?

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CHANGING VOLUME

Some fish can change their overall density by changing their volume. Most bony fish have an organ called a *swim bladder*. This swim bladder can fill with gases or release gases. The gases are less dense than the rest of the fish. When gases go into the swim bladder, the overall volume of the fish increases, but the mass of the fish does not change as much. This lowers the overall density of the fish and keeps it from sinking in the water. ☑

The fish's nervous system controls the amount of gas in the bladder. Some fish, such as sharks, do not have a swim bladder. These fish must swim constantly to keep from sinking.

READING CHECK

14. Explain How do most bony fish change their overall density?

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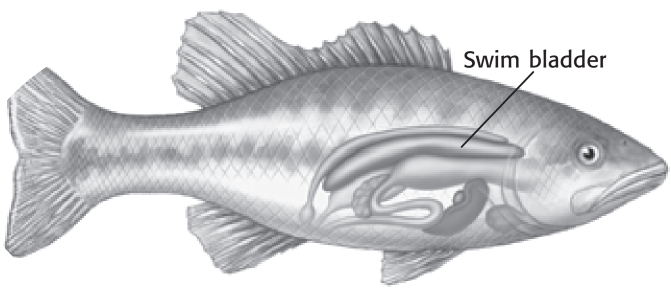

Most bony fish have a swim bladder, an organ that allows them to adjust their overall density.

Section 2 Review

NSES PS 1a, 2c

SECTION VOCABULARY

Archimedes' Principle the principle that states that the buoyant force on an object in a fluid is an upward force equal to the weight of the volume of fluid that the object displaces	**buoyant force** the upward force that keeps an object immersed in or floating on a liquid

1. **Predict** In Figure 1, a block of wood is floating on the surface of some water. In Figure 2, the same block of wood is pushed beneath the surface of the water. In the space below, predict what will happen to the wood when the downward force in Figure 2 is removed. Use the term *buoyant force* in your answer.

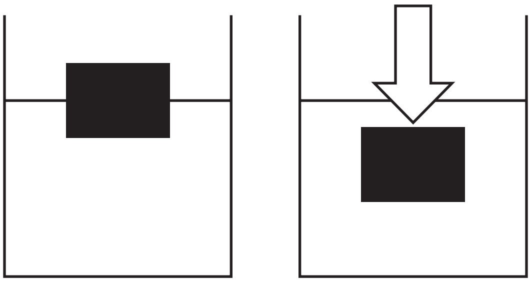

Figure 1 Figure 2

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2. **Calculate** A container that is filled with mercury has a mass of 4810 g. If the volume of the container is 355 mL, what is its overall density? Show your work. Round your answer to the nearest tenth.

3. **Identify** Give two ways that an object's overall density can change.

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4. **Explain** How can knowing an object's density help you to predict whether the object will float or sink in a fluid?

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Name ________________ Class ________________ Date ________________

CHAPTER 7 Forces in Fluids

SECTION 3

Fluids and Motion

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- How does fluid speed affect pressure?
- How do lift, thrust, and wing size affect flight?
- What is drag?
- What is Pascal's principle?

National Science Education Standards

PS 1a

What Are Fluid Speed and Pressure?

Usually, when you think of something flowing, it is a liquid such as water. But remember that a fluid is any material that can flow and that takes the shape of its container. So, gases such as air are fluids, too. Both liquids and gases flow when forces act on them.

An 18th century Swiss mathematician Daniel Bernoulli, found that fast-moving fluids have a lower pressure than slow-moving fluids. **Bernoulli's principle** states that as the speed of a moving fluid increases, the fluid's pressure decreases. ☑

Have you ever watched an airplane take off and wondered how it could stay in the air? Look at the picture of the airplane below and you'll see Bernoulli's principle at work.

STUDY TIP

Reading Organizer As you read this section, create an outline of the section. Use headings from the section in your outline.

READING CHECK

1. Describe What is Bernoulli's principle?

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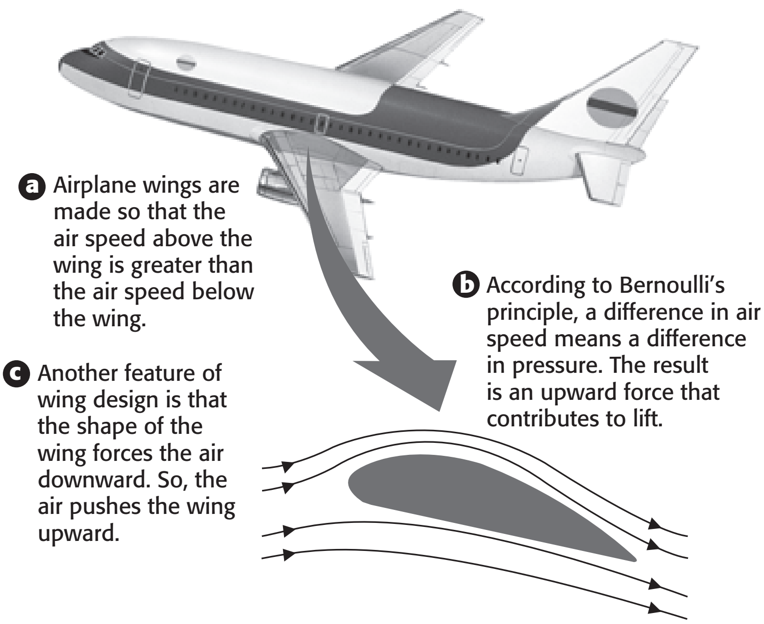
Wing Design and Lift



Critical Thinking

2. Infer Why do you need a windy day to fly a kite?

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What Factors Affect Flight?

A common airplane in the skies today is the Boeing 737 jet. Even without passengers, the plane weighs 350,000 N (about 79,000 lbs). How can something so big and heavy get off the ground? Wing shape plays a role in helping these big planes, as well as smaller planes, fly.

According to Bernoulli's principle, the fast-moving air above the wing exerts less pressure than the slow-moving air below the wing. As a result, the greater pressure below the wing exerts an upward force. This upward force, known as **lift**, pushes the wings (and the rest of the airplane or bird) upward against the downward pull of gravity. ☑

READING CHECK

3. Explain What is lift?

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THRUST AND LIFT

The amount of lift caused by a plane's wing is determined partly by the speed of the air around the wing. Thrust determines the speed of a plane. **Thrust** is the forward force that the plane's engine produces. Usually, a plane with a large amount of thrust moves faster than a plane that has less thrust. This faster speed means greater lift.

WING SIZE, SPEED, AND LIFT

The size of a plane's wings also affects the plane's lift. The jet plane in the picture below has small wings, but its engine gives a large amount of thrust. This thrust pushes the plane through the sky at great speeds. As a result, the jet creates a large amount of lift with small wings by moving quickly through the air.

A glider is an engineless plane. It rides rising air currents to stay in flight. Without engines, gliders produce no thrust and move more slowly than many other kinds of planes. So, a glider must have large wings to create the lift it needs to stay in the air. ☑

READING CHECK

4. Identify What are two factors that affect lift?

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Increased Thrust Versus Increased Wing Size

The engine of this jet creates a large amount of thrust, so the wings don't have to be very big.

This glider has no engine and therefore no thrust. So, its wings must be large in order to maximize the amount of lift achieved.

BERNOULLI, BIRDS, AND BASEBALL

Birds don't have engines, so they must flap their wings in order to supply thrust and lift. A small bird must flap its wings at a fast pace to stay in the air. But a hawk flaps its wings only occasionally. It flies with little effort because it has larger wings. Fully extended, a hawk's wings allow it to glide on wind currents and still have enough lift to stay in the air. ☑

READING CHECK

5. Identify What does a bird supply by flapping its wings?

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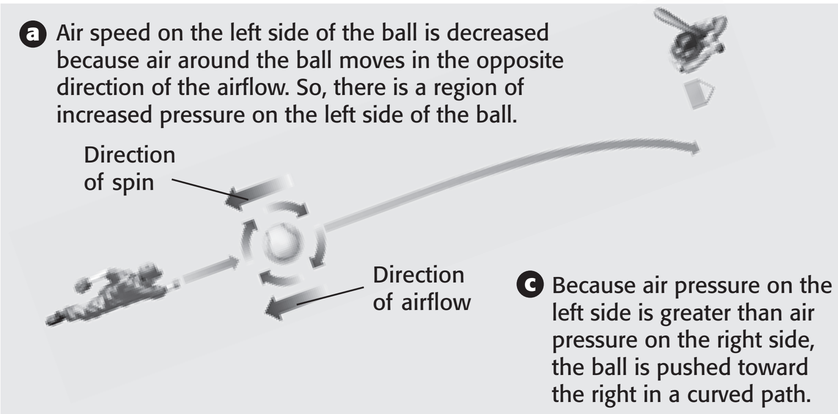
Bernoulli's Principle and the Screwball



TAKE A LOOK

6. Identify Suppose the pitcher threw the ball and it curved toward the batter. Would the ball be spinning in a clockwise or counterclockwise direction?

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The picture above shows how a baseball pitcher can use Bernoulli's principle to throw a confusing screwball. It is hard for a batter to hit.

DRAG AND MOTION IN FLUIDS

Have you ever walked into a strong wind and noticed that the wind seemed to slow you down or push you backward? Fluids exert a force that opposes the motion of objects moving through them. The force in a fluid that opposes or restricts motion is called **drag**. ☑

In a strong wind, air "drags" on your body and makes it difficult for you to move into the wind. Drag also works against the forward motion of a plane or bird in flight. Drag is usually caused by an irregular flow of air. An irregular or unpredictable flow of fluids is known as *turbulence*.

READING CHECK

7. Decribe What is drag?

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TURBULENCE AND LIFT

Turbulence causes drag and that reduces lift. Drag can be a serious problem for airplanes moving at high speeds. As a result, airplanes have ways to reduce turbulence. For example, airplanes have flaps on their wings. When the flaps move, it changes the shape or area of a wing. This change can reduce drag and increase lift. ☑

READING CHECK

8. Explain How do airplanes reduce turbulence?

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What Is Pascal's Principle?

Imagine that the water-pumping station in your town pumps water at a pressure of 20 Pa. Will the water pressure be higher at a store two blocks away or at a home 2 km away?

Believe it or not, the water pressure will be the same at both locations. This equal water pressure is explained by Pascal's principle. **Pascal's principle** states that a fluid contained in a vessel exerts a pressure of equal size in all directions. The 17the century French scientist, Blaise Pascal, discovered this principle.

Pascal's principle can be written as an equation:

$P_1 = P_2$ or $\frac{F_1}{A_1} = \frac{F_2}{A_2}$, where P is pressure, F is force, and A is area. $P_1 = P_2$ means the pressure in the fluid is the same everywhere in the fluid. However, if the areas pushed on by a fluid are different, the forces will be different. In the figure below, Area 2 is larger than Area 1.

Critical Thinking

9. Infer Would Pascal's principle still apply if there is a leak in the town's water system? Explain your answer.

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Suppose that force 1 = 10 N, area 1 = 2 cm², and area 2 = 100 cm², what is force 2? Rearrange the equation and put in the values.

$$F_2 = A_2 \times \frac{F_1}{A_1} = 100\ \text{cm}^2 \times \frac{10\ \text{N}}{2\ \text{cm}^2} = 500\ \text{N}$$

Pushing on one end of the fluid with a 10 N force caused a 500 N force on the other end. This will be used on the next page to explain how car brakes work.

Math Focus

10. Determine If force 1 = 20 N, area 1 = 5 cm², and area 2 = 200 cm², what is force 2? Show your work.

PASCAL'S PRINCIPLE AND MOTION

Hydraulic devices use Pascal's principle to move or lift objects. Hydraulic means the devices operate using fluids, usually oil. In hydraulic devices liquids cannot be easily compressed, or squeezed, into a smaller space. Cranes, forklifts, and bulldozers have hydraulic devices that help them lift heavy objects.

Hydraulic machines can multiply forces. Car brakes are a good example of this. In the picture below, a driver's foot exerts pressure on a cylinder of liquid. This pressure is transmitted to all parts of the liquid-filled brake system. The liquid moves the brake pads. The pads press against the wheels and friction stops the car. ☑

The force is multiplied. This is because the pistons that push the brake pads are larger than the piston pushed by the brake pedal.

READING CHECK

11. Explain How can forklifts and bulldozers lift such heavy loads?

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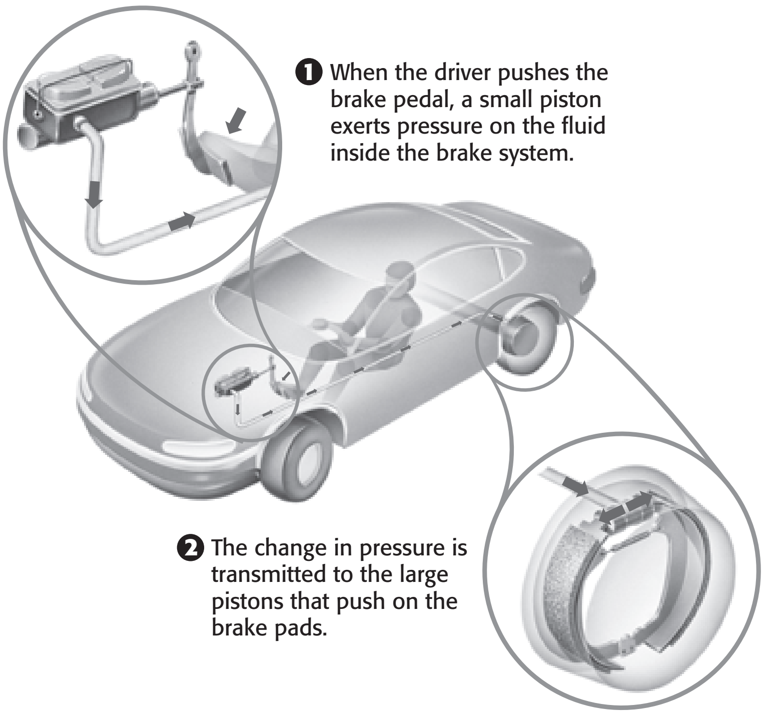
Because of Pascal's principle, the touch of a foot can stop tons of moving metal.



Name ________________ Class ________________ Date ________________

Section 3 Review

NSES PS 1a

SECTION VOCABULARY

Bernoulli's principle the principle that states that the pressure in a fluid decreases as the fluid's velocity increases

drag a force parallel to the velocity of the flow; it opposes the direction of an aircraft and, in combination with thrust, determines the speed of the aircraft

lift a upward force on an object that moves in a fluid

Pascal's principle the principle that states that a fluid in equilibrium contained in a vessel exerts a pressure of equal intensity in all direction

thrust the pushing or pulling force exerted by the engine of an aircraft or rocket

1. **Explain** What is the relationship between pressure and fluid speed?

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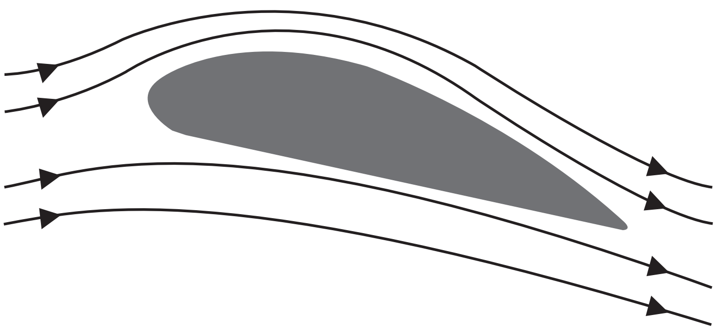
2. **Label** Write "fastest air speed" and "highest pressure" in the correct places on the wing.



3. **Identify** What force opposes motion through fluid?

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4. **Infer** Where is the pressure inside a balloon the highest? What principle explains your answer?

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5. **Explain** How do thrust and lift help an airplane fly?

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SECTION 1

Work and Power

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is work?
- How do we measure work?
- What is power and how is it calculated?

National Science Education Standards
PS 3a

What Is Work?

You may think of work as a large homework assignment. You have to read a whole chapter by tomorrow. That sounds like a lot of work, but in science, work has a different meaning. **Work** is done when a force causes an object to move in the direction of the force. You might have to do a lot of thinking, but you are not using a force to move anything. You are doing work when you to turn the pages of the book or move your pen when writing. ☑

The student in the figure below is bowling. She is doing work. She applies a force to the bowling ball and the ball moves. When she lets go of the ball she stops doing work. The ball keeps rolling but she is not putting any more force on the ball.

STUDY TIP
As you read this section, write the questions in Before You Read in your science notebook and answer each one.

READING CHECK
1. Describe When is work done on an object?

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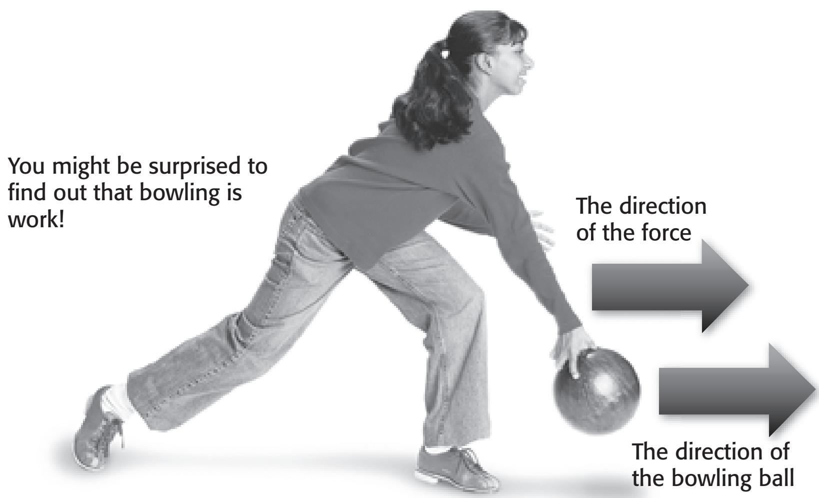

How Is Energy Transferred When Work Is Done?

The bowler in the figure above has done work on the bowling ball. Since the ball is moving, it now has *kinetic* energy. The bowler has transferred energy to the ball.

STANDARDS CHECK

PS 3a Energy is a property of many substances and is associated with heat, light, electricity, mechanical energy, motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.

2. Identify How is energy transmitted to a bowling ball to make it move down the alley?

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When Is Work Done On An Object?

Applying a force does not always mean that work is done. If you push a car but the car does not move, no work is done on the car. Pushing the car may have made you tired. If the car has not moved, no work is done on the car. When the car moves, work is done. If you apply a force to an object and it moves in that direction, then work is done.

How Are Work and Force Different?

You can apply a force to an object, but not do work on the object. Suppose you are carrying a heavy suitcase through an airport. The direction of the force you apply to hold the suitcase is up. The suitcase moves in the direction you are walking. The direction the suitcase is moving is not the same as the direction of the applied force. So when you carry the suitcase, no work is done on the suitcase. Work is done when you lift the suitcase off the ground.

Work is done on an object if two things happen.

1. An object moves when a force is applied.
2. The object moves in the direction of the force. ☑

READING CHECK

3. Describe What two things must happen to do work on an object?

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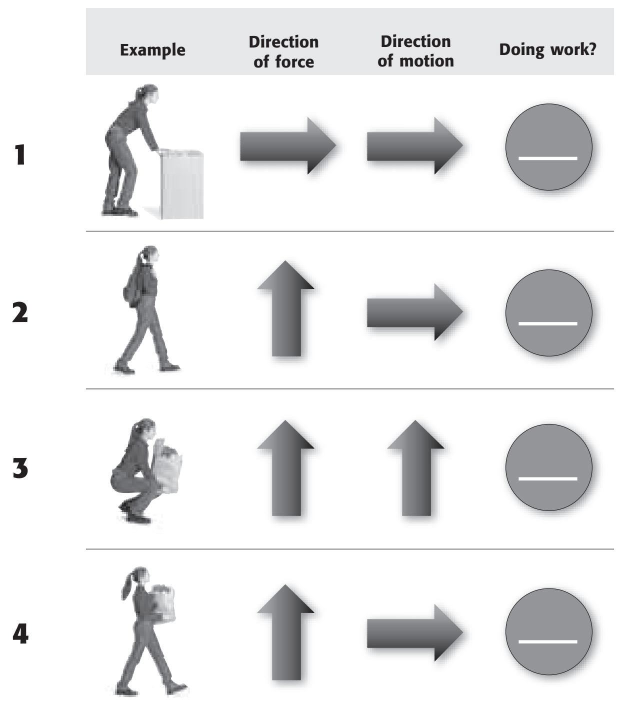
In the figure below, you can see how a force can cause work to be done.



TAKE A LOOK

4. Identify In the figure, there are four examples. For each example, decide if work is being done and write your answers in the figure.

How Is Work Calculated?

An equation can be written to calculate the work (W) it takes to move an object. The equation shows how work, force, and distance are related to each other:

$$W = F \times d$$

In the equation, F is the force applied to an object (in newtons). d is the distance the object moves in the direction of the force (in meters). The unit of work is the newton-meter (N×m). This is also called a **joule** (J). When work is done on an object, energy is transferred to the object. The joule is a unit of energy.

Let's try a problem. How much work is done if you push a chair that weighs 60 N across a room for 5 m?

Step 1: Write the equation.

$$W = F \times d$$

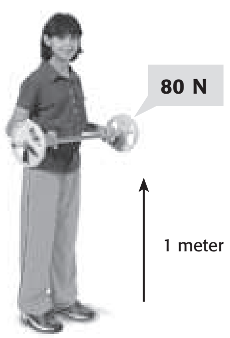
Step 2: Place values into the equation, and solve for the answer.

$$W = 60 \text{ N} \times 5 \text{ m} = 300 \text{ J}$$

The work done on the chair is 300 joules.

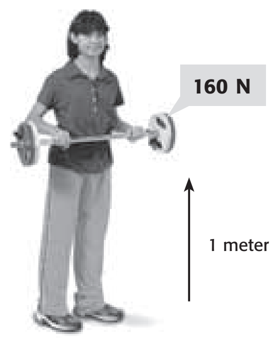
Math Focus

5. Calculate How much work is done pushing a car 20 m with a force of 300 N? Show your work.



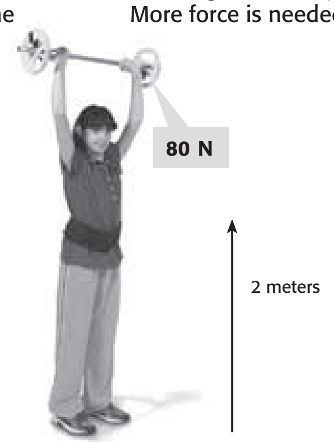
***W* = 80 N × 1 m = 80 J**

The force to lift an object is the same as the force of gravity on the object. In other words, the object's weight is the force.



***W* = 160 N × 1 m = 160 J**

The amount of work increases when the weight of an object increases. More force is needed to lift the object.



***W* =** ______________________

The amount of work also increases when the distance increases.

Math Focus

6. Calculate In the last figure, a barbell weighing 80 N is lifted 2 m off of the ground. How much work is done? Show your work.

Two Paths, Same Work?

A car is pushed to the top of a hill using two different paths. The first path is a long road that has a low, gradual slope. The second path is a steep cliff. Pushing the car up the long road doesn't need as much force as pulling it up the steep cliff. But, believe it or not, the same amount of work is done either way. It is clear that you would need a different amount of force for each path.

Look at the figure below. Pushing the car up the long road uses a smaller force over a larger distance. Pulling it up the steep cliff uses a larger force over a smaller distance. When work is calculated for both paths, you get the same amount of work for each path. ☑

READING CHECK

7. Explain Suppose it takes the same amount of work for two people to move an object. One person applies less force in moving the object than the other. How can they both do the same amount of work?

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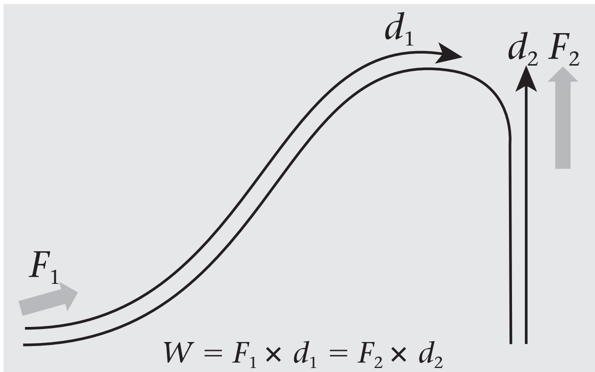


There are two paths to move the car to the top of the hill. d_1 follows the shape of the hill. d_2 is straight from the bottom to the top of the hill. The same work is done in both paths. The distance and force for each of the paths are different.

Let's do a calculation. Suppose path 1 needs a force of 200 N to push the car up the hill for 30 m. Path 2 needs a force of 600 N to pull the car up the hill 10 m. Show that the work is the same for both paths.

Step 1: Write the equation.

$$W_1 = F_1 \times d_1 \text{ and } W_2 = F_2 \times d_2$$

Step 2: Place values into the equation, and solve for the answer.

$$W_1 = 200 \text{ N} \times 30 \text{ m} \times 600 \text{ N and } W_2 = 600 \text{ N} \times 10 \text{ m} = 600 \text{ J}$$

The amount of work done is the same for both paths.

What Is Power?

The word *power* has a different meaning in science than how we often use the word. **Power** is how fast energy moves from one object to another.

Power measures how fast work is done. The *power output* of something is another way to say how much work can be done quickly. For example, a more powerful weightlifter can lift a barbell more quickly than a less powerful weightlifter.

How Is Power Calculated?

To calculate power (P), divide the work (W) by the time (t) it takes to do the work. This is shown in the following equation: $P = \frac{W}{t}$

Power is written in the units joules per second (J/s). This is called a **watt**. One *watt* (W) is the same as 1 J/s.

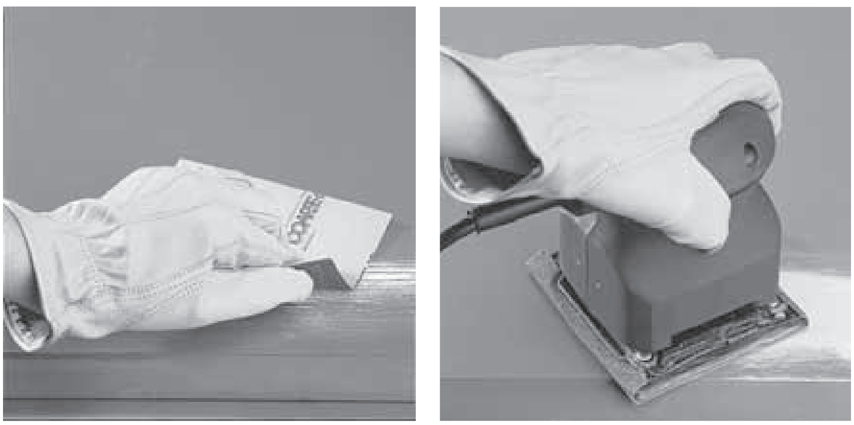
Let's do a problem. A stage manager at a play raises the curtain by doing 5,976 J of work on the curtain in 12 s. What is the power output of the stage manager?

Step 1: Write the equation.

$$P = \frac{W}{t}$$

Step 2: Place values into the equation, and solve for the answer.

$$P = \frac{5{,}976 \text{ J}}{12 \text{ s}} = 498 \text{ W}$$



Wood can be sanded by hand or with an electric sander. The electric sander does the same amount of work faster.

Critical Thinking

8. Apply Concepts An escalator and a elevator can transport a person from one floor to the next. The escalator does it in 15 s and the elevator takes 10 s.

Which does more work on the person? Which has the greater power output?

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Math Focus

9. Calculate A light bulb is on for 12 s, and during that time it uses 1,200 J of electrical energy. What is the wattage (power output) of the light bulb?

TAKE A LOOK

10. Explain Why does the electric sander have a higher power output than sanding by hand?

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Name ______________________ Class ______________ Date ____________

Section 1 Review

NSES PS 3a

SECTION VOCABULARY

joule the unit used to express energy; equivalent to the amount of work done by a force of 1 N acting through a distance of 1 m in the direction of the force (symbol, J)

power the rate at which work is done or energy is transformed

watt the unit used to express power; equivalent to a joule per second (symbol, W)

work the transfer of energy to an object by using a force that causes the object to move in the direction of the force

1. **Explain** Is work always done on an object when a force is applied to the object? Why or why not?

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2. **Analyze** Work is done on a ball when a pitcher throws it. Is the pitcher still doing work on the ball as it flies through the air? Explain your answer.

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3. **Calculate** A force of 10 N is used to push a shopping cart 10 m. How much work is done? Show how you got your answer.

4. **Compare** How is the term work different than the term power?

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5. **Identify** How can you increase your power output by changing the amount of work that you do? How can you increase your power output by changing the time it takes you to do the work?

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6. **Calculate** You did 120 J of work in 3 s. How much power did you use? Show how you got your answer.

SECTION 2

What Is a Machine?

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is a machine?
- How does a machine make work easier?
- What is mechanical advantage?
- What is mechanical efficiency?

What Is a Machine?

Imagine changing a flat tire without a jack to lift the car or a tire iron to remove the bolts. Would it be easy? No, you would need several people just to lift the car! Sometimes you need the help of machines to do work. A **machine** is something that makes work easier. It does this by lowering the size or direction of the force you apply. ☑

When you hear the word machine, what kind of objects do you think of? Not all machines are hard to use. You use many simple machines every day. Think about some of these machines. The following table lists some jobs you use a machine to do.

STUDY TIP

Brainstorm Think of ways that machines make your work easier and write them down in your science notebook.

READING CHECK

1. Describe How does a machine make work easier?

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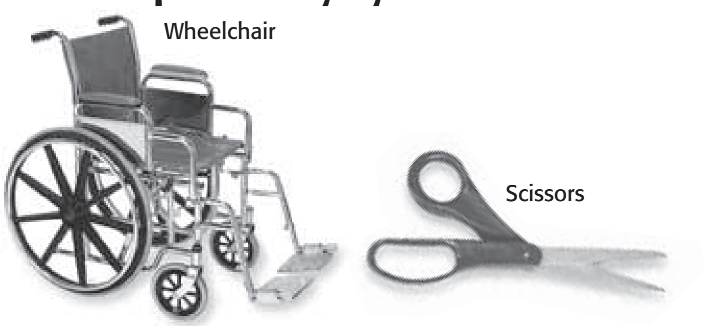
Work	Machine you could use
Removing the snow in your driveway	
Getting you to school in the morning	
Painting a room	
Picking up the leaves from your front yard	
Drying your hair	

TAKE A LOOK

2. Identify Complete the table by filling in the last column.

Two Examples of Everyday Machines



How Do Machines Make Work Easier?

You can use a simple machine, such as a screwdriver, to remove the lid from a paint can. An example of this is shown in the figure below. The screwdriver is a type of *lever*. The tip of the screwdriver is put under the lid and you push down on the screwdriver. The tip of the screwdriver lifts the lid as you push down. In other words, you do work on the screwdriver, and the screwdriver does work on the lid.

WORK IN, WORK OUT

When you use a machine, you do work and the machine does work. The work you do on a machine is called the **work input**. The force you apply to the machine to do the work is the *input force*. The work done by the machine on another object is called the **work output**. The force the machine applies to do this work is the *output force*. ☑

READING CHECK

3. Identify What is work input? What is work output?

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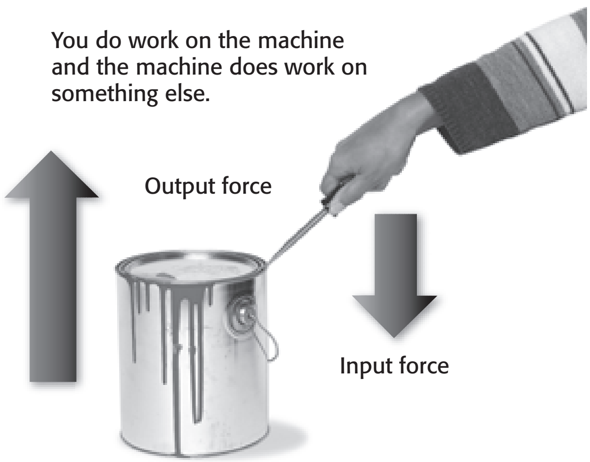

TAKE A LOOK

4. Identify What is the force you put on a screwdriver called?

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What is the force the screwdriver puts on the lid called?

____

HOW MACHINES HELP

Machines do not decrease the amount of work you do. Remember that work equals the force applied times the distance ($W = F \times d$). Machines lower the force that is needed to do the same work by increasing the distance the force is applied. This means less force is needed to do the same work.

In the figure above, you apply a force to the screwdriver and the screwdriver applies a force to the lid. The force the screwdriver puts on the lid is greater than the force you apply. Since you apply this force over a greater distance, your work is easier. ☑

READING CHECK

5. Identify To make work easier, what force is lowered?

____

SAME WORK, DIFFERENT FORCE

Machines make work easier by lowering the size or direction (or both) of the input force. A machine doesn't change the amount of work done. A ramp can be used as a simple machine shown in the figure below. In this example a ramp makes work easier because the box is pushed with less force over a longer distance.

Input Force and Distance

The boy lifts the box. The input force is the same as the weight of the box.

The girl uses a ramp to lift the box. The input force is the less than the weight of the box. She applies this force for a longer distance.

TAKE A LOOK

6. Describe Notice that the box is lifted the same distance by the boy and the girl. Which does more work on the box?

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Look at the boy lifting a box in the figure above. Suppose the box weighs 450 N and is lifted 1 m. How much work is done to move the box?

Step 1: Write the equation.

$$W = F \times d$$

Step 2: Place values into the equation, and solve.

$$W = 450 \text{ N} \times 1 \text{ m} = 450 \text{ N}{\times}\text{m, or } 450 \text{ J}$$

Look at the girl using a ramp. Suppose the force to push the box is 150 N. It is pushed 3 m. How much work is done to move the box?

Step 1: Write the equation.

$$W = F \times d$$

Step 2: Place values into the equation, and solve.

$$W = 150 \text{ N} \times 3 \text{ m} = 450 \text{ N}{\times}\text{m, or } 450 \text{ J}$$

Work done to move box is 450 J.

The same amount of work is done with or without the ramp. The boy uses more force and a shorter distance to lift the box. The girl uses less force and a longer distance to move the box. They each use a different force and a different distance to do the same work.

Math Focus

7. Calculate How much work is done when a 50 N force is applied to a 0.30 m screwdriver to lift a paint can lid?

FORCE AND DISTANCE CHANGE TOGETHER

When a machine changes the size of the output force, the distance must change. When the output force increases, the distance the object moves must decrease. This is shown in the figure of the nutcracker below. The handle is squeezed with a smaller force than the output force that breaks the nut. So, the output force is applied over a smaller distance.

Math Focus

8. Explain Why is the input arrow shorter than the output arrow in the photo of the nutcracker? Why are the arrows the same length in the figure of the pulley?

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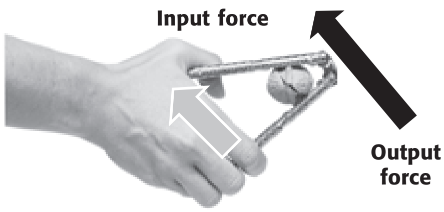
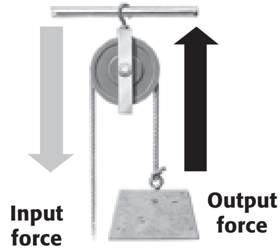
Machines Change the Size and/or Direction of a Force



A nutcracker increases the force but applies it over a shorter distance.



A simple pulley changes the direction of the input force, but the size of the output force is the same as the input force.

What Is Mechanical Advantage?

Some machines can increase the size of the force more than others. A machine's **mechanical advantage** tells you how much the force increases. The mechanical advantage compares the input force with the output force.

CALCULATING MECHANICAL ADVANTAGE

A machine's mechanical advantage can be calculated by using the following equation:

$$\textit{mechanical advantage } (MA) = \frac{\textit{output force}}{\textit{input force}}$$

Math Focus

9. Calculate What is the mechanical advantage of a nutcracker if the input force is 65 N and the output force is 130 N?

Look at this example. You push a box weighing 500 N up a ramp (output force) by applying 50 N of force. What is the mechanical advantage of the ramp?

Step 1: Write the equation.

$$\textit{mechanical advantage } (MA) = \frac{\textit{output force}}{\textit{input force}}$$

Step 2: Place values into the equation, and solve.

$$MA = \frac{500 \text{ N}}{50 \text{ N}} = 10$$

The mechanical advantage of the ramp is 10.

What Is a Machine's Mechanical Efficiency?

No machine changes all of the input work into output work. Some of the work done by the machine is lost to *friction*. Friction is always present when two objects touch. The work done by the machine plus the work lost to friction is equal to the work input. This is known as the *Law of Conservation of Energy*.

The **mechanical efficiency** of a machine compares a machine's work output with the work input. A machine is said to be efficient if it doesn't lose much work to friction.

CALCULATING MECHANICAL EFFICIENCY

A machine's mechanical efficiency is calculated using the following equation:

$$mechanical\ advantage\ (MA) = \frac{output\ force}{input\ force} \times 100$$

The 100 in the equation means that mechanical efficiency is written as a percentage. It tells you the percentage of work input that gets done as work output.

Let's try a problem. You do 100 J of work on a machine and the work output is 40 J. What is the mechanical efficiency of the machine?

Step 1: Write the equation.

$$mechanical\ effeciency\ (ME) = \frac{work\ output}{work\ input} \times 100$$

Step 2: Place values into the equation, and solve.

$$ME = \frac{40\ \text{J}}{100\ \text{J}} \times 100 = 40\%$$

Process Chart

You apply an input force to a machine.
↓
The machine changes the size and/or direction of the force.
↓
The machine applies an ____________ ____________ on the object.
↓
The mechanical efficiency and/or advantage of the machine can be determined.

Math Focus

10. Calculate What is the mechanical efficiency of a simple pulley if the input work is 100 N and the output work is 90 N?

Math Focus

11. Identify Fill in the missing words on the process chart.

____

Name ______________________ Class ______________ Date ______________

Section 2 Review

SECTION VOCABULARY

machine a device that helps do work by either overcoming a force or changing the direction of the applied force

mechanical advantage a number that tells how many times a machine multiplies force

mechanical efficiency a quantity, usually expressed as a percentage, that measures the ratio of work output to work input in a machine

work input the work done on a machine; the product of the input force and the distance through which the force is exerted

work output the work done by a machine; the product of the output force and the distance through which the force is exerted

1. **Explain** Why is it easier to move a heavy box up a ramp than it is to lift the box off the ground?

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2. **Identify** What are the two ways that a machine can make work easier?

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3. **Compare** What is the difference between work input and work output?

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4. **Calculate** You apply an input force of 20 N to a hammer that applies an output force of 120 N to a nail. What is the mechanical advantage of the hammer? Show your work.

5. **Explain** Why is a machine's work output always less than the work input?

____

6. **Calculate** What is the mechanical efficiency of a machine with a work input of 75 J and a work output of 25 J? Show your work.

Name ______________________ Class ______________ Date ____________

CHAPTER 8 Work and Machines

SECTION 3

Types of Machines

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What are the six simple machines?
- What is a compound machine?

What Are the Six Types of Simple Machines?

All machines are made from one or more of the six simple machines. They are the lever, the pulley, the wheel and axle, the inclined plane, the wedge, and the screw. They each work differently to change the size or direction of the input force.

STUDY TIP

As you read through the section, study the figures of the types of machines. Make a list of the six simple machines and a sentence describing how each works.

What Is a Lever?

A commonly used simple machine is the **lever**. A *lever* has a bar that rotates at a fixed point, called a *fulcrum*. The force that is applied to the lever is the *input force*. The object that is being lifted by the lever is called the *load*. A lever is used to apply a force to move a load. There are three classes of levers. They all have a different location for the fulcrum, the load, and the input force on the bar. ☑

READING CHECK

1. Describe How does a lever do work?

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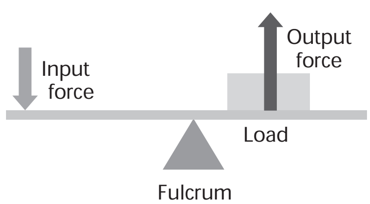
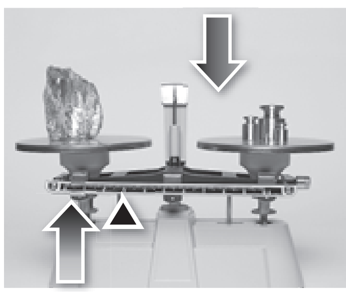
FIRST-CLASS LEVERS

In first-class levers, the fulcrum is between the input force and the load as shown in the figure below. The direction of the input force always changes in this type of lever. They can also be used to increase either the force or the distance of the work.

Examples of First-Class Levers



The fulcrum can be located closer to the load than to the input force. This lever has a mechanical advantage that is greater than 1. The output force is larger than the input force.



The fulcrum can be located exactly in the middle. This lever has a mechanical advantage that is equal to 1. The output force is the same as the input force.

Critical Thinking

2. Predict Suppose the fulcrum in the figure to the far left is located closer to the input force. How will this change the mechanical advantage of the lever? Explain.

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Critical Thinking

3. Explain How does a second-class lever differ from a first-class lever?

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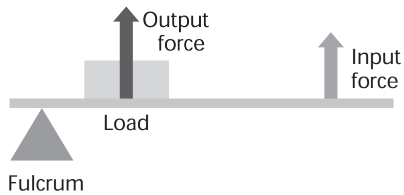
SECOND-CLASS LEVERS

In second-class levers, the load is between the fulcrum and the input force as shown in the figure below. They do not change the direction of the input force. Second-class levers are often used to increase the force of the work. You apply less force to the lever than the force it puts on the load. This happens because the force is applied over a larger distance.

Examples of Second-Class Levers



In a second-class lever, the output force, or load, is between the input force and the fulcrum.

A wheelbarrow is an example of a second-class lever. Second-class levers have a mechanical advantage that is greater than 1.

THIRD-CLASS LEVERS

In third-class levers, the input force is between the fulcrum and the load as shown in the figure below. The direction of the input force does not change and the input force does not increase. This means the output force is always less than the input force. Third-class levers do increase the distance that the output force works.

Critical Thinking

4. Explain Why can't a third-class lever have a mechanical advantage of 1 or more?

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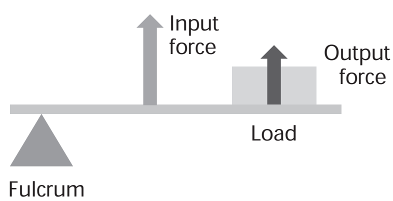
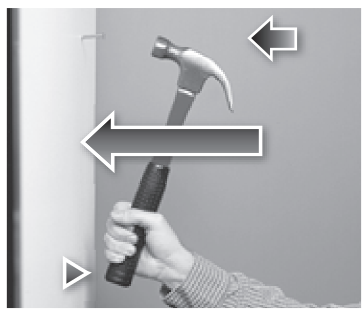
Examples of Third-Class Levers



In a third-class lever, the input force is between the fulcrum and the load.



A hammer is an example of a third-class lever. Third-class levers have a mechanical advantage that is less than 1. The output force is less than the input force. Third-class levers increase the distance that the output force acts on.

What Is a Pulley?

When you open window blinds by pulling on a cord, you are using a pulley. A **pulley** is a simple machine with a grooved wheel that holds a rope or a cable. An input force is applied to one end of the cable. The object being lifted is called the load. The load is attached to the other end. The different types of pulleys are shown in the figure at the bottom of the page. ☑

READING CHECK

5. Describe What is a pulley?

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FIXED PULLEYS

A *fixed pulley* is connected to something that does not move, such as a ceiling. To use a fixed pulley, you pull down on the rope to lift the load. The direction of the force changes. Since the size of the output force is the same as the input force, the mechanical advantage (*MA*) is 1. An elevator is an example of a fixed pulley. ☑

READING CHECK

6. Describe Why can't a fixed pulley have a mechanical advantage greater than 1?

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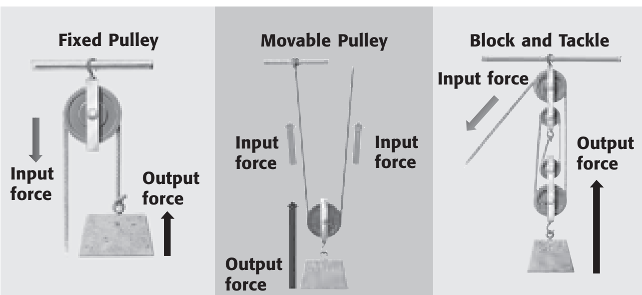
MOVABLE PULLEYS

Moveable pulleys are connected directly to the object that is being moved, which is the load. The direction does not change, but the size of the force does. The mechanical advantage (*MA*) of a movable pulley is 2. This means that less force is needed to move a heavier load. Large construction cranes often use movable pulleys.

BLOCK AND TACKLES

If you use a fixed pulley and a movable pulley together, you form a pulley system. This is a *block and tackle*. The mechanical advantage (*MA*) of a block and tackle is equal to the number of sections of rope in the system.

Types of Pulleys



A **fixed pulley** only turns. The size of the output force is the same as the size of the input force. That means the mechanical advantage is 1.

A **movable pulley** moves with the load as it is lifted. The mechanical advantage in this movable pulley is 2.

A **block and tackle** is a fixed pulley and a movable pulley that work together. The mechanical advantage is the same as the number of rope segments.

TAKE A LOOK

7. Identify The section of rope labeled Input force for the block and tackle is not counted as a rope segment. There are four rope segments in this block and tackle. What is the mechanical advantage of the block and tackle?

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Critical Thinking

8. Explain If the input force remains constant and the wheel is made smaller, what happens to the output force?

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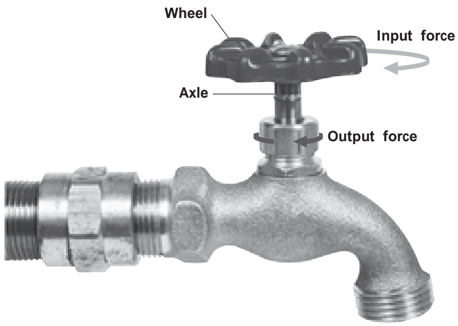


a When a small input force is applied to the wheel, it turns in a circular distance.

b When the wheel turns, so does the axle. The axle is smaller than the wheel. Since the axle turns a smaller distance, the output force is larger than the input force.

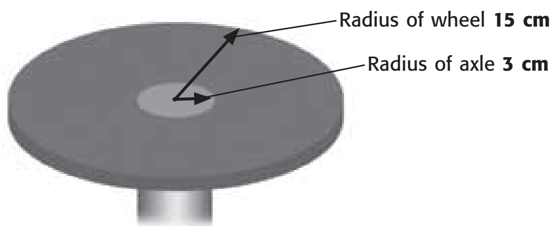
What Is a Wheel and Axle?

Did you know that a faucet is a machine? The faucet in the figure above is an example of a **wheel and axle**. It is a simple machine that is made up of two round objects that move together. The larger object is the *wheel* and the smaller object is the *axle*. Some examples of a wheel and axle are doorknobs, wrenches, and steering wheels.

MECHANICAL ADVANTAGE OF A WHEEL AND AXLE

The mechanical advantage (*MA*) of a wheel and axle can be calculated. To do this you need to know the *radius* of both the wheel and the axle. Remember, the radius is the distance from the center to the edge of the round object. The equation to find the mechanical advantage (*MA*) of a wheel and axle is:

$$\textit{mechanical advantage } (MA) = \frac{\textit{radius of wheel}}{\textit{radius of axle}}$$



The mechanical advantage of a wheel and axle is the wheel radius divided by the axle radius.

Math Focus

9. Calculate A car has a wheel and axle. If the radius of the axle is 7.5 cm and the radius of the wheel is 75 cm, what is the mechanical advantage? Show your work.

Let's calculate the mechanical advantage of the wheel and axle in the figure above.

Step 1: Write the equation.

$$\textit{mechanical advantage } (MA) = \frac{\textit{radius of wheel}}{\textit{radius of axle}}$$

Step 2: Place values into the equation, and solve.

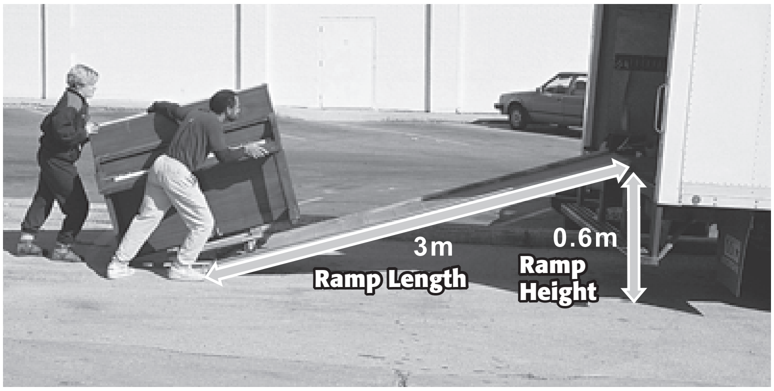
$$\text{MA} = \frac{15 \text{ cm}}{3 \text{ cm}} = 5$$

The mechanical advantage of this wheel and axle is 5.

What Is an Inclined Plane?

The Egyptians built the Great Pyramid thousands of years ago using the **inclined plane**. An *inclined plane* is a simple machine that is a flat, slanted surface. A ramp is an example of an inclined plane.

Using an inclined plane to move a heavy object into a truck is easier than lifting the object. The input force is smaller than the object's weight. The same work is done, but it happens over a longer distance. ☑



You do work to push a piano up a ramp. This is the same amount of work you would do to lift it straight up. An inclined plane lets you apply a smaller force over a greater distance.

READING CHECK

10. Explain How does an incline plane make lifting an object easier?

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MECHANICAL ADVANTAGE OF INCLINED PLANES

The mechanical advantage (*MA*) of an inclined plane can also be calculated. The length of the inclined plane and the height the object that is lifted must be known. The equation to find the mechanical advantage (*MA*) of an inclined plane is:

$$\textit{mechanical advantage } (MA) = \frac{\textit{length of inclined plane}}{\textit{height load raised}}$$

We can calculate the mechanical advantage (*MA*) of the inclined plane shown in the figure above.

Step 1: Write the equation.

$$\textit{mechanical advantage } (MA) = \frac{\textit{length of inclined plane}}{\textit{height load raised}}$$

Step 2: Place values into the equation, and solve for the answer.

$$\text{MA} = \frac{3\text{ m}}{0.6\text{m}} = 5$$

The mechanical advantage (*MA*) is 5.

If the length of the inclined plane is much greater than the height, the mechanical advantage is large. That means an inclined plane with a gradual slope needs less force to move objects than a steep-sloped one.

Math Focus

11. Determine An inclined plane is 10 m and lifts a piano 2.5 m. What is the mechanical advantage of the inclined plane? Show your work.

What Is a Wedge?

A knife is often used to cut because it is a **wedge**. A *wedge* is made of two inclined planes that move. Like an inclined plane, a wedge needs a small input force over a large distance. The output force of the wedge is much greater than the input force. Some useful wedges are doorstops, plows, ax heads, and chisels.

TAKE A LOOK
12. Predict What would happen to the mechanical advantage of the wedge if it were longer in length?

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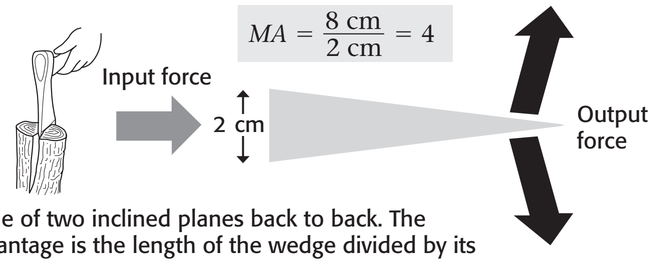


A wedge is made of two inclined planes back to back. The mechanical advantage is the length of the wedge divided by its greatest thickness.

MECHANICAL ADVANTAGE OF WEDGES

The mechanical advantage of a wedge can be found by dividing the length of the wedge by its greatest thickness. The equation to find a wedge's mechanical advantage is:

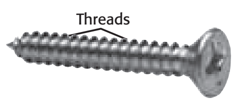
$$\textit{mechanical advantage } (MA) = \frac{\textit{length of wedge}}{\textit{largest thickness of wedge}}$$

A wedge has a greater mechanical advantage if it is long and thin. When you sharpen a knife you are making the wedge thinner. This needs a smaller input force.

What Is a Screw?

A **screw** is an inclined plane that is wrapped around a cylinder. To turn a screw, a small force over a long distance is needed. The screw applies a large output force over a short distance. Screws are often used as fasteners.

Say It
Demonstrate Take a long pencil and a piece of paper cut so it looks like an inclined plane. Roll the paper around the pencil so it looks like threads on a screw. Show the class how the paper looks like threads on a screw. Then unwind the paper showing that it looks like an inclined plane.



If you could unwind a screw, you would have a very long inclined plane.

MECHANICAL ADVANTAGE OF SCREWS

To find the mechanical advantage of a screw you need to first unwind the inclined plane. Then, if you compare the length of the inclined plane with its height you can calculate the mechanical advantage. This is the same as calculating the mechanical advantage of an inclined plane. The longer the spiral on a screw and the closer the threads, the greater the screw's mechanical advantage.

What Is a Compound Machine?

There are machines all around you. Many machines do not look like the six simple machines that you have read about. That is because most of the machines in the world are **compound machines**. These are machines that are made of two or more simple machines. A block and tackle is one example of a compound machine that you have already seen. It is made of two or more pulleys. ☑

A common example of a compound machine is a can opener. A can opener may look simple, but it is made of three simple machines. They are the second-class lever, the wheel and axle, and the wedge. When you squeeze the handle, you are using a second-class lever. The blade is a wedge that cuts the can. When you turn the knob to open the can, you are using a wheel and axle.

READING CHECK

13. Describe What is a compound machine?

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A can opener is a compound machine. The handle is a second-class lever, the knob is a wheel and axle, and a wedge is used to open the can.

TAKE A LOOK

14. Describe Describe the process of using a can opener. Tell the order in which each simple machine is used and what it does to open the can.

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MECHANICAL EFFICIENCY OF COMPOUND MACHINES

The *mechanical efficiency* of most compound machines is low. Remember that mechanical efficiency tells you what percentage of work input gets done as work output. This is different than the mechanical advantage. The efficiency of compound machines is low because they usually have many moving parts. This means that there are more parts that contact each other and more friction. Recall that friction lowers output work. ☑

Cars and airplanes are compound machines that are made of many simple machines. It is important to lower the amount of friction in these compound machines. Friction can often damage machines. Grease is usually added to cars because it lowers the friction between the moving parts.

READING CHECK

15. Identify Why do most compound machines have low mechanical efficiency?

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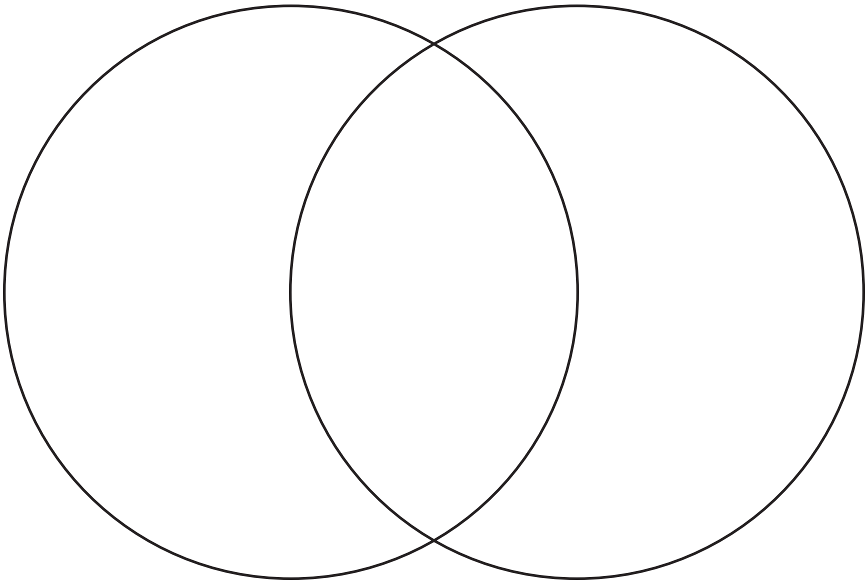
Name ______________________ Class ______________ Date ____________

Section 3 Review

SECTION VOCABULARY

compound machine a machine made of more than one simple machine **inclined plane** a simple machine that is a straight, slanted surface, which facilitates the raising of loads; a ramp **lever** a simple machine that consists of a bar that pivots at a fixed point called a fulcrum **pulley** a simple machine that consists of a wheel over which a rope, chain, or wire passes	**screw** a simple machine that consists of an inclined plane wrapped around a cylinder **wedge** a simple machine that is made up of two inclined planes and that moves; often used for cutting **wheel and axle** a simple machine consisting of two circular objects of different sizes; the wheel is the larger of the two circular objects

1. **Compare** Use a Venn Diagram to compare a first-class lever and a second-class lever.



2. **Calculate** A screwdriver is used to put a screw into a piece of wood. The radius of the handle is 1.8 cm and the radius of shaft is 0.6 cm. What is the mechanical advantage of using the screwdriver? Show your work.

3. **Compare** What is the difference between a wedge and a screw?

____

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4. **Analyze** When there is a lot of friction in a machine, what is lowered and causes mechanical efficiency to be lowered?

____

Name ______________________ Class ______________ Date ______________

CHAPTER 9 Energy and Energy Resources

SECTION 1

What Is Energy?

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- How are energy and work related?
- How is kinetic energy different from potential energy?
- What are some of the other forms of energy?

National Science Education Standards

PS 3a, 3d, 3e, 3f

What Is Energy?

A tennis player needs energy to hit a ball with her racket. The ball has energy as it flies through the air. Energy is all around you, but what is energy?

In science, **energy** is the ability to do work. *Work* is done when a force makes an object move in the direction of the applied force. How do energy and work help you play tennis? The tennis player does work on her racket by applying a force to it. The racket does work on the ball to make it fly into the air.

When the racket does work on the ball, energy moves from the racket to the ball. Energy is the reason the racket can do work. So, work is the transfer of energy. Both work and energy are written in the units joules (J). ☑

STUDY TIP

Make a Venn Diagram to compare and contrast kinetic energy and potential energy. Make a list of other forms of energy and tell if they are kinetic energy or potential energy.

READING CHECK

1. Identify When work is done by one object on another, what is transferred?

____

Work is done by the tennis player on the racket.

↓

Energy moves from the ______________________

______________________ to the ______________.

↓

The tennis racket does work on the ball.

↓

Energy moves from the ______________________

______________________ to the ______________.

TAKE A LOOK

2. Identify Fill in the process chart to show how energy moves when work is done on an object.

What Is Kinetic Energy?

When the tennis player hits the ball with the racket, energy moves from the racket to the ball. The tennis ball has kinetic energy. **Kinetic energy** is the energy of motion. All moving objects have kinetic energy. Like all other forms of energy, kinetic energy can be used to do work. The kinetic energy of a hammer does work on a nail. This is seen in the figure below. ☑

READING CHECK

3. Identify For an object to have kinetic energy, what must it be doing?

____

The hammer has kinetic energy.

When you swing a hammer, it is moving. It has kinetic energy. This energy does work on the nail driving it into the wood.

CALCULATING KINETIC ENERGY

You can calculate the kinetic energy of an object by using the following equation.

$$kinetic\ energy = \frac{mv^2}{2}$$

The m is the object's mass in kilograms. The v is the object's speed. The kinetic energy of an object is large if:

- the object has a large mass, or
- the object is moving fast

What is the kinetic energy of a car that has a mass of 1,000 kg and is moving at a speed of 20 m/s?

Step 1: Write the equation for kinetic energy.

$$kinetic\ energy = \frac{mv^2}{2}$$

Step 2: Place values into the equation and solve.

$$kinetic\ energy = \frac{1{,}000\ \text{kg} \times (20\ \text{m/s})^2}{2} = 200{,}000\ \text{J}$$

The kinetic energy of the car is 200,000 J.

Math Focus

4. Calculate What is the kinetic energy of a 0.50 kg hammer that hits the floor at a speed of 10 m/s?

What Is Potential Energy?

An object does not have to be moving to have energy. **Potential energy** is the energy an object has because of its position. This kind of energy is harder to see because we do not see the energy at work. In the figure below, when the bow is pulled back, it has potential energy. Work has been done on it, and that work has been turned into potential energy. ☑

READING CHECK

5. Identify What causes an object to have potential energy?

____

The bow and the string have energy that is stored as potential energy. When the man lets go of the string, the potential energy does work on the arrow.

Critical Thinking

6. Infer What would the man need to do to give the arrow more potential energy?

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GRAVITATIONAL POTENTIAL ENERGY

When you lift an object, you do work on it. You move it in an opposite direction from the force of gravity. As you lift the object, you transfer energy to the object and give it gravitational potential energy. The amount of *gravitational potential energy* of an object depends on the object's weight and its distance from the ground.

CALCULATING GRAVITATIONAL POTENTIAL ENERGY

The gravitational potential energy of an object can be determined by using the following equation:

gravitational potential energy = *weight* × *height*

The weight is in newtons (N) and the height is in meters (m). Gravitational potential energy is written in newton × meters (N × m). This is the same as a joule (J).

Let's do a calculation. What is the gravitational potential energy of a book with a weight of 13 N at a height of 1.5 m off the ground?

Step 1: *gravitational potential energy* = *weight* × *height*

Step 2: *gravitational potential energy* = 13 N × 1.5 m = 19.5 J

The book now has 19.5 J of potential energy.

Math Focus

7. Calculate What is the potential energy of a 300 N rock climber standing 100 m from the base of a rock wall?

What Is Mechanical Energy?

Look at the figure below. All the energy in the juggler's pins is in the form of mechanical energy. **Mechanical energy** is the total energy of motion and position of an object. In other words, it is the kinetic energy plus the potential energy of an object. ☑

READING CHECK

8. Identify Adding what two energies gives the mechanical energy of an object?

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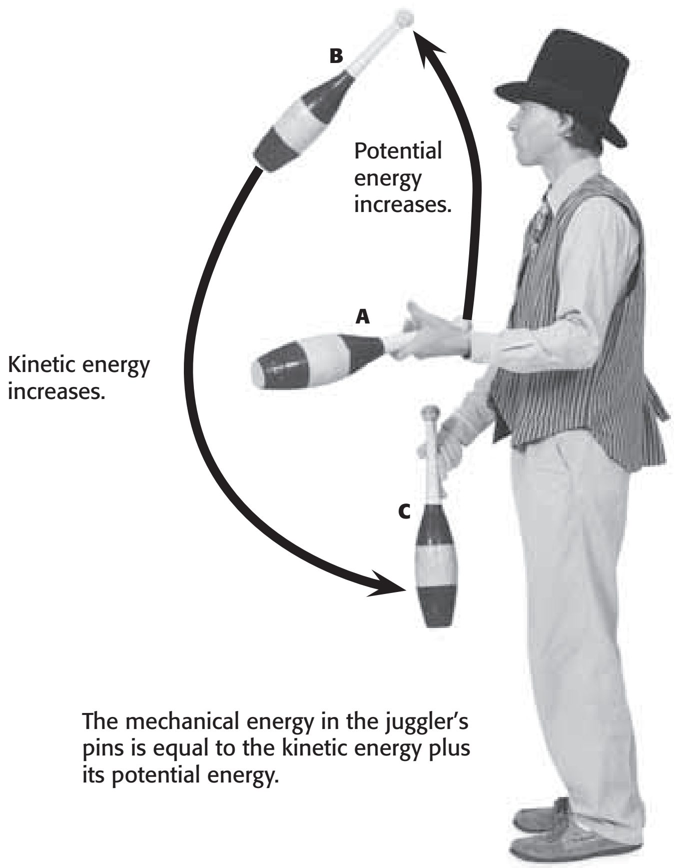

The mechanical energy in the juggler's pins is equal to the kinetic energy plus its potential energy.

TAKE A LOOK

9. Identify In the figure, circle the pin with the most potential energy.

MECHANICAL ENERGY IN A JUGGLER'S PIN

The mechanical energy of an object doesn't change unless energy is transferred to or from another object.

Look again at the figure of the juggler. The juggler moves the pin by doing work on it. He gives the pin kinetic energy. When he lets go of the pin, the pin's kinetic energy changes into potential energy. As the pin goes up, it slows down. When all of the pin's kinetic energy is turned into potential energy, it stops going up.

When the pin starts to fall, its energy is mostly potential energy. As it falls, the potential energy is changed back into kinetic energy. At different times, the pin may have more kinetic energy or more potential energy. The total mechanical energy at any point is always the same.

Say It

Discuss Suppose a batter hits a pop-up in baseball that goes straight up. With a partner, discuss the changes in kinetic and potential energy as the ball leaves the bat and rises to its highest height.

What Are the Other Forms of Energy?

Energy can be in a form other than mechanical energy. The other energy forms are thermal, chemical, electrical, sound, light, and nuclear energy. All of these energy forms are connected in some way to kinetic energy and potential energy.

THERMAL ENERGY

Matter is made of particles that are moving. These particles have kinetic energy. *Thermal energy* is all the kinetic energy from the movement of the particles in an object. ☑

The figure below shows the thermal energy of particles at different temperatures. Particles move faster at higher temperatures than at lower temperatures. The faster the particles move, the greater their kinetic energy and thermal energy are.

READING CHECK

10. Describe What is thermal energy?

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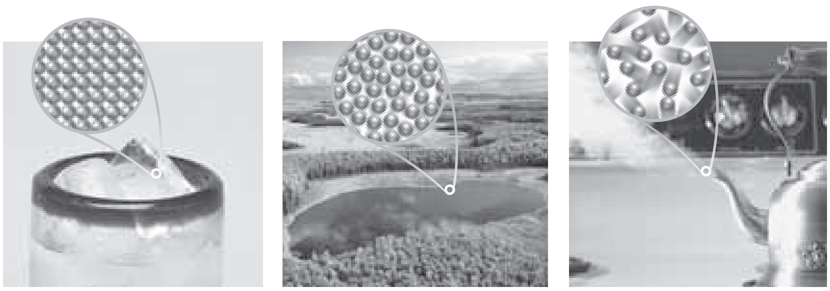
The Thermal Energy in Water



The particles in an ice cube vibrate in fixed positions and do not have a lot of kinetic energy.

The particles in water in a lake can move more freely and have more kinetic energy than water particles in ice do.

The particles in water in steam move rapidly, so they have more energy than particles in liquid water do.

CHEMICAL ENERGY

Chemical compounds such as sugar, salt, and water store energy. These compounds are made of many atoms that are held together by chemical bonds. Work is done to join the atoms together to form these bonds. *Chemical energy* is the energy stored in the chemical bonds that hold the compounds together. Chemical energy is a type of potential energy because it depends on the position of the atoms in the compound. ☑

READING CHECK

11. Identify Chemical energy is a form of what type of energy?

____

ELECTRICAL ENERGY

You use electrical energy every day. Electrical outlets in your home allow you to use this energy. *Electrical energy* is the energy of moving particles called electrons. Electrons are the negatively charged particles of atoms.

What happens when you plug an electrical device, such as an amplifier shown in the figure below, into an outlet? You use electrical energy. The electrons in the wires move to the amplifier. The moving electrons do work on the speaker in the amplifer. This makes the sound that you hear from the amplifier.

Electrical energy has both kinetic energy and potential energy. When electrical energy runs through a wire, it uses its kinetic energy. Electrical energy that is waiting to be used is potential energy. This potential energy is in the wire before you plug in an electrical appliance.

STANDARDS CHECK

PS 3d Electrical circuits provide a means of transferring electrical energy when heat, light, sound, and chemical changes are produced.

12. Describe How does an amplifier make sound?

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The movement of electrons produces the electrical energy that an amplifier and the microphone use to produce sound.

As the guitar strings vibrate, they cause particles in the air to vibrate. These vibrations transmit sound energy.

TAKE A LOOK

13. Identify What is the energy source for the amplifier? What kind of energy is transmitted by the guitar?

____

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SOUND ENERGY

Sound energy is the energy from a vibrating object. *Vibrations* are small movements of particles of an object. In the figure above, the guitar player pulls on the guitar string. This gives the string potential energy. When she lets go of the string, the potential energy turns into kinetic energy. This makes the string vibrate.

When the guitar string vibrates, some of its kinetic energy moves to nearby air particles. These vibrating air particles cause sound energy to travel. When the sound energy reaches your ear, you hear the sound of the guitar.

LIGHT ENERGY

Light helps you see, but not all light can be seen. We use light in microwaves, but we do not see it. *Light energy* is made from vibrations of electrically charged particles. Light energy is like sound energy. They both happen because particles vibrate. However, light energy doesn't need particles to travel. This makes it different than sound energy. Light energy can move through a *vacuum*, which is an area where there is no matter.

Microwave Oven

The energy used to cook food in a microwave is a form of

________________ ________________.

TAKE A LOOK

14. Identify Complete the sentence found in the figure.

NUCLEAR ENERGY

Another kind of energy is stored in the nucleus of an atom. This energy is *nuclear energy*. This energy is stored as potential energy.

There are two ways nuclear energy can be given off by a nucleus. When two or more small nuclei join together, they give off energy in a reaction called *fusion*. The sun's light and heat come from fusion reactions.

The second way nuclear energy is given off is when a nucleus splits apart. This process is known as *fission*. Large nuclei, like uranium, can be broken apart with fission. Fission is used to create electrical energy at nuclear power plants. ☑

READING CHECK

15. Compare How do nuclear fusion and fission differ?

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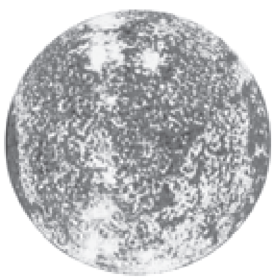
Our Sun



Without ____________________ ____________________ that gives the sun its energy, life on Earth would not be possible.

TAKE A LOOK

16. Identify Complete the sentence found in the figure.

Name ______________________ Class ______________ Date ______________

Section 1 Review

NSES PS 3a, 3d, 3e, 3f

SECTION VOCABULARY

energy the capacity to do work **kinetic energy** the energy of an object that is due to the object's motion	**mechanical energy** the amount of work an object can do because of the object's kinetic and potential energies **potential energy** the energy that an object has because of the position, shape, or condition of the object

1. **Identify** An object's kinetic energy depends on two things. What are they?

____

2. **Calculate** A book weighs 16 N and is placed on a shelf that is 2.5 m from the ground. What is the gravitational potential energy of the book? Show your work.

3. **Calculate** What is the kinetic energy of a 2,000 kg bus that is moving at 25 m/s? Show your work.

4. **Explain** A girl is jumping on a trampoline. When she is at the top of her jump, her mechanical energy is in what form? Explain why.

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5. **Identify** How are sound energy and light energy similar?

____

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6. **Conclude** Which type of nuclear reaction is more important for life on Earth? Explain why.

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SECTION 2
Energy Conversions

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What are energy conversions?
- How do machines use energy conversions?

National Science Education Standards
PS 3a, 3f

What Is an Energy Conversion?

Think of a book sitting on a shelf. The book has gravitational potential energy when it is on the shelf. What happens if the book falls off the shelf? Its potential energy changes into kinetic energy. This is an example of an energy conversion.

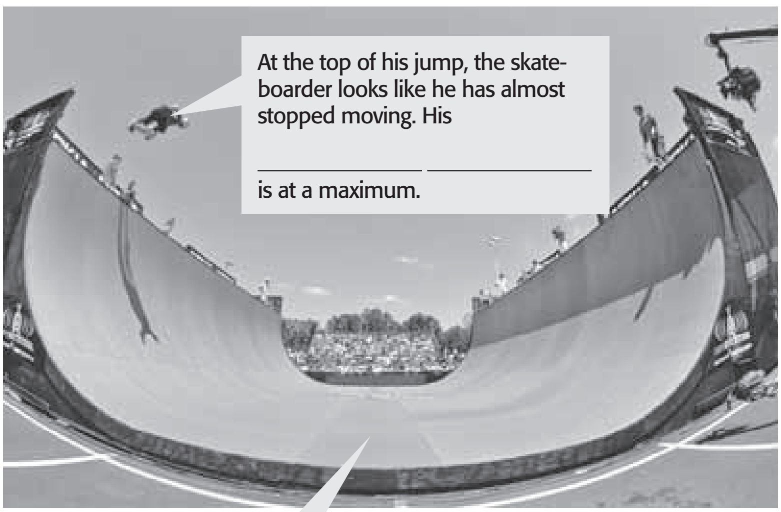
An **energy conversion** is a change from one form of energy to another. Any form of energy can change into any other form of energy. One form of energy can sometimes change into more than one other energy form.

STUDY TIP
Make a list in your science notebook of the energy conversions discussed in this section.

KINETIC AND POTENTIAL ENERGY CONVERSION

A common energy conversion happens between potential energy and kinetic energy. When the skateboarder in the figure below moves down the half-pipe, he has a lot of kinetic energy. As he travels up the half-pipe, his kinetic energy changes into potential energy.

Potential Energy and Kinetic Energy



At the top of his jump, the skateboarder looks like he has almost stopped moving. His ______________ ______________ is at a maximum.

At the bottom of the half-pipe, the skateboarder has a lot of speed. His ______________ ______________ is at a maximum.

TAKE A LOOK
1. Identify Complete the two blanks in the figure.

ELASTIC POTENTIAL ENERGY

Another example of potential energy changing into kinetic energy is shown in a rubber band. When you stretch a rubber band, you give it potential energy. This energy is called *elastic potential energy*. When you let go of the rubber band, it flies across the room. The stored potential energy in the stretched rubber band is turned into kinetic energy. ☑

READING CHECK

2. Describe How does a rubber band gain elastic potential energy?

____

How Do Chemical Energy Conversions Happen?

You may have heard that breakfast is the most important meal of the day. Why is eating breakfast so important? *Chemical energy* comes from the food you eat. Your body changes the chemical energy from food into several different energy forms that it can use. Some of these are:

- mechanical energy, to move your muscles
- thermal energy, to keep your body temperature constant
- electrical energy, to help your brain think

So eating breakfast helps your body do all of your daily activities.

Food has chemical energy.

↓

You eat ______________.

↓

Your body stores the chemical energy of the food.

↓

Chemical energy is converted into:

____

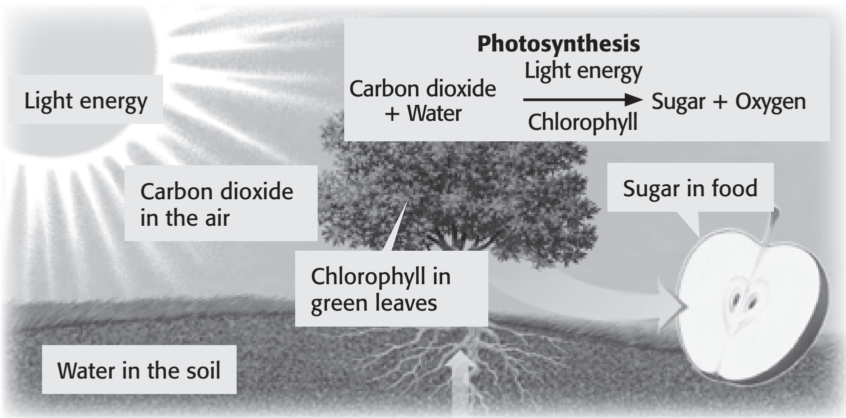
____

______________.

TAKE A LOOK

3. Identify Fill in the process chart to show how energy is converted in your body.

From Light Energy to Chemical Energy



STANDARDS CHECK

PS 3f The sun is a major source of energy for changes on the earth's surface. The sun loses energy by emitting light. A tiny fraction of that light reaches the earth, transferring energy from the sun to the earth. The sun's energy arrives as light with a range of wave lengths, consisting of visible light, infrared, and ultraviolet radiation.

4. Identify Light energy from the sun is converted into what kind of energy by green leaves?

____

ENERGY CONVERSIONS IN PLANTS

Did you know the chemical energy in the food you eat comes from the sun's energy? When you eat fruits, vegetables, or grains, you are taking in chemical energy. Energy from the sun was used to make the chemical energy in the food. Many animals also eat plants. If you eat meat from these animals, you are also taking in energy that comes from the sun.

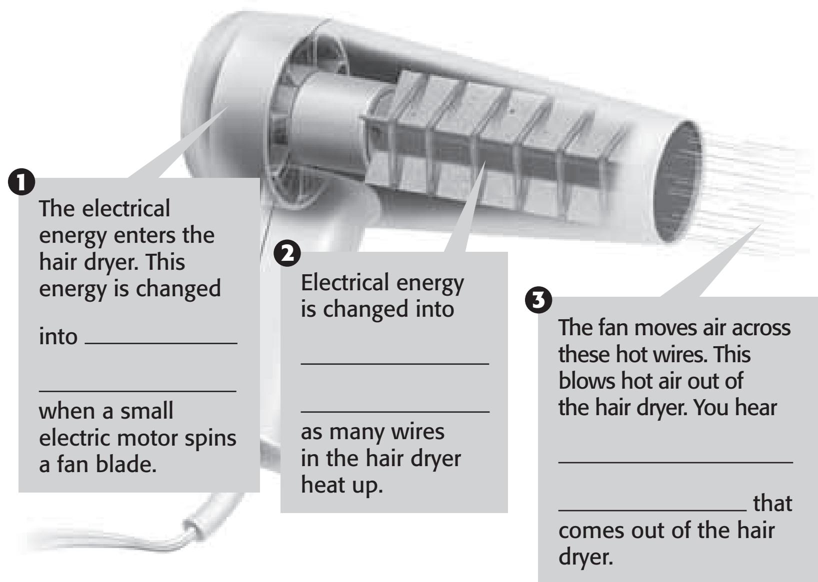
The figure above shows how light energy is used to make new material that has chemical energy. When photosynthesis happens in plants, light energy from the sun is changed into chemical energy. *Photosynthesis* is a chemical reaction in plants that changes light energy into chemical energy. When we eat fruits, vegetables, or grains, we are eating the chemical energy that is stored in the plants.

The chemical energy from a tree can also be changed into thermal energy. This change happens when you burn a tree's wood. If you go back far enough, you would see that the energy from a wood fire comes from the sun.

Say It

Discuss With a partner, describe how light energy from the sun becomes chemical energy in meat from animals.

Energy Conversions in a Hair Dryer



TAKE A LOOK

5. Identify Fill in the blanks in the figure.

Why Are Energy Conversions Important?

Energy conversions happen everywhere. Heating our homes and getting energy from food are just a few examples of how we use energy conversions. Machines also convert and use energy. This can be seen from the figure of the hair dryer above. Electrical energy by itself won't dry your hair. The hair dryer changes electrical energy into thermal energy. This heat helps dry your hair.

ELECTRICAL ENERGY CONVERSIONS

You use electrical energy all of the time. Some examples of when you use electrical energy are listening to the radio, making toast, and taking a picture. Electrical energy changes into other kinds of energy easily.

Some Conversions of Electrical Energy		
Alarm Clock	Electrical energy →	
Hair dryer	Electrical energy →	
Light bulb	Electrical energy →	
Blender	Electrical energy →	

TAKE A LOOK

6. Identify Look at the table. In each example, think about what kind of energy conversion happens. Then, fill in the last column of the table with the kind (or kinds) of energy that is formed.

How Do Machines Use Energy?

You have seen how energy can change into different forms. Another way to look at energy is to see how machines use energy. Remember that a machine can make work easier. It does this by changing the size or direction (or both) of the force that does the work. The machine converts the energy you put into the machine into work.

There is another way that machines can help you use energy. They can convert energy into a form that you need, such as a stove using electrical energy to cook food. ☑

An example of how energy is used by a machine is shown in the figure below. The biker puts a force on the pedals. This transfers kinetic energy from the biker into kinetic energy to move the pedals. This energy moves to other parts of the bike. The bike lets the biker use less force over a greater distance. This makes his work easier.

READING CHECK

7. Describe What are two ways a machine converts energy?

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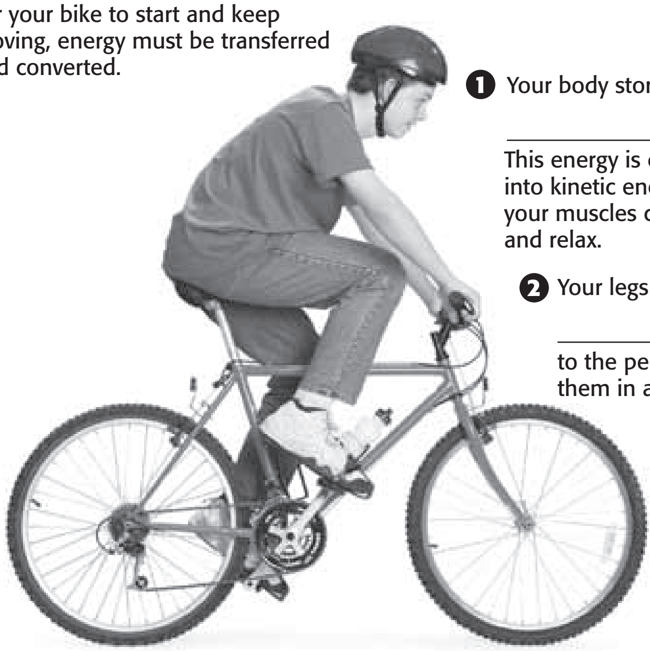
Energy Conversions in a Bicycle

For your bike to start and keep moving, energy must be transferred and converted.



1 Your body stores ______________ energy. This energy is changed into kinetic energy when your muscles contract and relax.

2 Your legs transfer ______________ energy to the pedals by pushing them in a circle.

4 The chain moves and transfers kinetic energy to the back wheel.

This gets you ______________ and keeps you moving.

3 The pedals transfer ______________ energy to the wheel and then to the chain.

TAKE A LOOK

8. Identify Complete the blanks in the figure.

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Name ______________________ Class ______________ Date ____________

Section 2 Review

NSES PS 3a, 3f

SECTION VOCABULARY

energy conversion a change from one form of energy to another	

1. **Identify** Suppose a skier is standing still at the top of a hill. What kind of energy does the skier have?

____

2. **Explain** What happens to the energy of the skier in Question 1 if he goes down the hill?

____

3. **Describe** How does your body get the energy that it needs to do all of its daily activities? Describe the energy conversions that take place.

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4. **Explain** What energy conversion happens when green plants use energy from the sun to make sugar?

____

____

5. **Analyze** A vacuum cleaner is a machine that uses electrical energy. What are three forms of energy that the electrical energy changes into in the vacuum cleaner?

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6. **Compare** How are the energy conversions of a machine similar to the energy conversions in your body?

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CHAPTER 9 Energy and Energy Resources

SECTION 3

Conservation of Energy

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- How does friction affect energy conversions?
- What is the law of conservation of energy?
- What happens to energy in a closed system?

National Science Education Standards
PS 3a

Where Does Energy Go?

Most roller coasters use a chain to pull the cars up to the top of the first hill. As the cars go up and down the rest of the hills, their potential energy and kinetic energy keep changing. Since no additional energy is put into the cars, they never go as high as the first hill. Is energy lost? No, it just changes into other forms of energy.

When a roller coaster's energy is changing, some of its energy is lowered by friction. **Friction** is a force that is present when two objects touch each other. There is friction between the cars' wheels and the track. There is also friction between the cars and the air around them. Friction slows the motion of a roller coaster.

STUDY TIP
In your science notebook, list the energy conversions in this section and note why energy is not conserved in the conversion.

READING CHECK
1. Identify What causes the energy of a roller coaster to be lowered when the coaster's energy changes form?

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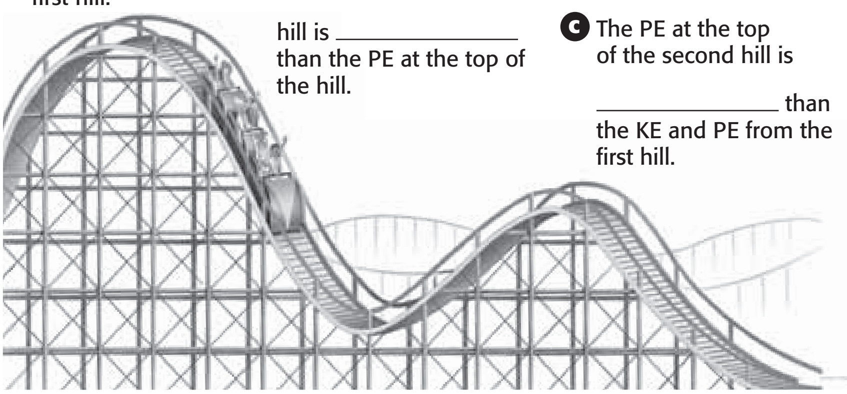
Energy Conversions in a Roller Coaster



Not all of the cars' potential energy (PE) changes into kinetic energy (KE) as the cars go down the first hill. When the cars move up hill 2, not all of its KE is converted into PE at the top of hill 2. Some of it is changed into thermal energy because of friction.

TAKE A LOOK
2. Complete Fill in the blanks in the figure with the following terms (they can be used more than once): greater, less, largest, smallest.

What Happens to Energy in a Closed System?

A *closed system* is a group of objects that move energy only to each other. On a roller coaster, a closed system would be the track, the cars, and the air around the cars.

Some of the mechanical energy (kinetic energy plus potential energy) of the cars changes into thermal energy. This happens because of friction. Mechanical energy is also converted into sound energy. You hear this energy when you are near the roller coaster. The rest of the potential energy changes into kinetic energy. This is seen by the roller coaster racing down the track.

If you add up all of this energy, it equals the cars' potential energy at the top of the first hill. The energy at the top of the hill is the same as the energy that is converted to other forms. So, energy is conserved and not lost in a closed system.

STANDARDS CHECK

PS 3a Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.

3. Identify Into what form of energy does friction convert mechanical energy?

____

LAW OF CONSERVATION OF ENERGY

Energy is always conserved. This is always true, so it is called a law. In the **law of conservation of energy**, energy cannot be created or destroyed. In a closed system, energy can change from one form to another, but the total energy is always the same. It doesn't matter how many or what kinds of energy conversions take place. The energy conversions that happen in a light bulb are shown in the figure below. ☑

READING CHECK

4. Describe What is the law of conservation of energy?

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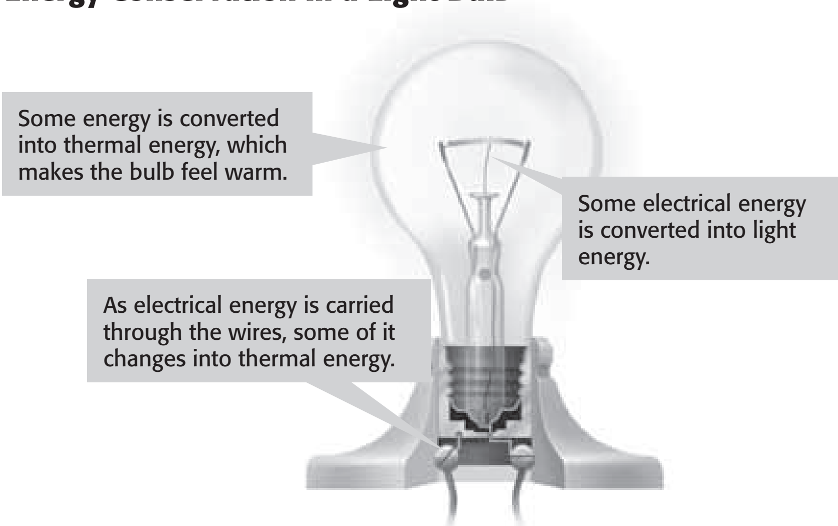
Energy Conservation in a Light Bulb



Critical Thinking

5. Explain Why is the light bulb *not* a closed system?

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Why Can't a Machine Run Forever Without Adding Energy?

Any time an energy conversion happens, some of the energy always changes into thermal energy. This thermal energy is in the form of friction. The energy from friction is not useful energy. It is not used to do work.

Think about a car. You put gas into a car. Not all of the chemical energy from the gas makes the car move. Some energy is wasted as thermal energy. This energy leaves through the radiator and the exhaust pipe.

It is impossible to create a machine that runs forever without adding more energy to it. This kind of machine is called a *perpetual motion machine*. A machine has to have a constant supply of energy because energy conversions always produce wasteful thermal energy. ☑

READING CHECK

6. Describe Why can't there be a perpetual motion machine?

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EFFICIENT ENERGY CONVERSIONS

If a car gets good gas mileage, it is energy efficient. The *energy efficiency* is found by comparing the amount of starting energy with the amount of useful energy produced. A car with high energy efficiency goes farther than other cars with the same amount of gasoline.

More efficient energy conversions waste less energy. For example, smooth, *aerodynamic* cars have less friction between the car and the air around it. They use less energy, so they are more efficient. If less energy is wasted, then less energy is needed to run the car.

Car A

Car B

The shape of newer cars lowers the friction between the car and the air passing over it.

READING CHECK

7. Describe Which car is more aerodynamic in shape?

____

Name ______________________ Class ______________ Date ______________

Section 3 Review

NSES PS 3a

SECTION VOCABULARY

friction a force that opposes motion between two surfaces that are in contact	**law of conservation of energy** the law that states that energy cannot be created or destroyed but can be changed from one form to another

1. Explain Suppose you drop a ball. It bounces a few times and then stops. Does the energy disappear? Explain your answer.

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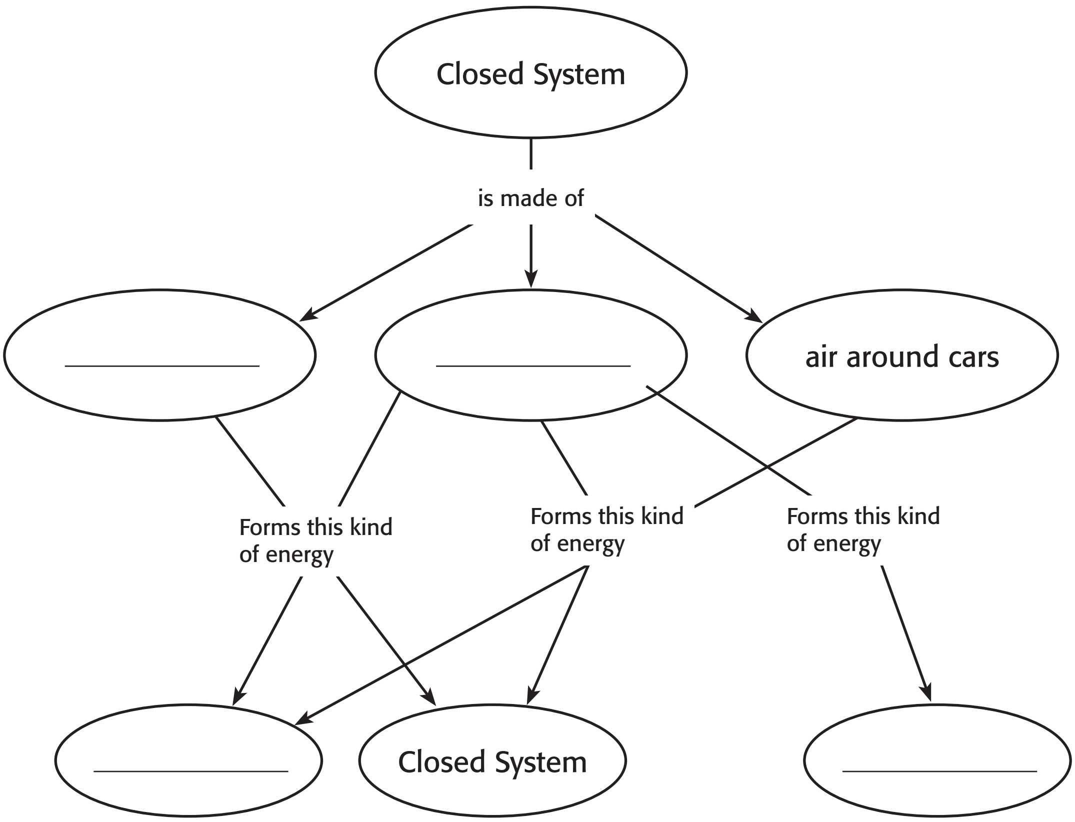
2. Identify Fill in the following concept map for a closed system of a roller coaster. Include the parts of the closed system and the energy that is produced.



3. Identify What causes thermal energy always formed in an energy conversion?

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Name ______________________ Class ______________ Date ______________

CHAPTER 9 Energy and Energy Resources

SECTION 4

Energy Resources

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is an energy resource?
- How do we use nonrenewable energy resources?
- What are renewable energy resources?

National Science Education Standards
PS 3a, 3e, 3f

What Is an Energy Resource?

Energy is used for many things. It is used to light our homes, to make food and clothing, and to move people from place to place. An *energy resource* is a natural product that can be changed into other energy forms to do work. There are many types of energy resources.

STUDY TIP
In your science notebook, make a table that lists nonrenewable and renewable energy resources.

What Are Nonrenewable Energy Resources?

Some energy resources are **nonrenewable resources**. These are resources that can never be replaced or are replaced more slowly than they are used. ☑

Oil, natural gas, and coal are nonrenewable resources called fossil fuels. **Fossil fuels** are energy resources that formed from buried plants and animals that lived a very long time ago. Millions of years ago, the plants stored energy from the sun by photosynthesis. The animals stored and ate the energy from the plants. When we burn fossil fuels today, we are using the sun's energy from millions of years ago. ☑

READING CHECK
1. Identify What are nonrenewable resources?

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READING CHECK
2. Identify Where did the energy contained in fossil fuels come from?

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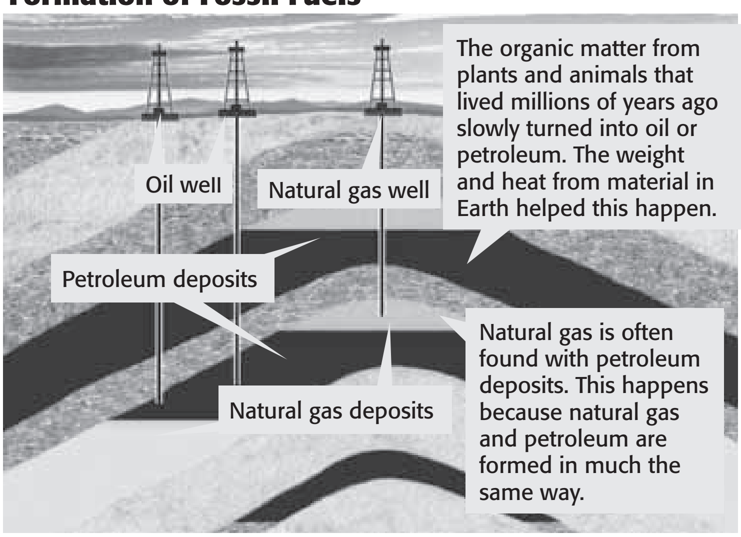
Formation of Fossil Fuels



USES OF FOSSIL FUELS

All fossil fuels have stored energy from the sun. This can be changed into other kinds of energy. The figure below shows how we use fossil fuels.

The three most common fossil fuels are coal, natural gas, and oil (petroleum). Burning coal is a way to produce electrical energy. Gasoline, wax, and plastics are made from petroleum. Natural gas is often used to heat homes. ☑

READING CHECK

3. Identify What are the three most common fossil fuels?

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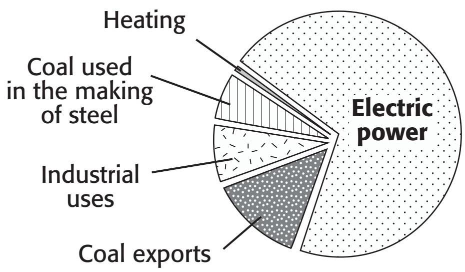
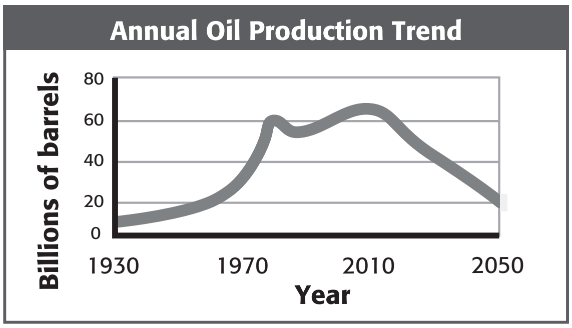
Everyday Uses of Some Fossil Fuels

Coal Use (U.S.)



Most coal used in the United States is burned. This produces steam that runs electrical generators.



Gasoline, kerosene, wax, and petrochemicals come from petroleum. Scientists continue to look for other energy sources.

Math Focus

4. Analyze Graph What is the annual oil production trend after the year 2010?

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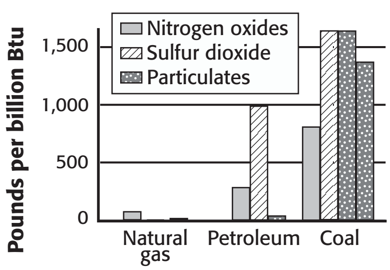
Fossil-Fuel Emissions



Natural gas is used to heat homes, stoves, and ovens, and to power vehicles. Natural gas has lower emissions than other fossil fuels.

ELECTRICAL ENERGY FROM FOSSIL FUELS

Electrical energy can be produced when fossil fuels are burned. Most of the electrical energy produced in the United States is from fossil fuels. *Electric generators* change the chemical energy from the fossil fuels into electrical energy. This is shown in the figure below.

STANDARDS CHECK

PS 3e In most chemical and nuclear reactions, energy is transferred into or out of a system. Heat, light, mechanical motion, or electricity might all be involved in such transfers.

5. Identify What is most often used to produce electricity in the United States?

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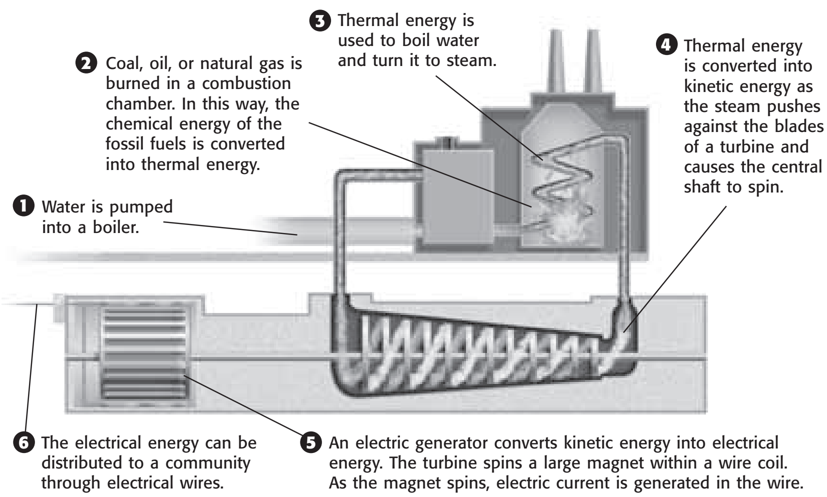
Converting Fossil Fuels into Electrical Energy



NUCLEAR ENERGY

Electrical energy is also produced from nuclear energy. Nuclear energy comes from radioactive elements like uranium. The nucleus of a uranium atom splits into two smaller nuclei in a process called *nuclear fission*. There is not a large supply of radioactive elements, so nuclear energy is a nonrenewable resource. ☑

A nuclear power plant changes the thermal energy from nuclear fission into electrical energy. Splitting uranium atoms creates thermal energy. This thermal energy is changed to electrical energy in a process similar to how fossil fuel power plants work. The figure above shows how this happens.

READING CHECK

6. Identify What nuclear process is used to produce electricity?

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What Are Renewable Energy Resource?

Some energy sources are replaced faster than they are used. These are **renewable resources**. Some of these resources can almost produce an endless supply of energy.

SOLAR ENERGY

The energy from the sun can be changed into electrical energy by solar cells. A *solar cell* is a device that changes solar energy into electrical energy. You may have seen solar cells in calculators or on the roof of a house. ☑

READING CHECK

7. Describe What does a solar cell do?

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ENERGY FROM WATER

The potential energy of water can be changed into kinetic energy in a dam. The water falls over the dam and turns turbines. The turbines are connected to a generator that changes kinetic energy into electrical energy.

WIND ENERGY

Because the sun does not heat Earth's surface the same in all places, wind is created. The kinetic energy of wind can turn the blades of a windmill. Wind turbines change this kinetic energy into electrical energy by turning a generator.

GEOTHERMAL ENERGY

Thermal energy made by the heating of Earth's crust is called *geothermal energy*. Geothermal power plants pump water under the ground near hot rock. The water turns into steam, which is used to turn the turbines of a generator.

BIOMASS

Biomass is organic matter, like plants, wood, or waste. When biomass is burned, it gives off the energy it got from the sun. This can be used to make electrical energy.

TAKE A LOOK

8. Identify The table lists many renewable resources. Complete the missing boxes in the table.

Renewable energy source	Direct source of energy	Original source of energy
Solar energy	sun	______________
Energy from water	______________	sun
Wind energy	______________	sun
Geothermal energy	heat of earth's crust	______________
Biomass	organic matter	______________

How Do You Decide What Energy Source to Use?

All energy resources have advantages and disadvantages. The table below compares many energy resources. The energy source you choose often depends on where you live, what you need it for, and how much you need. To decide which source to use, advantages and disadvantages must be thought about.

One disadvantage of using fossil fuels you have often heard is that fossil fuels pollute the air. Another disadvantage is that we can run out of fossil fuels if we use them all up.

Some renewable resources have disadvantages, too. It is hard to produce a lot of energy from solar energy. Many renewable resources are limited to places where that resource is available. For example, you need a lot of wind to get power from wind energy. ☑

Energy planning around the world is important. Energy planning means determining your energy needs and your available energy resources, and then using this energy responsibly.

READING CHECK

9. Describe What is a disadvantage of solar energy?

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Advantages and Disadvantages of Energy Resources

Resource	Advantages	Disadvantages
Fossil Fuels	• produces large amounts of energy • easy to get • makes electricity • makes products like plastic	• nonrenewable • produces smog • produces acid precipitation • risk of oil spills
Nuclear	• concentrated energy form • no air pollution	• produces radioactive waste • nonrenewable
Solar	• almost endless source • no pollution	• expensive • works best in sunny areas
Water	• renewable • inexpensive • no pollution	• needs dams, which hurt water ecosystem • needs rivers
Wind	• renewable • inexpensive • no pollution	• needs a lot of wind
Geothermal	• almost endless source • little land needed	• needs a ground hot spot • produces wastewater
Biomass	• renewable • inexpensive	• needs a lot of farmland • produces smoke

TAKE A LOOK

10. Identify What are some advantages to using wind power?

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Section 4 Review

NSES **PS 3a, 3e, 3f**

SECTION VOCABULARY

fossil fuel a nonrenewable energy resource formed from the remains of organisms that lived long ago

nonrenewable resource a resource that forms at a rate that is much slower than the rate at which the resource is consumed

renewable resource a natural resource that can be replaced at the same rate at which the resource is consumed

1. **Compare** What is the difference between a nonrenewable energy resource and a renewable energy resource?

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2. **Analyze** Why can it be said that the energy from burning fossil fuels ultimately comes from the sun?

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3. **Explain** How is nuclear energy used to make electrical energy?

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4. **Identify** What is a renewable energy resource that does not depend on the sun?

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5. **Analyze** What are some possible reasons that solar power is not used for all of our energy needs?

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SECTION 1

Temperature

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- How are temperature and kinetic energy related?
- How is temperature measured?
- What is thermal expansion?

National Science Education Standards

PS 3a, 3b

What Is Temperature?

You may think of temperature as how hot or cold something is. But using the words *hot* and *cold* can be confusing. Pretend that you are outside on a hot day. If you step onto a porch with a fan blowing, you might think it feels cool. Then, your friend enters the porch from an air-conditioned house. She thinks the porch is warm!

Using the words cool and warm to describe the porch is confusing. Measuring the temperature on the porch tells you exactly how hot or cold it is. The **temperature** tells you the average kinetic energy of the particles in an object.

STUDY TIP

Describe Describe how temperature affects the average kinetic energy and thermal expansion. Give several examples of thermal expansion.

READING CHECK

1. Identify What is used to tell how hot or cold something is?

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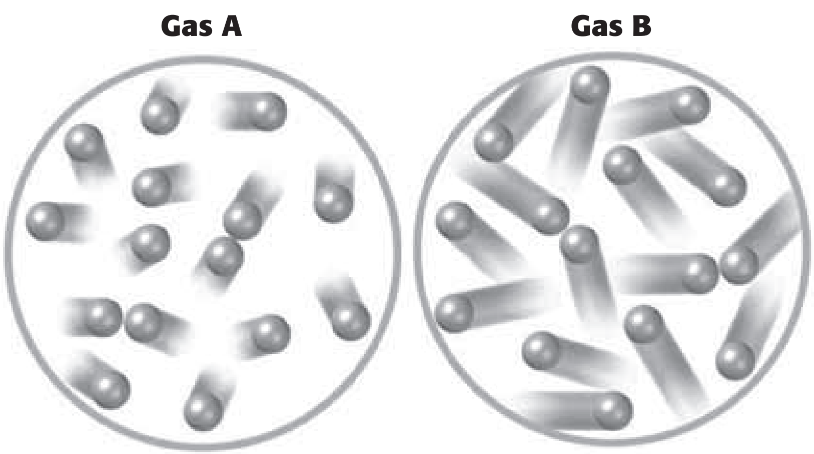
TEMPERATURE AND KINETIC ENERGY

All matter is made of atoms or molecules that are always moving. The particles that are moving have kinetic energy. The faster they move, the more kinetic energy they have. Look at the figure below. The more kinetic energy the particles have, the higher the temperature is.



The gas particles on the right have higher kinetic energy than those on the left.

TAKE A LOOK

2. Identify Which gas shows particles at the higher temperature?

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AVERAGE KINETIC ENERGY

The particles that make up matter are always moving in different directions and speeds. This movement is random. Since the particles move at different speeds, each particle has its own kinetic energy. The temperature of a substance is a measure of the *average kinetic energy* of all the particles in a substance. A high temperature means more of the particles in the object are moving fast rather than slow.

The temperature of a substance does not depend on how much of it you have. Look at the figure below. A pot of tea and a cup of tea each have a different amount of tea. Their atoms have the same average kinetic energy. There may be more tea in the teapot than in the cup, but they are at the same temperature.

STANDARDS CHECK

PS 3a Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.

3. Identify The temperature of a substance is a measure of what kind of energy?

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There is more tea in the teapot than in the cup. But the temperature of the tea in the cup is the same as the temperature of the tea in the teapot.

Critical Thinking

4. Infer As the tea in the cup cools, what happens to the average kinetic energy of the particles in the tea? What happens to the motion of the particles in the tea?

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How Is Temperature Measured?

How do you measure the temperature of a cup of hot chocolate? If you took a sip of it, you would not be able to measure the temperature very well. The best way is to use a thermometer.

USING A THERMOMETER

Many thermometers are thin glass tubes filled with a liquid. Mercury and alcohol are often used in thermometers because they are a liquid over a wide range of temperatures. They also expand at a constant rate.

Thermometers that use liquids can measure temperature because of thermal expansion. **Thermal expansion** is the increase in the volume of a substance when the temperature of the substance increases. When a substance's temperature increases, its particles move faster and farther away from each other. There is more space between the particles, so the substance expands. ☑

If you look at the figure below, all three thermometers are at the same temperature. The alcohol in each thermometer has expanded the same amount. The number reading for each thermometer is different because a different temperature scale is used for each one.

READING CHECK

5. Describe What is thermal expansion?

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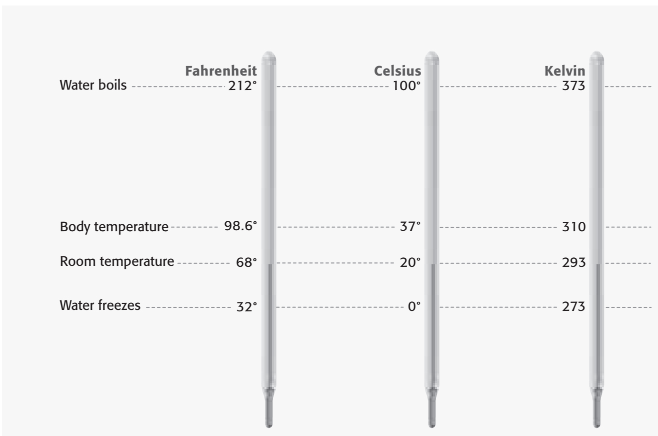
Three Temperature Scales



TEMPERATURE SCALES

There are three different temperature scales that are often used. They are the Fahrenheit scale, the Celsius scale, and the Kelvin scale. When you hear a weather report, you hear the temperature given in degrees Fahrenheit (°F). Scientists often use the Celsius scale. The Kelvin (or absolute) scale is the official SI temperature scale. The Kelvin scale has units called kelvins (K). The Kelvin scale does not use degrees, so 25 K is 25 kelvins. ☑

The lowest temperature on the Kelvin scale is 0 K. This is called **absolute zero**. Absolute zero (−459°F) is the temperature at which all molecules stop moving. It is not possible to reach absolute zero because molecules are always moving.

READING CHECK

6. Identify Which temperature scale is the SI temperature scale?

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TEMPERATURE CONVERSION

For a given temperature, each temperature scale has a different number reading. For example, the freezing point of water is 32°F, 0°C, or 273 K. You can change from one scale to another using the equations in the table below.

Converting Between Temperature Units

To convert	Use the equation	Example
Celsius to Fahrenheit °C → °F	$F = \left(\frac{9}{5}C\right) + 32$	Change 45°C to degrees Fahrenheit.
Fahrenheit to Celsius °F → °C	$C = \frac{5}{9} \times (F - 32)$	Change 68°F to degrees Celsius.
Celsius to Kelvin °C → K	$K = C + 273$	Change 45°C to Kelvins.
Kelvin to Celsius K → °C	$C = K - 273$	Change 32 K to degrees Celsius.

Math Focus

7. Calculate In the last column of the table, calculate the temperature for the temperature scale given.

A change of one Kelvin is the same as a change of one Celsius degree. So a temperature change from 0°C to 1°C is the same as a change from 273 K to 274 K. However, a temperature change of 1°C is higher than a change of 1°F. It's almost two times as large.

What Are Other Examples of Thermal Expansion?

You have learned how thermal expansion is used in thermometers. Thermal expansion has many other uses. Sometimes it is harmful, but other times it is useful.

EXPANSION JOINTS ON HIGHWAYS

Have you ever gone across a bridge in a car? You may have felt bumps every few seconds. The car is going over small spaces called *expansion joints*. If the weather is really hot, the bridge can heat up and expand. When it expands, the bridge can break. Expansion joints separate parts of the bridge so they can expand and not break. ☑

READING CHECK

8. Describe What is the purpose of expansion joints in a bridge?

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BIMETALLIC STRIPS IN THERMOSTATS

Another example of thermal expansion happens in a *thermostat*, a device that controls the temperature in your home. The thermostat has a *bimetallic strip* with two different metals coiled together. The strip coils and uncoils as the temperature changes. ☑

Most thermostats have a tube of mercury that is moved by a bimetallic strip. The figure below shows how a mercury thermostat works. The mercury in a tube moves to touch or not touch electrical contacts. Electrical contacts are two pieces of metal that can touch to complete a circuit. This makes the electric circuit in the thermostat close or open. So the thermostat turns on and off the heater in your home.

READING CHECK

9. Explain What does the bimetallic strip do in a thermostat? Why?

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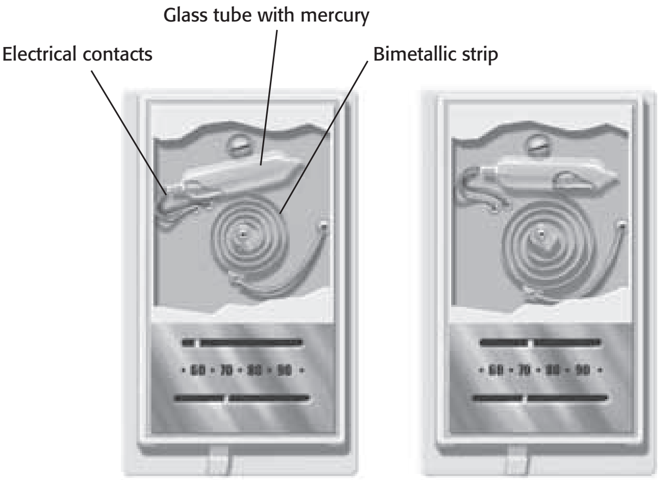
How a Thermostat Works



a When the room temperature is lower than the temperature setting, the bimetallic strip coils. This causes the glass tube above the strip to tilt. Mercury flows and closes the electrical circuit. The result is that the heater turns on.

b When the room temperature is higher than the temperature setting, the bimetallic strip uncoils. It becomes larger. This causes the glass tube above the strip to flatten out. The mercury moves away and opens the electrical circuit. The result is that the heater turns off.

TAKE A LOOK

10. Explain What happens to the mercury in a thermostat that results in the heater turning on?

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THERMAL EXPANSION IN HOT AIR BALLOONS

Thermal expansion is also used in hot air balloons. When air inside a balloon is heated, the air takes up more space. The air particles move faster because they have more kinetic energy. The gas expands to fill the volume of the balloon. The air inside the balloon is less dense than the air outside the balloon. So, the balloon goes up into the air because it is less dense than the air around it.

Section 1 Review

NSES PS 3a, 3b

SECTION VOCABULARY

absolute zero the temperature at which molecular energy is at a minimum (0 K on the Kelvin scale or −273.16°C on the Celsius scale) **thermal expansion** an increase in the size of a substance in response to an increase in the temperature of the substance	**temperature** a measure of how hot (or cold) something is; specifically, a measure of the average kinetic energy of the particles in an object

1. **Compare** How is the temperature of an object related to its kinetic energy?

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2. **Calculate** The thermometer outside your window reads 77°F. What is the same temperature on the Celsius scale? Show your work.

3. **Determine** You are doing a science experiment and watching the temperature change in Celsius degrees. If the temperature changes by 5°C, how does it change in Kelvins?

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4. **Explain** How is the liquid in a thermometer used to measure temperature? Why are mercury and alcohol used in thermometers?

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5. **Analyze** How is thermal expansion used to get a hot air balloon off of the ground?

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What Is Heat?

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is heat?
- What is thermal energy?
- How is thermal energy transferred?

National Science Education Standards

PS 3a, 3b

What Is Heat?

You might use the word *heat* to describe things that feel hot. However, heat also has to do with things that feel cold. Heat is what makes objects feel hot or cold. **Heat** is the energy that moves between objects that are at different temperatures. ☑

Why do some things feel hot, and other things feel cold? When two objects touch each other, energy moves from one object to the other. This energy is heat. Heat always moves from an object with a higher temperature to an object with a lower temperature. If you touch a cold piece of metal, energy from your hand moves to the metal. So, the metal feels cold when you touch it.

STUDY TIP

Describe Describe one example of energy transfer by each method—conduction, convection, and radiation—that occurs in your science classroom.

READING CHECK

1. Describe What is heat?

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The metal stethoscope feels cold because of heat.

TAKE A LOOK

2. Identify In the figure, which way is heat flowing if the stethoscope feels cold?

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HEAT AND THERMAL ENERGY

If heat is the movement of energy, what kind of energy is moving? The answer is thermal energy. **Thermal energy** is the total kinetic energy of the particles that make up a substance. Thermal energy is measured in joules (J). Thermal energy depends on the substance's temperature and how much of the substance there is. For example, a large lake contains more thermal energy than a smaller lake if both are at the same temperature.

STANDARDS CHECK

PS 3b Heat moves in predictable ways, flowing from warmer objects to cooler ones, until both reach the same temperature.

3. Compare When two objects at different temperatures are touching, what will energy do?

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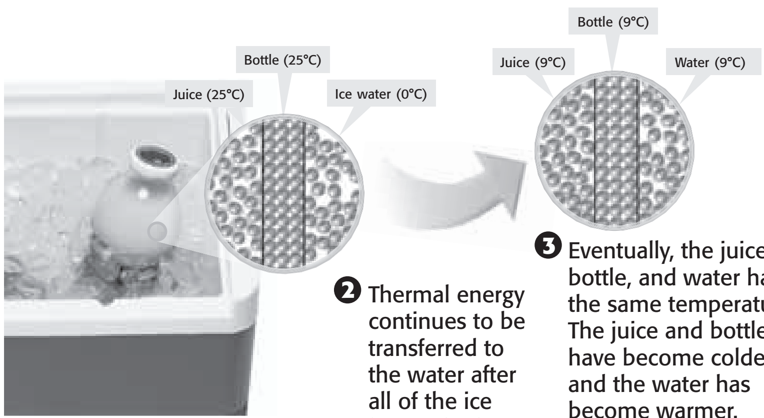
REACHING THE SAME TEMPERATURE

When two objects with different temperatures touch each other, energy moves. Energy moves from the warmer object to the cooler object. This happens until both objects are at the same temperature. When they have the same temperature, the thermal energy of the objects no longer changes. One object might have more thermal energy than the other, but the temperature of both objects is the same.

Transfer of Thermal Energy

1. Energy is transferred from the particles in the juice to the particles in the bottle. These particles transfer energy to the particles in the ice water, causing the ice to melt.



2. Thermal energy continues to be transferred to the water after all of the ice has melted.

3. Eventually, the juice, bottle, and water have the same temperature. The juice and bottle have become colder, and the water has become warmer.

Say It

Brainstorm The ice melts in a cooler used to keep a six-pack of cola cold on a hot day. Discuss with a partner energy transfers that occur in the cooler of ice that cause the ice to melt.

How Is Thermal Energy Transferred?

Every day you see some ways that energy is transferred. Stoves transfer energy to soup in a pot. The temperature of your bath water can change by adding hot or cold water. There are three ways that thermal energy moves from one object to another. They are *conduction*, *convection*, and *radiation*.

CONDUCTION

What happens when you put a cold metal spoon in a bowl of hot soup? The spoon warms up. Even the handle of the spoon gets warm, and it is not touching the soup. The whole spoon gets warm because of conduction. This is shown in the figure below. **Thermal conduction** is the transfer of thermal energy when two objects touch each other. ☑

Conduction also happens within a substance. This is how the handle of the spoon gets warm.

READING CHECK

4. Describe What is thermal conduction?

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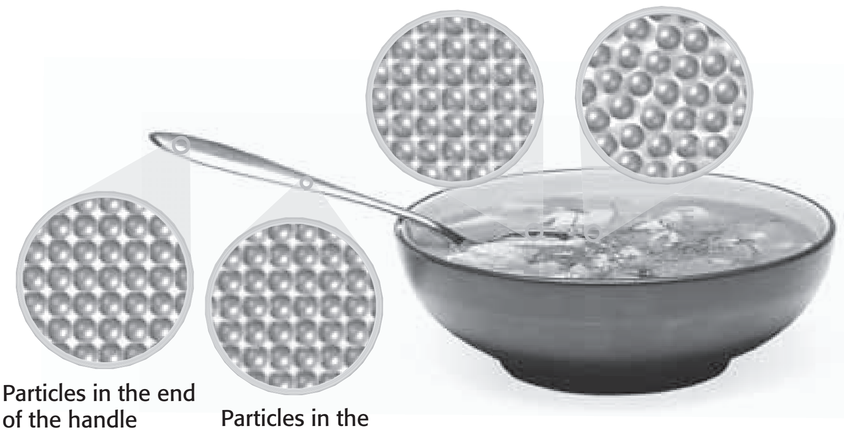

The circles show the energy in the particles of the spoon and the soup. Energy will move from the soup to the spoon until all of the particles have the same energy. Even the handle of the spoon will have the same energy.

When two objects touch, their particles bump into each other. Thermal energy moves from the higher-temperature substance to the lower-temperature substance. When the particles bump into each other, their kinetic energy moves from one particle to another. This makes some particles move faster, and some move slower. This happens until the particles have the same average kinetic energy. Then, both objects will be at the same temperature. ☑

READING CHECK

5. Identify What kind of energy is the same for objects at the same temperature?

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CONDUCTORS AND INSULATORS

Substances that transfer thermal energy easily are called **thermal conductors**. The cold metal spoon from the figure on the previous page is an example of a conductor. Energy moves easily from the soup to the spoon.

Some substances do not transfer thermal energy very well and are called **thermal insulators**. The bowl from the figure on the previous page does not get hot as quickly as the spoon. Energy does not move easily from the soup to the bowl, so the bowl is an insulator. The table below shows some examples of common conductors and insulators.

Critical Thinking

6. Compare What is the difference between thermal conductors and thermal insulators?

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Common Conductors and Insulators	
Conductors	**Insulators**
Curling iron	Flannel shirt
Cookie sheet	Oven mitt
Iron pan	Plastic spatula
Copper pipe	Fiberglass insulation
Stove	Ceramic bowl

CONVECTION

The second way thermal energy can be transferred is by convection. **Convection** is the transfer of thermal energy by the movement of a liquid or gas. Look at the figure below. When you boil water in a pot, the water moves in a circular motion because of convection. This circular motion is called a *convection current*. ☑

READING CHECK

7. Describe What is convection?

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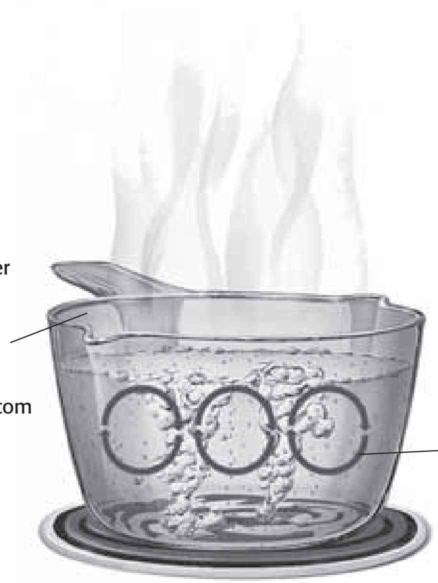

The repeated rising and sinking of water during boiling are due to convection.

TAKE A LOOK

8. Identify Fill in the missing words in the figure.

RADIATION

The third way thermal energy is transferred is by radiation. **Radiation** is the transfer of energy by electromagnetic waves. Some examples of electromagnetic waves are visible light and infrared waves. Radiation can transfer energy between particles or through a vacuum, like outer space. Conduction or convection cannot transfer energy through outer space. ☑

All objects radiate electromagnetic waves. The sun gives off visible light that you see. The sun also gives off other waves, like infrared and ultraviolet waves, that you cannot see. When your body takes in infrared waves, you feel warmer.

READING CHECK

9. Identify Radiation is transferred by what kind of waves?

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RADIATION AND THE GREENHOUSE EFFECT

The atmosphere of Earth acts like the windows of a greenhouse. The sun's visible light goes through it. A greenhouse stays warm because it traps energy. The atmosphere traps energy, too. This is called the *greenhouse effect*. You can see how this works in the figure below.

Greenhouse gases absorb infrared light from the sun. This energy is trapped in the atmosphere. Some of these gases are water vapor, carbon dioxide, and methane. Some scientists are concerned about increasing amounts of greenhouse gases in the atmosphere. They think that too much energy will become trapped and make Earth too warm. ☑

READING CHECK

10. Describe Why are some scientists concerned about increasing amounts of greenhouse gas in the atmosphere?

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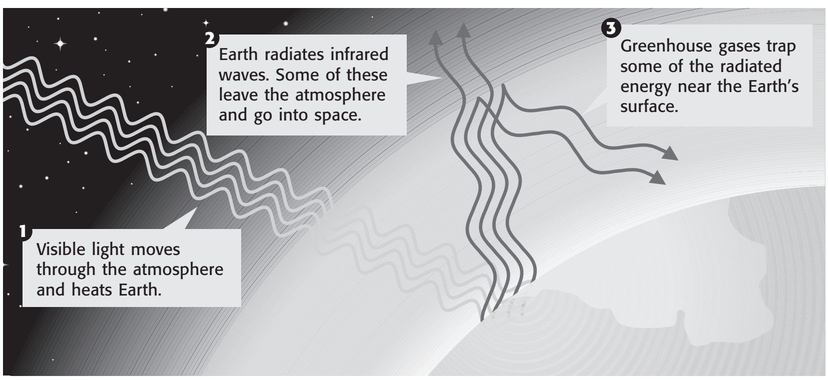

Why Are Some Substances Warmer Than Others?

Have you ever put on your seat belt on a hot summer day? If so, the metal buckle may have felt hotter than the cloth belt did. Why?

THERMAL CONDUCTIVITY

One reason is because the metal buckle has a higher thermal conductivity than the cloth belt. *Thermal conductivity* is a measure of how fast a substance transfers thermal energy. When you touch the metal, energy moves quickly from the belt to your hand. The cloth and the metal are at the same temperature, but the metal feels hotter. ☑

READING CHECK

11. Identify Which has a higher thermal conductivity, a piece of metal or a piece of cloth?

____

SPECIFIC HEAT

Another difference between the metal and the cloth is how easily each changes temperature. When the same amount of energy is given to equal masses of metal and cloth, the metal gets hotter. The temperature change depends on the substance's specific heat. **Specific heat** is the amount of energy it takes to change the temperature of 1 kg of a substance by 1°C. ☑

READING CHECK

12. Define What is the specific heat of a substance?

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The higher the specific heat of something is, the more energy it takes to raise its temperature. The specific heat of the cloth is more than two times the specific heat of the metal buckle. So, the same thermal energy will raise the temperature of the metal two times as much as the cloth. The table below shows the specific heat of many common substances. The table shows that most metals have very low specific heats.

Math Focus

13. Identify and Explain Suppose that the same mass of each substance in the table gains the same amount of energy. Which substance will have the greatest increase in temperature? Explain why.

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Specific Heat of Some Common Substances

Substance	Specific heat (J/kg•°C)	Substance	Specific heat (J/kg•°C)
Lead	128	Glass	837
Gold	129	Aluminum	899
Copper	387	Cloth of seat belt	1,340
Iron	448	Ice	2,090
Metal of seat belt	500	Water	4,184

CALCULATING HEAT

When a substance changes temperature, the temperature change alone does not tell you how much energy has been transferred. To calculate energy transfer, you must know the substance's mass, its change in temperature, and its specific heat. The equation below is used to calculate the energy, or heat, transferred between objects. ☑

heat = specific heat × mass × change in temperature

How much energy is needed to heat a cup of water to make tea? Using the equation above, you can calculate the heat that is transferred to the water. The temperature of the water increases, so heat is a positive number. You can also use this equation to calculate the heat that leaves an object when it cools down. The value for heat when it cools is negative because the temperature decreases.

READING CHECK

14. Describe What data are needed to calculate the amount of energy transferred to a substance?

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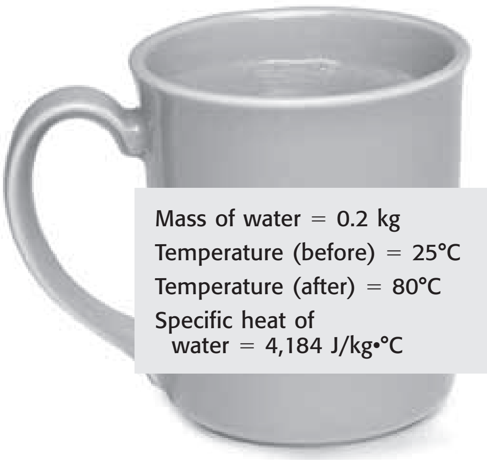

Information used to calculate heat, the amount of energy transferred to the water, is shown here.

Let's try a problem. You heat 2.0 kg of water to make pasta. The temperature of the water before you heat it is 40°C. The temperature of the water after you heat it is 100°C. How much heat was transferred to the water? (The specific heat of water is 4,184 J/kg•°C).

Step 1: Write the equation.

heat = specific heat × mass × change in temperature

Step 2: Place values into the equation, and solve.

heat = 4,184 J/kg•°C × 2.0 kg × (100°C − 40°C) = 502,080 J.

The heat transferred is 502,080 J.

Math Focus

15. Calculate Use the data in the figure to determine the energy needed to warm the water in the cup.

Section 2 Review

NSES PS 3a, 3b

SECTION VOCABULARY

convection the transfer of thermal energy by the circulation or movement of a liquid or gas

heat the energy transferred between objects that are at different temperatures

radiation the transfer of energy as electromagnetic waves

specific heat the quantity of heat required to raise a unit mass of homogeneous material 1 K or 1°C in a specified way given constant pressure and volume

thermal conduction the transfer of energy as heat through a material

thermal conductor a material through which energy can be transferred as heat

thermal energy the kinetic energy of a substance's atoms

thermal insulator a material that reduces or prevents the transfer of heat

1. Explain Why can heat describe both hot and cold objects?

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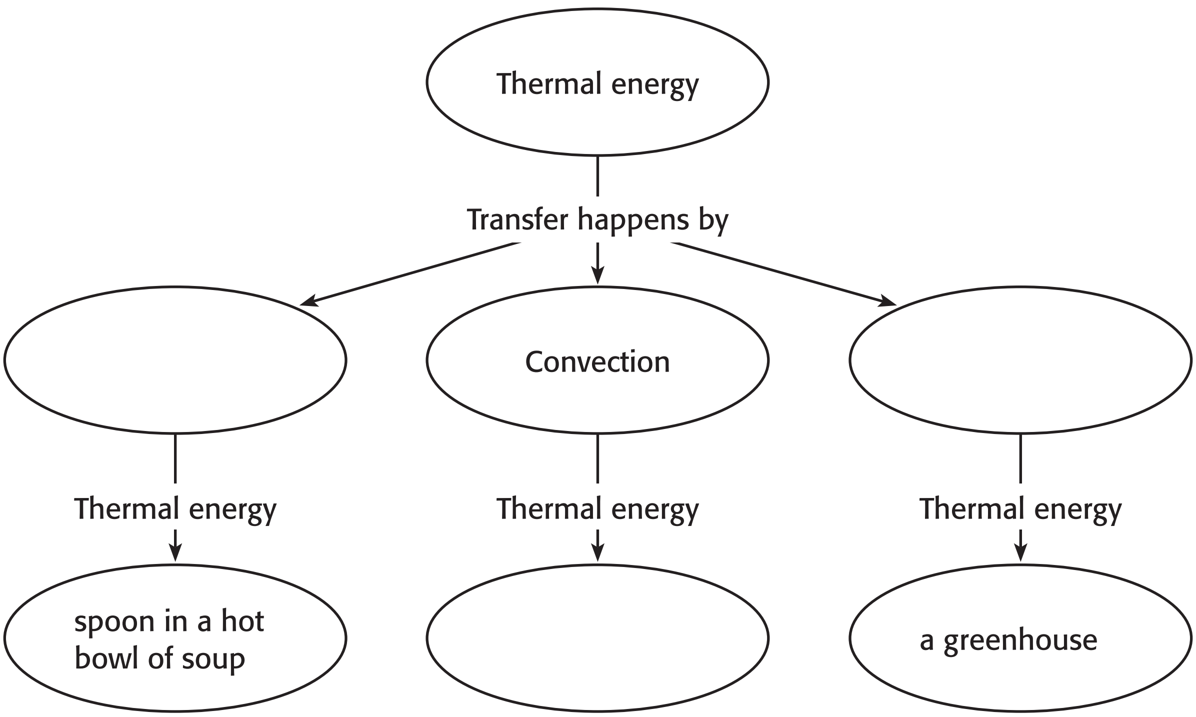
2. Identify Use the following Concept Map to describe how thermal energy moves from one object to another.



3. Calculate The specific heat of lead is 128 J/kg•°C. How much heat is needed to raise the temperature of a 0.015 kg sample of lead by 10°C? Show your work.

SECTION 3

Matter and Heat

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What are the states of matter?
- How can heat cause a change of state?
- How can heat cause a chemical change?
- What is a calorimeter?

National Science Education Standards

PS 3a, 3b

What Are the States of Matter?

Have you ever tried to eat a frozen juice bar outside on a hot day? The juice bar melts quickly because the sun transfers energy to the bar. This increases the kinetic energy of the juice bar's molecules and it starts to change to a liquid.

The matter in the frozen juice bar is the same whether it is frozen or melted. The matter is just in a different form, or state. The **states of matter** are the physical forms of a substance. A substance's state depends on three things. It depends on how fast its particles move, the attractive forces between the particles, and the atmospheric pressure. The three well-known states of matter are solid, liquid and gas. All three are shown in the figure below. ☑

Suppose you had the same amount of a substance in a solid, in a liquid, and in a gas. The substance will have the most thermal energy as a gas and the least as a solid. This is because the particles in a gas move the fastest.

STUDY TIP

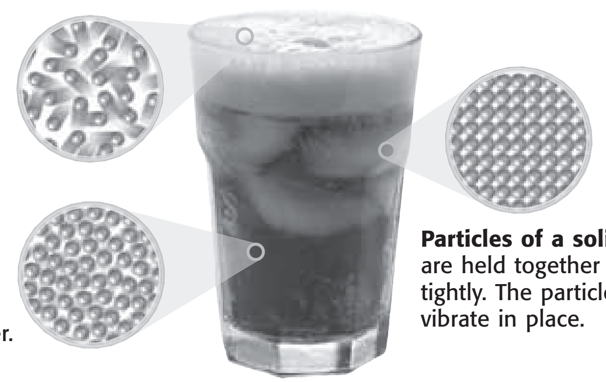
Identify Make a list of three changes of state and three chemical changes that you feel are important. Describe the role of energy in each.

READING CHECK

1. Identify What are the physical forms of a substance called?

____

Particles of a Solid, a Liquid, and a Gas



TAKE A LOOK

2. Identify Which state of matter has the least interaction between its particles?

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How Does Matter Change State?

A **change of state** is a change of a substance from one state of matter to another. A change of state is a *physical change*. That means a physical property of a substance changes, but the substance is the same. There are four types of changes of state. They are *freezing* (liquid to solid), *melting* (solid to liquid), *boiling* (liquid to gas), and *condensing* (gas to liquid). ☑

READING CHECK

3. Identify What are the four types of changes of state?

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ENERGY AND CHANGES OF STATE

What would happen if you put an ice cube in a pan and put the pan on a stove burner? The ice will first turn into water and then to steam. You could make a graph of the temperature of the ice as energy is added to it. This graph would look something like the graph below.

TAKE A LOOK

4. Identify During a change of state, does the temperature increase, decrease, or stay the same? Explain your answer using the graph.

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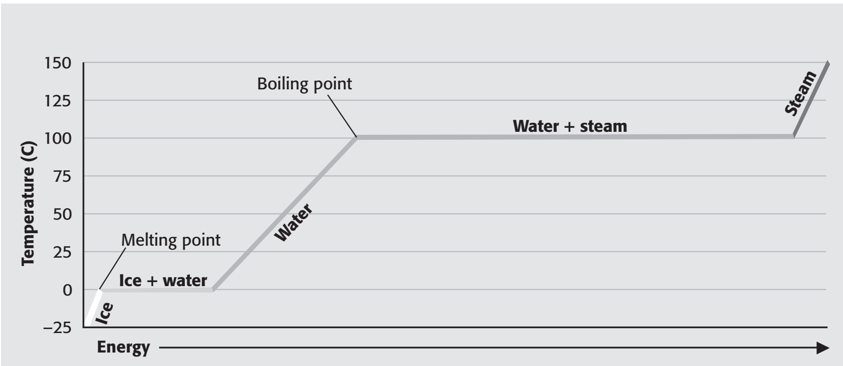
Changes of State of Water



As the ice is heated, the temperature increases from −25°C to 0°C. The ice changes into liquid water at 0°C. Its temperature stays at 0°C until there is only liquid water left in the pan. The energy is being used only to melt the ice, not change its temperature. Then the water temperature increases between 0°C and 100°C. At 100°C the liquid water changes into steam. The water temperature stays at 100°C until there is no more water in the pan.

How Is Heat Involved in Chemical Changes?

We have seen how heat is important in changing the state of matter. Heat is also an important part of chemical changes. A *chemical change* happens when one or more substances combine to make new substances.

To make a new substance, energy is needed to break the old bonds. Energy is released when new bonds are formed. Sometimes, more thermal energy is needed for a reaction to happen than is released when new bonds form. Other times, more energy is given off in the reaction than was needed to break old bonds. ☑

READING CHECK

5. Identify When bonds are formed, is energy needed or released?

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FOOD AND ENERGY

You have probably seen a Nutrition Facts label on some of the food you eat. These labels tell you how much chemical energy the food has. The *Calorie* is the amount of chemical energy in food. One Calorie is the same as 4,184 J. Since the Calorie is a measure of energy, it is also a measure of heat. The amount of energy in food can be measured by a calorimeter.

STANDARDS CHECK

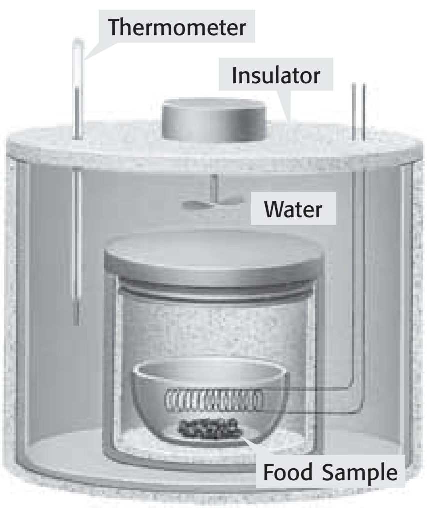
PS 03a Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.

6. Identify The energy found in food is in what form of energy?

____

CALORIMETERS

A *calorimeter* is a device that measures heat. In a *bomb calorimeter*, a food sample is burned in a chamber inside the calorimeter as shown below. The amount of energy (heat) given off equals the energy content of the food.



A bomb calorimeter can measure energy content in food by measuring how much heat is given off by a food sample when burned. If a food sample releases 523,000 J of heat, what is the energy content of the food? Since 1 Calorie is 4,184 J,

$$523{,}000 \text{ J} \times \frac{1 \text{ Calorie}}{4{,}184 \text{ J}} = 125 \text{ Calories.}$$

Math Focus

7. Calculate When a peanut is burned in a bomb calorimeter, it releases 8,368 J of energy. What is the energy content of the peanut? Show your work.

Name ______________________ Class ______________ Date ______________

Section 3 Review

NSES PS 3a, 3b

SECTION VOCABULARY

change of state the change of a substance from one physical state to another	**states of matter** the physical forms of matter, which include solid, liquid, and gas

1. **Analyze** What determines if a substance is a solid, a liquid, or a gas?

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2. **Identify** What are the ways that a substance can change its state?

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3. **Explain** During a change of state, why doesn't the temperature of the substance change?

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4. **Explain** What are the ways that heat takes part in a chemical change?

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5. **Compare** How is a physical change different from a chemical change?

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6. **Calculate** A sample of popcorn had 627,600 J of energy when it was measured in a calorimeter. How much energy, in Calories, did the popcorn have? Show your work.

SECTION 4

Heat Technology

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What are the types of heating systems?
- How does an automobile use heat?
- How do cooling systems work?
- How does thermal pollution affect the environment?

National Science Education Standards
PS 3a, 3b

What Is Heat Technology?

You may not be surprised to learn that the heater in your home is an example of heat technology. However, cars, refrigerators, and air conditioners are also examples of heat technology. Heat technology heats your home, runs your car, keeps food cold, and keeps you cool.

STUDY TIP

Describe As you and a partner read about heating and cooling systems, quiz each other on how they work.

What Is a Heating System?

The temperature of most homes and buildings is controlled by a *central heating system*. There are different types of central heating systems that you will see on the next few pages.

HOT-WATER HEATING

Water has a high specific heat. This property makes it useful for heating systems because it allows water to hold onto its heat. A hot-water heating system is described in the figure below. ☑

READING CHECK

1. Identify What property of water makes it useful for a heating system?

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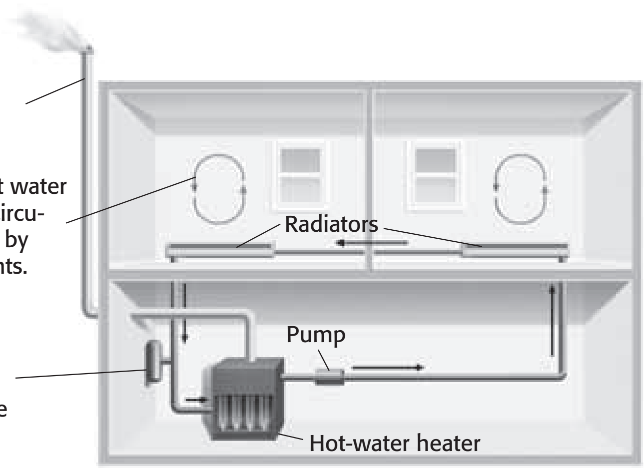
A Hot-Water Heating System



TAKE A LOOK

2. Identify How does the water get from the hot-water heater to the radiators?

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STANDARDS CHECK

PS 03a Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.

3. Identify How is warm air circulated in the rooms of a home?

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WARM-AIR HEATING

The specific heat of air is less than water, so air holds less thermal energy than water. Still, warm-air heating systems are often used in homes. In a warm-air heating system, air is heated by burning fuel (like natural gas) in a furnace. This is shown in the figure below.

The warm air moves through ducts to heat the rooms of the house. The vents are placed on the floor because that is where the cooler air is. A fan pulls the cool air into the furnace. The cool air is heated and returns to the rooms.

TAKE A LOOK

4. Identify How does the air get from the furnace to the vent?

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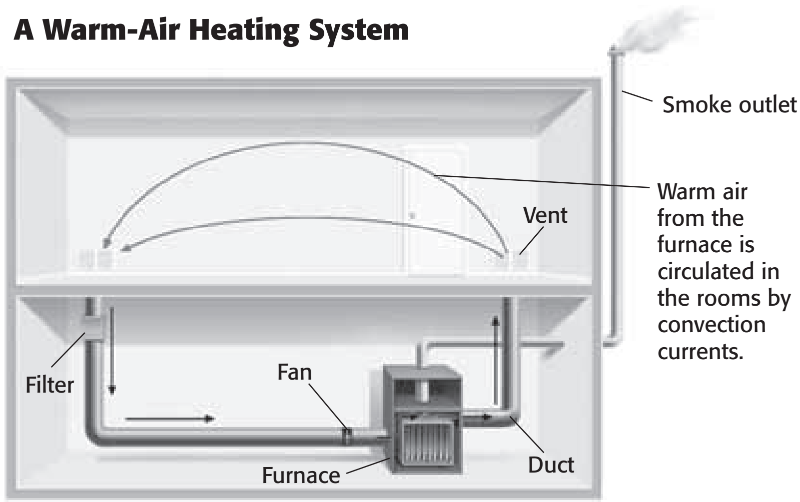
A Warm-Air Heating System



HEATING AND INSULATION

There are many places in a home where heat can leave and enter. It can be wasteful to run a heating or cooling system all of the time. So, insulation is used to lower the amount of energy that leaves or enters a building.

Insulation is a material that prevents the movement of thermal energy. When insulation is used in walls, ceiling, and floors, less heat leaves or enters the building. Insulation helps a house stay warm in winter and cool in summer. ☑

READING CHECK

5. Explain Why is insulation used in buildings and homes?

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SOLAR HEATING

The sun gives off a lot of energy. Solar heating systems use some of this energy to heat homes and buildings. A *passive solar heating system* does not have moving parts. It uses the design of the building and special building material to heat with the sun's energy. An *active solar heating system* has moving parts. It uses pumps and fans to move the sun's energy through the building. ☑

The figure of the house below shows how both passive and active solar heating systems work. The large windows and thick concrete walls are part of the passive heating system.

The active heating system is made of several parts. Water is pumped to a solar collector where it is heated by the sun's energy. The hot water moves through pipes. A fan blows over the pipes and thermal energy is transferred to the air. This warm air is used to heat the rooms of the house.

READING CHECK

6. Compare How does a passive solar heating system differ from an active solar heating system?

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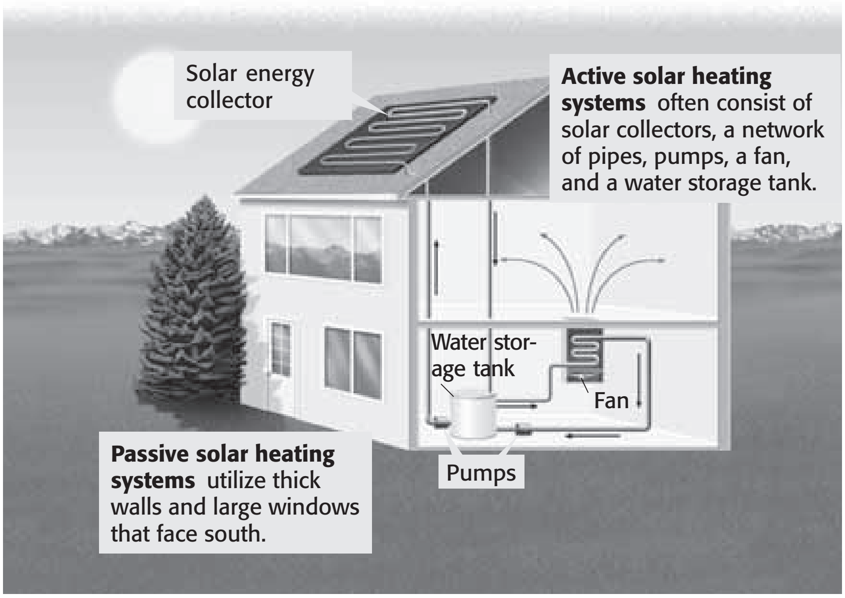
Passive and active solar heating systems work together to use the sun's energy to heat an entire house.



TAKE A LOOK

7. Identify From the figure, list:

1. the parts of the passive solar heating system.
2. the parts of the active solar heating system.

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What Are Heat Engines?

Automobiles work because of heat. A car has a **heat engine**, which is a machine that uses heat to do work. Fuel is burned in a heat engine to make thermal energy in a process called *combustion*. If a heat engine burns fuel outside the engine, it is an *external combustion engine*. If a heat engine burns fuel inside the engine, it is an *internal combustion engine*. ☑

READING CHECK

8. Identify Where is the fuel burned for an external combustion engine?

____

____

READING CHECK

9. Identify Today, what are most steam engines used for?

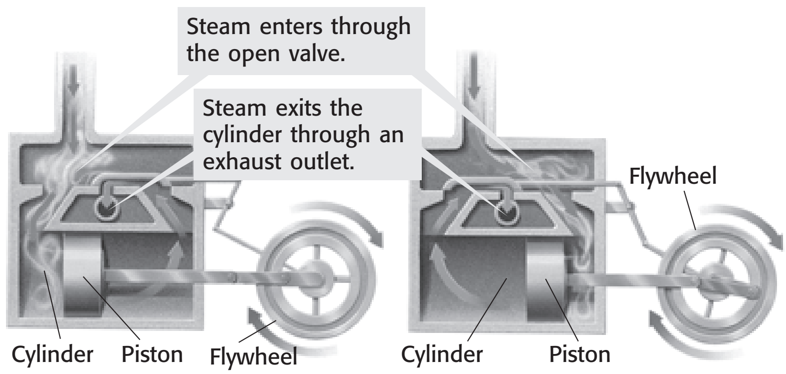
____

EXTERNAL COMBUSTION ENGINES

A simple steam engine is an example of an external combustion engine. This is seen in the figure below. Coal is burned in a boiler (not shown in the figure). The boiler heats water, which turns into steam. The steam comes into the engine and expands, which pushes a piston.

Modern steam engines are used to generate electricity at power plants. The steam turns turbine blades in generators. Generators that use steam to do work convert thermal energy into electrical energy. ☑

An External Combustion Engine



1. The expanding steam enters the cylinder from one side. The steam does work on the piston, forcing the piston to move.
2. As the piston moves to the other side, a second valve opens, and steam enters. The steam does work on the piston and moves it back. The motion of the piston turns a flywheel.

INTERNAL COMBUSTION ENGINES

A car engine is a common example of an internal combustion engine. It usually has four, six, or eight cylinders. Fuel is burned inside the engine, in the cylinders. In order for this engine to work, four steps must happen inside each of the cylinders. The cylinders cycle, so each cylinder is at a different step at a different time. This type of engine is called a *four-stroke engine*.

First, gasoline and air enter the cylinder when the piston moves down. This is the *intake stroke*. Then, the *compression stroke* moves the piston up and compresses the gas mixture. Next, in the *power stroke*, a spark plug ignites the fuel mixture. As it expands, it forces the pistons back down. In the last step, the *exhaust stroke*, the piston moves back up. This pushes the exhaust gases out of the cylinder.

Critical Thinking

10. Infer Which stroke coverts chemical energy into mechanical motion?

____

An Internal Combustion Engine: Four Steps	
Cause	**Effect**
Intake Stroke: The piston in the cylinder moves down.	______________ enter the cylinders
Compression Stroke: The piston in the cylinder moves back up.	the gas mixture gets ______________
Power Stroke: A spark plug ignites the fuel mixture.	the gas mixture expands and ______________
Exhaust Stroke: The piston in the cylinder moves back up.	______________ are pushed out of the cylinder

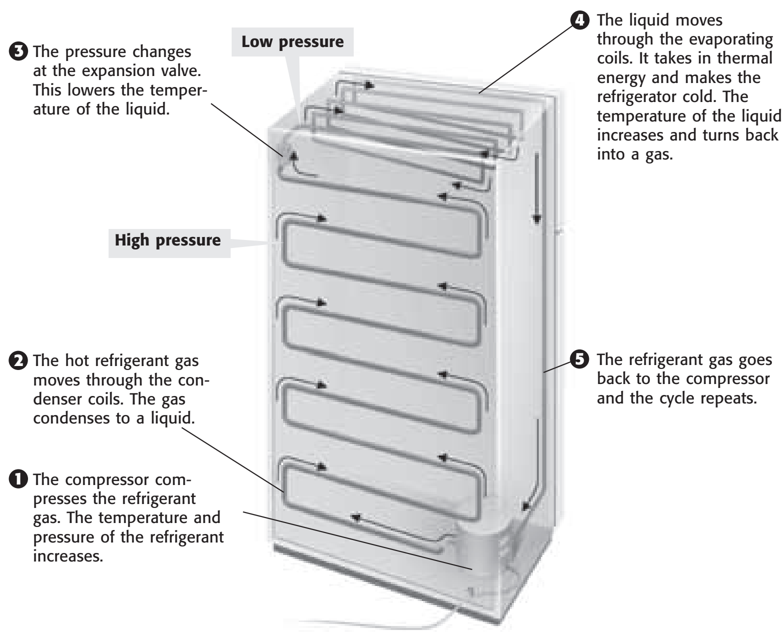
TAKE A LOOK

11. Analyze Fill in the Cause-and-Effect Table with the events that happen in an internal combustion engine.

What Is a Cooling System?

An air-conditioned room can feel refreshing on a hot summer day. Cooling systems, like air conditioners, can move thermal energy out of an area so that it feels cooler. Thermal energy normally moves from a high temperature to a lower temperature. An air-conditioning system moves warm air outside. This is against the normal flow of thermal energy. So, it must do work. It's like walking uphill: if you are going against gravity, you must do work.

How a Refrigerator Works



TAKE A LOOK

12. Describe When the refrigerator is getting cold, what is happening to the refrigerant?

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COOLING AND ENERGY

Most cooling systems need electrical energy to do the work of cooling. Cooling systems have a *compressor* that uses electrical energy to do the work of turning a refrigerant into a liquid. The *refrigerant* is a gas that has a boiling point below room temperature. This allows it to condense (change from a gas to a liquid) easily. ☑

Foods are kept in a refrigerator so they stay fresh. A refrigerator is a cooling system. Thermal energy moves from inside the refrigerator to the coils on the outside of the refrigerator. That is why the lower back of the refrigerator feels warm.

READING CHECK

13. Describe What is the purpose of the compressor in a refrigerator?

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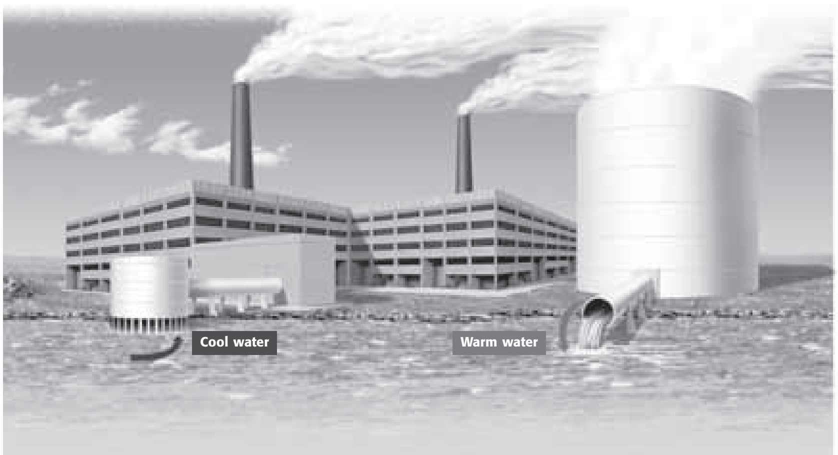
What Is Thermal Pollution?

Heating systems, car engines, and cooling systems all put thermal energy into the environment. However, too much thermal energy can be harmful.

Say It

Investigate Research thermal pollution where you live. See what your local power plant does to minimize thermal pollution. Report your findings to your class.



Thermal pollution from power plants can result if the plant raises the water temperature of lakes and streams.

THERMAL POLLUTION

One of the negative effects of too much thermal energy is **thermal pollution**. This happens when the temperature of a body of water rises a lot. Power plants burn fuel, and this gives off thermal energy. Not all of the thermal energy is used to do work. Some is wasted and released into the environment. Many power plants are near a body of water where they can dump the waste thermal energy.

A power plant may use cool water from a body of water to absorb the waste thermal energy. The cool water absorbs the energy and warms up. Then, this warm water may be dumped back into the same water that it came from. This makes the temperature of the water rise. Higher water temperatures in lakes and streams can hurt the animals in it. It can also harm the entire ecosystem of the river or lake. ☑

Some power plants cool the water before putting it back. This helps to lower the amount of thermal pollution.

The flow chart below shows how thermal pollution might occur and its effects.

A power plant pumps in cool water from a river.

↓

The cool water is used to absorb _______________.

↓

The cool water heats up.

↓

The warm water is put back into the _______________.

↓

The water temperature in the river rises.

↓

The ecosystem and the animals may be _______________.

READING CHECK

14. Describe What can thermal pollution do to lakes and streams?

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TAKE A LOOK

15. Complete Fill in the Flow Chart with the missing words.

Name ______________________ Class ______________ Date ____________

Section 4 Review

NSES PS 3a, 3b

SECTION VOCABULARY

heat engine a machine that transforms heat into mechanical energy, or work **insulation** a substance that reduces the transfer of electricity, heat, or sound	**thermal pollution** a temperature increase in a body of water that is caused by human activity and that has a harmful effect on water quality and on the ability of that body of water to support life

1. **Compare** What is the difference between a hot-water heating system and a warm-air heating system?

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2. **Analyze** What happens during the intake and compression strokes of a four stroke engine?

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3. **Compare** What is the difference between an external combustion engine and an internal combustion engine?

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4. **Explain** Why must a cooling system do work to transfer thermal energy?

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5. **Identify** What property must a refrigerant of a cooling system have? Why?

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6. **Explain** Explain how power plants cause thermal pollution and how it affects the environment.

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SECTION 1

Development of the Atomic Theory

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is the atomic theory?
- How has the atomic theory changed over time?

How Does New Information Change Scientific Ideas?

Have you ever watched a mystery movie and thought you knew who the criminal was? You may have changed your mind once you saw a new fact or clue. This is what happens in science. Sometimes an idea or a model is changed when new information is collected. One example of this is the atomic model. Our ideas about atoms have changed over time as we gather new information.

STUDY TIP

Connect Concepts In your notebook, create a Concept Map about the scientists who studied atoms and what they learned.

What Is an Atom?

Imagine cutting something in half, then cutting again and again. Could you keep cutting forever? Around 440 BCE, a Greek philosopher named Democritus studied this question. He thought that you would eventually reach a piece of matter that could not be cut. He called this particle an atom.

It was a long time before there was scientific evidence that Democritus was on the right track. We now know that all matter is made of tiny particles called atoms. An **atom** is the smallest particle into which an element can be divided and still keep its properties. ☑

The figure shows images of aluminum atoms taken with a scanning tunneling electron microscope. Early scientists had ideas about atoms and models of atoms even though they did not have pictures of them.

READING CHECK

1. Identify What is an atom?

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Aluminum cans are made of atoms. Aluminum atoms can be seen in the image from a scanning tunneling electron microscope (STM). Notice the regular, repeating pattern of the aluminum atoms.

TAKE A LOOK

2. Describe How are the atoms of aluminum arranged?

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What Was the First Scientific Theory of Atoms?

The first scientific theory about atoms was published by John Dalton in 1803. Unlike Democritus, Dalton based his ideas on experiments. His theory helped explain observations that he and other scientists had made about elements and compounds. Dalton's theory stated that:

- All substances are made of atoms. Atoms are small particles that cannot be created, destroyed, or divided.
- All atoms of one element are exactly alike, and atoms of different elements are different.
- Atoms can join with other atoms to make new substances.

Many scientists agreed that Dalton's theory explained much of what they saw. However, scientists later found new information that did not fit Dalton's theory. The atomic theory was changed to more correctly describe the atom. ☑

READING CHECK

3. Discuss When would scientists need to change a theory?

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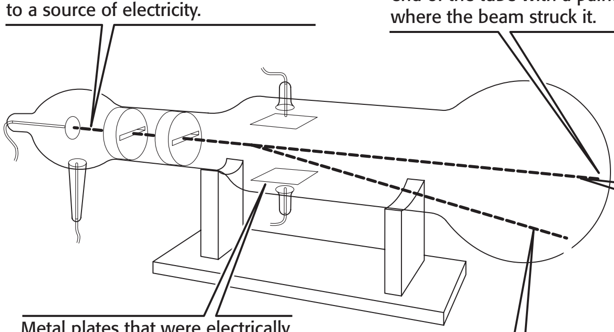
How Were Electrons Discovered?

In 1897, J. J. Thomson, a British scientist, discovered that atoms are not the smallest particles. There are even smaller particles inside the atom. Thomson made this discovery when he was experimenting with invisible beams called *cathode rays*. Cathode rays were made by connecting a special glass tube to a source of electricity.

To find out more about cathode rays, Thomson placed two metal plates inside the tube. One plate had a positive electrical charge and the other had a negative charge. Thomson discovered that cathode rays are attracted to the plate with the positive charge.

Thomson's Cathode-Ray Tube Experiment



TAKE A LOOK

4. Identify What is the electrical charge on the plate that causes the beam to bend toward that plate?

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THOMSON'S PLUM PUDDING MODEL

Thomson concluded that cathode rays must be made of tiny particles that come from atoms. Since the particles are attracted to a positively charged metal plate, the particles must have a negative charge. Remember that opposite charges attract each other. These negatively charged particles are called **electrons**. ☑

Thomson's experiment showed that atoms contain electrons, but it did not show where electrons are located within an atom. Thomson suggested that electrons might be scattered throughout the atom. This new model of the atom was called the plum pudding model. It was named after a popular dessert at the time. Today, we would probably call this a "chocolate chip ice cream" model of the atom.

READING CHECK

5. Identify What type of electrical charge does an electron have?

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How Did Rutherford Study the Atom?

In 1909, one of Thomson's students wanted to test the theory that electrons are scattered throughout the atom. Ernest Rutherford decided to shoot a beam of tiny, positively charged particles at a thin sheet of gold foil. ☑

Rutherford guessed that atoms are soft blobs of matter with electrons and positively charged particles scattered throughout. He thought that most of the particles would pass right through the gold atoms. Particles that hit other particles would stop or bounce to the side.

When Rutherford performed the experiment, he found that most of the positively charged particles did pass through the gold foil. Some were deflected sideways, just as he expected. What surprised him was that some particles bounced straight back.

READING CHECK

6. Identify What did Rutherford shoot at the gold foil in his experiment?

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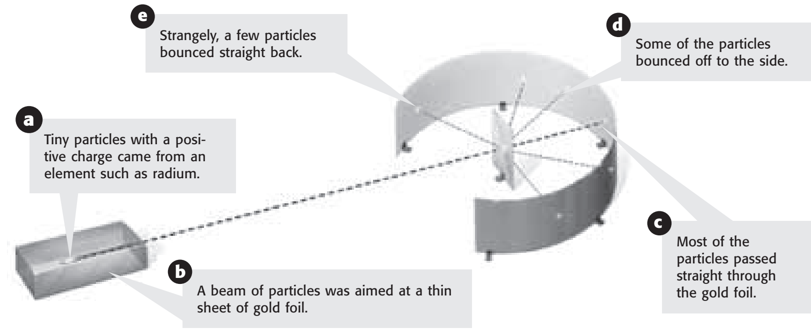
Rutherford's Gold-Foil Experiment



TAKE A LOOK

7. Compare What happened to most of the particles that were shot at the gold foil?

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What Was Rutherford's Atomic Model?

The plum pudding model did not explain what Rutherford saw. He reasoned that there was only one way that the positively charged particles could bounce straight back. That was if they hit a very dense part of the atom that had a positive charge. Remember that identical charges repel. He concluded that most of the matter in the atom must be in a very small part of the atom.

Based on the results of his experiment, Rutherford proposed a new model of the atom, called the *nuclear model*. In his model, the center of the atom is a tiny, dense, positively charged area called the **nucleus**. The electrons move outside the nucleus in mostly empty space. ☑

READING CHECK

8. Describe What is the nuclear model of the atom?

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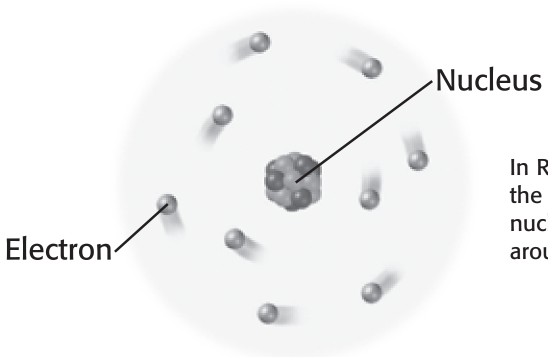

In Rutherford's model, the atom contains a nucleus. Electrons move around the nucleus.

Rutherford concluded that the nucleus must be very small but very dense in order to deflect the fast-moving particles. He used his observations to calculate the diameter of an atom. It was about 100,000 times greater than the diameter of its nucleus. The atom is mostly empty space.

Math Focus

9. Make Comparisons If an atom had a nucleus 1 ft in diameter, what would be the diameter of the atom, in miles? Show your work. Round to the nearest mile. (1 mi = 5,280 ft)

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What Did Bohr Discover about the Atom?

In 1913, Niels Bohr, a Danish scientist, studied the way that atoms react to light. He made a slight change to Rutherford's model, based on his observations.

Bohr proposed that electrons move around the nucleus in definite paths, or *orbits*, called energy levels. In Bohr's model, electrons could not exist between these levels. Think of the levels as rungs on a ladder. You can stand on the rungs of a ladder, but not between the rungs. However, the electrons could jump from one level to another as they gained or lost energy. Once again, the atomic theory was changed to account for new data. ☑

READING CHECK

10. Describe According to Bohr's theory, how do electrons move around the nucleus?

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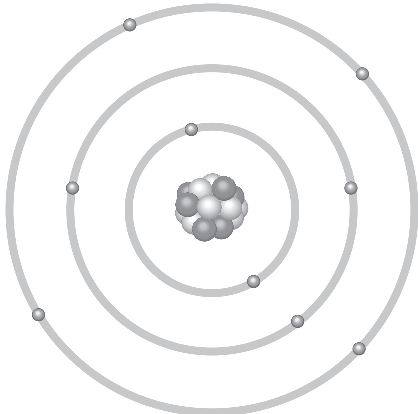
Bohr Model of the Atom



In the Bohr model, electrons move around the nucleus like planets around the sun.

TAKE A LOOK

11. Identify Label the nucleus and the electrons in the figure.

What Is the Modern Atomic Theory?

Atomic theory has changed over the past 100 years. Scientists such as Erwin Schrödinger from Austria and Werner Heisenberg from Germany have done important work. They have made observations that show that the Bohr model is not quite right.

Scientists still think that electrons are moving constantly around the nucleus. However, they now know that electrons do not orbit the nucleus like planets orbit the sun. In fact, no one can predict the exact path an electron will follow as it moves around the nucleus. However, scientists can predict where electrons are likely to be found.

In the modern atomic model, the locations of electrons are described with electron clouds. **Electron clouds** are regions where electrons are most likely to be found. The figure below shows this model. ☑

READING CHECK

12. Define What are electron clouds?

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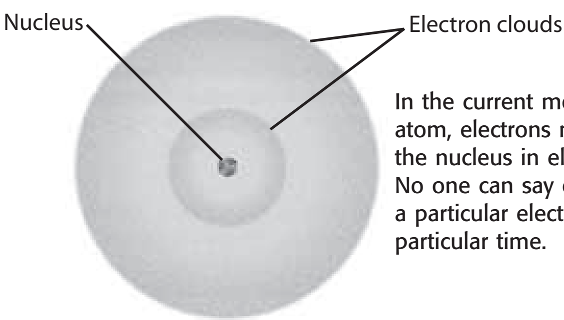

In the current model of the atom, electrons move around the nucleus in electron clouds. No one can say exactly where a particular electron is at any particular time.

Section 1 Review

SECTION VOCABULARY

atom the smallest unit of an element that maintains the properties of that element

electron a subatomic particle that has a negative charge

electron cloud a region around the nucleus of an atom where electrons are likely to be found

nucleus in physical science, an atom's central region, which is made up of protons and neutrons

1. **Describe** How does the diameter of an atom compare with the diameter of the nucleus?

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2. **Recall** Finish the table below to summarize some of the advances in the development of atomic theory and those responsible for them.

Scientist	Idea that was added to the atomic theory
	Each element is made of a different type of atom.
Thomson	
Rutherford	
	Electrons are found in specific energy levels.
Modern scientists	

3. **Apply** How did the discovery of electrons show that there are also positively charged parts of the atom?

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4. **Evaluate** What would cause scientists to change or replace the modern atomic theory?

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5. **Explain** Describe Thomson's plum pudding model of the atom.

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Name ______________________ Class ______________ Date ______________

CHAPTER 11 Introduction to Atoms

SECTION 2

The Atom

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What are the parts of an atom?
- How do atoms of different elements differ?
- What are isotopes?
- What forces work inside atoms?

National Science Education Standards

PS 1c

How Small Is an Atom?

An atom is very small. If you think about the size of a penny, it contains 2 × 1022 atoms of copper and zinc. This number is written as 20,000,000,000,000,000,000,000 atoms. That's 20 thousand billion billion atoms, which is much more than the number of people on Earth. So, each atom must be very small.

Even things that are very thin are made up of a large number of atoms. If you had a piece of aluminum foil, it might seem very thin to you. However, it is still about 50,000 atoms thick.

STUDY TIP

Compare In your notebook, make a table to compare the features of protons, neutrons, and electrons. Include mass, charge, and location in an atom.

What Are the Parts of an Atom?

Even though atoms are small, they are made of even smaller particles. Atoms are made of three different types of particles: protons, neutrons, and electrons. These particles can be seen in the figure below. ☑

READING CHECK

1. List What are the three types of particles in an atom?

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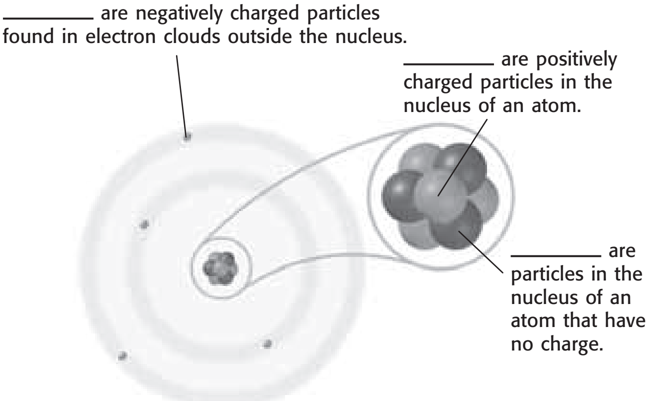
Parts of an Atom



When the model of an atom is shown in a book, it does not show the correct scale of the particles in an atom. If protons were the size of those in an illustration, the electrons would need to be hundreds of feet away from the nucleus.

TAKE A LOOK

2. Identify Fill in the names of the subatomic particles on the blank lines in the figure.

THE NUCLEUS

Protons are the particles inside the nucleus of an atom that give the nucleus its positive charge. The mass of a proton is about 1.7×10^{-24} g. This is the same as 0.0000000000000000000000017 g. This is a very small number. Since this number is so small, scientists created a new unit to measure the masses of the particles in atoms. This is called the **atomic mass unit** (amu). A proton has a mass of about 1 amu.

There are other particles inside the nucleus as well. **Neutrons** are particles in the nucleus of an atom that do not have an electric charge. A neutron has a little more mass than a proton does. However, the difference in mass is so small that the mass of a neutron can be thought of as 1 amu. ☑

READING CHECK

3. Identify What is the SI unit for the mass of subatomic particles?

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OUTSIDE THE NUCLEUS

Electrons are the negatively charged particles in atoms. They are found in electron clouds outside the nucleus. Electrons are much smaller than protons and neutrons. You would need about 1,840 electrons to equal the mass of a proton. Electrons are so small that they are usually not included in calculating the mass of an atom. ☑

READING CHECK

4. Describe Where are electrons found in an atom?

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The masses of an electron and a proton are different, but their electric charges are the same size. However, the signs of the charges are opposite. Electrons have a negative charge (1^-), and protons have a positive charge (1^+). Neutrons, on the other hand, have no charge at all. Because each atom has an equal number of electrons and protons, atoms are neutral (they have no charge).

TAKE A LOOK

5. Identify Fill in the charge and mass of a neutron.

Particle	Charge	Mass (amu)
Proton	1^+	1
Neutron		
Electron	1^-	1/1,840

If an atom gains or loses an electron, it becomes an *ion*. An ion formed by losing an electron has a positive charge. This kind of ion has more protons than electrons. An ion formed by gaining an electron has a negative charge because it has more electrons than protons.

How Are Atoms of Different Elements Different?

There are more than 110 known elements. Each element has atoms that are different from atoms of all the other elements. All atoms of the same element have the same number of protons. Atoms of different elements have different numbers of protons. ☑

READING CHECK

6. Define How do atoms of different elements differ?

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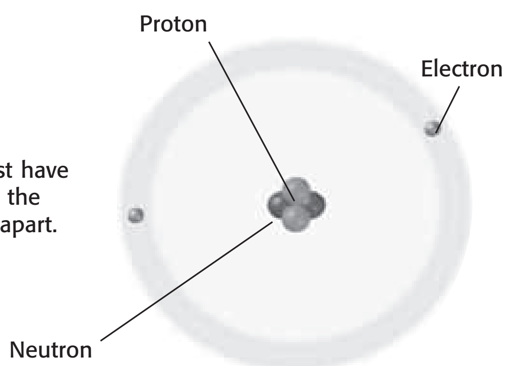
STARTING SIMPLE

The simplest atom is hydrogen. All atoms have protons and electrons, and a hydrogen atom has just one of each. It doesn't have a neutron. You can build a hydrogen atom by putting a proton in the center of the atom for the nucleus. Then, put one electron in the electron cloud. You have just built a hydrogen atom.

ADDING NEUTRONS

An atom with two positively charged protons in its nucleus is an atom of helium. Every helium atom has two protons. You must also add two neutrons. So that it has a neutral charge, you need to add two electrons outside the nucleus. A model of this atom is shown below.



A helium nucleus must have neutrons in it to keep the protons from moving apart.

TAKE A LOOK

7. Describe Why must a helium nucleus have neutrons?

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BUILDING BIGGER ATOMS

Because the protons repel each other, the atoms of every element, except hydrogen, must have neutrons in their nuclei. For example, most helium atoms have two protons and two neutrons. ☑

The number of protons is not always the same as the number of neutrons. In fact, nuclei usually have more neutrons than protons. For example, most fluorine atoms have nine electrons, nine protons, and ten neutrons. Most uranium nuclei have 92 protons and 146 neutrons.

READING CHECK

8. Explain Why must nuclei with more than one proton also have neutrons?

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PROTONS AND ATOMIC NUMBER

The number of protons in the nucleus is called the **atomic number** of the atom. All atoms of an element have the same atomic number. Every hydrogen atom has only one proton in its nucleus, so hydrogen has an atomic number of 1. Every carbon atom has six protons in its nucleus, so carbon has an atomic number of 6. ☑

READING CHECK

9. Define What does the atomic number tell you about an atom?

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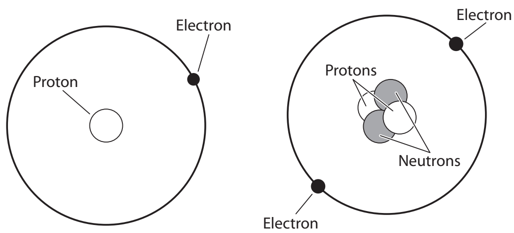
Comparison of a Hydrogen Atom and a Helium Atom



Element	**Hydrogen**	**Helium**
Number of protons		
Number of neutrons		
Number of electrons		
Atomic number		

TAKE A LOOK

10. Identify In the table, fill in the blank boxes for each element.

What Are Isotopes?

Most hydrogen atoms only have a proton in their nucleus. However, about one hydrogen nucleus out of 10,000 also has a neutron. The atomic number of this atom is 1, so the atom is still hydrogen. The nucleus has two particles, a proton and a neutron. This nucleus has a greater mass than a hydrogen atom that has only a proton in it.

Atoms that have the same number of protons but a different number of neutrons are called **isotopes**. The two hydrogen atoms in the figure on the next page are isotopes of each other. They are both hydrogen because each has only one proton. Because they have a different number of neutrons, they have different masses. ☑

READING CHECK

11. Describe What are isotopes?

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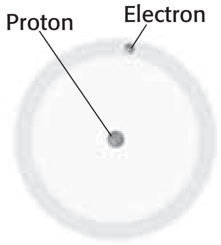
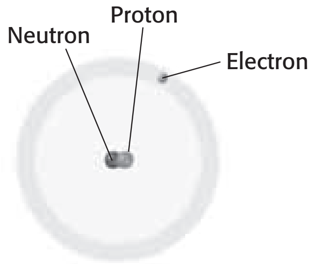
Isotopes of Hydrogen



This isotope is a hydrogen atom that has one proton in its nucleus.



This isotope is a hydrogen atom that has one proton and one neutron in its nucleus.

PROPERTIES OF ISOTOPES

There are a small number of isotopes for each element found in nature. Some isotopes have special properties. For example, some isotopes are unstable, and their nuclei change over time. Atoms with this type of nucleus are called *radioactive*. A radioactive atom can break down, giving off small particles and energy.

Isotopes share most of the same physical and chemical properties. For example, there are three isotopes of oxygen. The most common isotope of oxygen has eight neutrons in its nucleus. Other oxygen isotopes have nine or ten neutrons. All three isotopes are colorless, odorless gases at room temperature. Each isotope can combine with another substance as it burns.

Critical Thinking

12. Explain Why doesn't it matter which nonradioactive isotope of oxygen you breathe?

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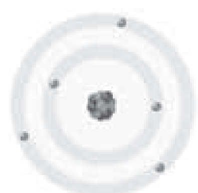
DIFFERENCES BETWEEN ISOTOPES

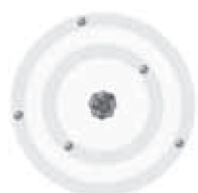
Since isotopes contain different numbers of neutrons, they have different masses. The **mass number** of an isotope is the sum of the protons and neutrons in an atom. Electrons are not included in the mass number because they are so small. The figure below shows two isotopes of boron. The isotope on the left has a mass number of 10. The isotope on the right has a mass number of 11.

Two Isotopes of Boron



Protons: 5
Neutrons: 5
Electrons: 5
Mass number = protons + neutrons = 10

Boron-10



Protons: 5
Neutrons: 6
Electrons: 5
Mass number = protons + neutrons = 11

Boron-11

Math Focus

13. Determine Boron has an atomic number of 5. How many neutrons are found in boron-10, and how many in boron-11?

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NAMING ISOTOPES

You can identify an isotope of an element by its mass number. For example, a hydrogen atom with one proton and no neutrons has a mass number of 1. Its name is hydrogen-1. Hydrogen-2 has one proton and one neutron.

A carbon isotope with a mass number of 12 is called carbon-12. If you know that the atomic number for carbon is 6, you can calculate the number of neutrons in carbon-12. You would subtract the atomic number from the mass number. For carbon-12, the number of neutrons is 12 minus 6, or six.

TAKE A LOOK

14. Identify Fill in the table with the isotope by using the mass number and atomic number columns.

Isotope	Mass number	Atomic number
	2	1
	4	2
	13	6
	16	8

What Is the Atomic Mass of an Element?

For most elements, there are usually two or more isotopes that exist. For example, copper is made of copper-63 atoms and copper-65 atoms. This means that the number of neutrons differs from atom to atom. The **atomic mass** of an element is the weighted average of the masses of all the natural isotopes of that element.

The percentage of each isotope is usually known. So, a weighted average uses these percentages of each isotope present for that element. For example, a sample of copper is about 69% copper-63 atoms and 31% copper-65 atoms. So, the atomic mass of copper is 63.6 amu.

Critical Thinking

15. Explain Can the mass number of an atom ever be smaller than its atomic number? Explain your answer.

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Now, let's try a problem. In nature, the percentage of chlorine-35 is 76%, and chlorine-37 is 24%. What is the atomic mass of chlorine?

Step 1: Multiply the mass number of each isotope by its percentage in decimal form.

$(35 \times 0.76) = 26.60$

$(37 \times 0.24) = \ \ 8.88$

Step 2: Add the amounts together.

$$\begin{aligned}(35 \times 0.76) &= \ \ 26.60\\ (37 \times 0.24) &= \underline{+8.88}\\ &\ \ \ \ 35.48 \text{ amu}\end{aligned}$$

Math Focus

16. Determine Calculate the atomic mass of boron, which occurs as 20% boron-10 and 80% boron-11. Show your work.

What Forces Affect the Particles in Atoms?

Because charged particles attract and repel one another, there must be other forces that hold atoms and nuclei together. Scientists have discovered that there are four basic forces in nature. These forces work together to give atoms their structure and properties.

ELECTROMAGNETIC FORCE

The *electromagnetic force* causes objects with like charges to repel each other. It also causes objects with opposite charges to attract each other. Protons and electrons are attracted to one another because of the electromagnetic force. The electromagnetic force holds the electrons around the nucleus.

Say It

Discuss What would happen if each of the basic forces did not exist? Taking the forces one at a time, in a small group, discuss what would happen if that force didn't exist.

GRAVITATIONAL FORCE

Gravitational force pulls objects toward one another. It depends on the masses of the objects and the distance between them. Since the particles in an atom are so small, the gravitational force has almost no effect within atoms.

Critical Thinking

17. Infer In some radioactive nuclei, a neutron can change into an electron and a proton. The electron leaves the nucleus, but the proton does not. What happens to the identity of the atom when this happens?

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STRONG FORCE

The *strong force* holds the nucleus together. Inside the nucleus, the attraction of the strong force is greater than the repulsion of the electromagnetic force. If there were no strong force, protons in the nucleus would repel one another, and the nucleus would fly apart.

WEAK FORCE

The *weak force* is important in radioactive atoms. In certain unstable atoms, a neutron can change into a proton and an electron. The weak force plays an important role in this change.

Forces in the Atom

Description	Force
Force that affects changes of particles in the nucleus	
Attractive interaction between objects with mass	
Attractive force between particles in the nucleus	
Attractive or repulsive force between objects with opposite charges	

TAKE A LOOK

18. Identify Fill in the names of the four forces in the table.

Name ______________________ Class ______________ Date ______________

Section 2 Review

NSES PS 1c

SECTION VOCABULARY

atomic mass the mass of an atom expressed in atomic mass units

atomic mass unit a unit of mass that describes the mass of an atom or molecule

atomic number the number of protons in the nucleus of an atom; the atomic number is the same for all atoms of an element

isotope an atom that has the same number of protons (or the same atomic number) as other atoms of the same element do but that has a different number of neutrons (and thus a different atomic mass)

mass number the sum of the numbers of protons and neutrons in the nucleus of an atom

neutron a subatomic particle that has no charge and that is located in the nucleus of an atom

proton a subatomic particle that has a positive charge and that is located in the nucleus of an atom; the number of protons in the nucleus is the atomic number, which determines the identity of an element

1. **Compare** Why do two isotopes of an element have the same atomic number but different mass numbers?

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2. **Identify** What are the three types of particles, and their charge, that can be found in an atom?

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3. **Apply** Why does every element except hydrogen need at least one neutron in its nucleus?

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4. **Compare** The atomic number of carbon is 6 and the atomic number of nitrogen is 7. How do the number of neutrons and protons in the nuclei of carbon-14 and nitrogen-14 differ?

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5. **Calculate** What is the atomic mass of gallium, which occurs naturally as 60% gallium-69 and 40% gallium-71? Show your work.

SECTION 1

Arranging the Elements

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- How are elements arranged on the periodic table?
- What are metals, nonmetals, and metalloids?
- What patterns are shown by the periodic table?

National Science Education Standards
PS 1b

What Are Patterns of Elements?

By the 1860s, scientists had discovered more than 60 different elements. As they studied these elements, the scientists saw that some elements had properties that were very similar. For example, sodium and potassium are both metals that can explode if put into water. On the other hand, gold and silver are stable metals that react very slowly with water.

To understand the elements, chemists needed a way to organize what they knew about these elements. If the properties of elements formed a pattern, it would help scientists understand how elements interact with one another. A Russian chemist, Dmitri Mendeleev, discovered a pattern in 1869. ☑

Mendeleev wrote the names of the elements and their properties on cards. When he arranged the cards in order of increasing atomic mass, he found that a pattern developed. He put elements that had similar properties in the same vertical column. See the table below.

STUDY TIP

Clarifying Concepts Take turns reading this section out loud with a partner. Stop to discuss ideas that seem confusing.

READING CHECK

1. Describe What discovery allowed Mendeleev to make his periodic table?

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Arranging the Elements in a Table

Hydrogen 1						
Lithium 7	Beryllium 9	Boron 11	Carbon 12		Oxygen 16	Fluorine 19
Sodium 23	Magnesium 24	Aluminum 27	Silicon 28		Sulfur 32	Chlorine 35
Potassium 39	Calcium 40					

The elements were placed in order by atomic mass. Sodium is similar to lithium and potassium, so they are in the same column. The same is true for elements in the other columns.

TAKE A LOOK

2. Make a Prediction Look at the pattern of atomic masses of the elements. Predict where element X (atomic mass 31) and element Y (atomic mass 14) should be placed. Write X or Y in the correct boxes in the table.

Say It

Discuss Many things occur in patterns that are periodic. In groups of three or four, discuss things in your life or in the world around you that occur at regular intervals. How many different types of patterns can you think of?

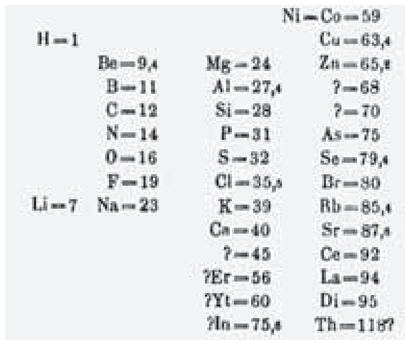
How Were The Patterns Used?

Mendeleev found that the pattern repeated several times. He started a new row with an element whose properties, such as reactivity, were similar to lithium. Then all the elements in the first column reacted in a similar way. All the elements in the second row also had similar properties.

The pattern continued across the table, and then was repeated for elements in the third row, forming a periodic pattern. **Periodic** means "happening at regular intervals."

Mendeleev found that the pattern of elements repeated after every seven elements. His table became known as the periodic table of the elements. The figure below shows part of a chart that Mendeleev made using his periodic table. Notice that there are several question marks beside atomic masses.

Mendeleev used question marks to note elements that he thought would be found later.



TAKE A LOOK

3. Identify Look at Mendeleev's chart. How many new elements did he predict that would be discovered later?

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When all the known elements were placed on the chart, there seemed to be gaps in the pattern. Mendeleev left blanks in his periodic table where these gaps appeared. He predicted that elements would be discovered that would fill these blanks.

By 1886, the gaps in the table had been filled by newly discovered elements. These elements had the properties that Mendeleev had predicted. The table below compares one of Mendeleev's predictions with the actual element, germanium, discovered in 1871.

Math Focus

4. Compare Mendeleev predicted an atomic mass for the element that was later discovered and named germanium. How much does germanium's actual atomic mass differ from his prediction?

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Properties of Germanium

	Mendeleev's predictions (1869)	Actual properties
Atomic mass	70 amu	72.6 amu
Density*	5.5 g/cm^3	5.3 g/cm^3
Appearance	dark gray metal	gray metal
Melting point*	high	937°C

* at room temperature and pressure

What Does The Modern Periodic Table Look Like?

The first periodic table included only 63 elements. Today, scientists know about more than 100 elements, although some of them are very rare. The modern table contains information that is similar to Mendeleev's, but there are some differences.

Mendeleev's periodic table showed the elements in order of atomic mass. A few of the elements did not appear to fall in the right order. Mendeleev placed them where he thought they should be based on their properties. He thought that better atomic mass measurements would correct the problem.

In 1914, scientists began using *atomic numbers*. An atomic number is the number of protons in an atom. The elements were all in the right place when they were ordered by atomic number instead of atomic mass. The figure below shows a modern periodic table.

Each row of elements, from left to right, is called a **period**. The physical and chemical properties of elements in a period follow the same pattern as those of the periods above and below. Each column of elements (top to bottom) is called a **group**. Elements in a group tend to have similar chemical and physical properties. Groups are sometimes called families.

Critical Thinking

5. Explain Why is atomic number a better property for organizing the elements than atomic mass?

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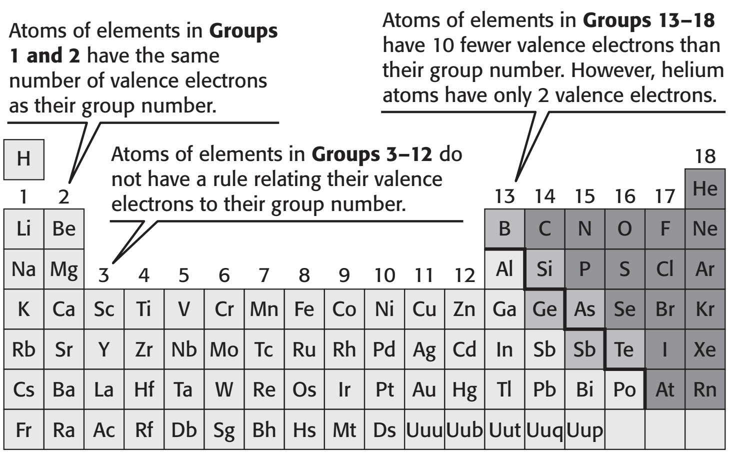

TAKE A LOOK

6. Describe How many groups and how many periods does the modern periodic table have? Hint: hydrogen and helium should be counted as in the first period.

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STANDARDS CHECK

PS 1b Substances react chemically in characteristic ways with other substances to form new substances (compounds) with different characteristics. In chemical reactions, the total mass is conserved. Substances are often placed in categories or groups if they react in similar ways; metals is an example of such a group.

Word Help: chemical
of or having to do with properties or actions of substances

Word Help: reaction
a response or change

7. Compare What are four categories of elements found on the periodic table?

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How Are the Elements on the Table Classified?

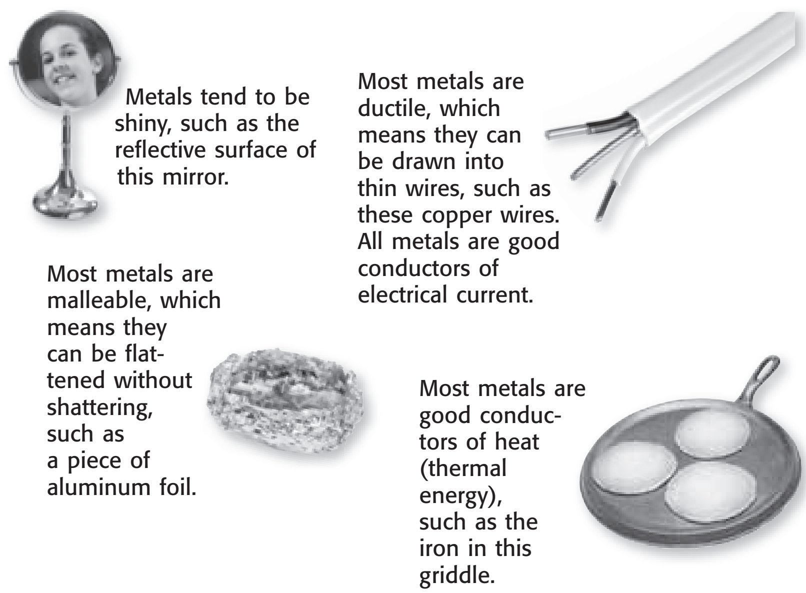
When you look at the elements on the periodic table, there are three classes of elements. Usually, the classes of elements are related to the number of electrons in the outer energy level, the valence electrons. The number of valence electrons increases from left to right in a period. Based on their properties, the elements are classified as:

- metals - the lighter shade to the left and center of the periodic table
- nonmetals - the darker shade to the right side of the table
- metalloids - the region shown on either side of a zigzag line between the metals and nonmetals
- inert gases - Group 18 on the periodic table

METALS

When you look at the periodic table, you can see that most of the elements are metals. Most metal atoms have few electrons in their outer energy levels. Except for mercury, which is a liquid, metals are solids at room temperature. The figure below shows some of the properties of metals.

Properties of Metals



TAKE A LOOK

8. Identify What are five properties of metals?

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NONMETALS

Nonmetals are found on the right side of the table. Atoms of most nonmetals have a nearly full outer energy level. Many of the nonmetal elements are gases at room temperature. In general, the properties of nonmetals are the opposite of the properties of metals. Some of the properties of nonmetals are described in the figure below. ☑

READING CHECK

9. Compare How are the outer energy levels of nonmetals different from the outer energy levels of metals?

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METALLOIDS

Metalloids are the elements found on either side of the zigzag line between metals and nonmetals. Their outer energy levels are about half filled. Metalloids have some properties of metals and some properties of nonmetals, as described in the figure below.

Properties of Nonmetals and Metalloids

Nonmetals are not malleable or ductile. Solid nonmetals, such as carbon in the graphite of pencil lead, are brittle and will break or shatter when hit with a hammer.

Boron, a metalloid, is almost as hard as a diamond and is also very brittle. At high temperatures, it is a good conductor of electric current.

TAKE A LOOK

10. Identify Circle the word in the figure's text that describes how a metalloid responds to a hammer blow.

What Information Is on the Periodic Table?

The next page is a more detailed look at parts of the periodic table. It includes the two groups to the left side of the table and the six groups to the right. Each element occupies one block that includes information about that element. This includes the element's name, its atomic number, and its atomic mass.

Each block also shows the chemical symbol of the element. This is a one or two letter abbreviation that represents that element in a chemical formula. These symbols are used in the chemical formulas for compounds. If you see an unfamiliar symbol in a formula, you can use the periodic table to identify the element. ☑

READING CHECK

11. Describe What is a chemical symbol?

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TAKE A LOOK

12. List What are the four pieces of information about an element that are shown on the periodic table?

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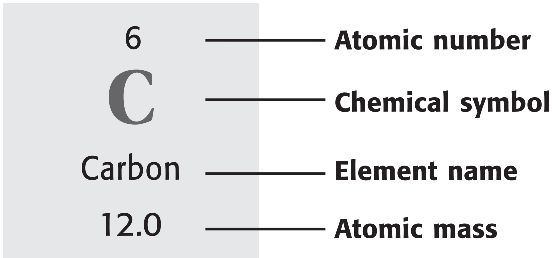

Each square on the periodic table of elements includes the element's name, chemical symbol, atomic number, and atomic mass.

Periodic Table of Elements

	Group 1	Group 2	Group 13	Group 14	Group 15	Group 16	Group 17	Group 18
Period 1	1 H Hydrogen 1.0							2 He Helium 4.0
Period 2	3 Li Lithium 6.9	4 Be Beryllium 9.0	5 B Boron 10.8	6 C Carbon 12.0	7 N Nitrogen 14.0	8 O Oxygen 16.0	9 F Fluorine 19.0	10 Ne Neon 20.2
Period 3	11 Na Sodium 23.0	12 Mg Magnesium 24.3	13 Al Aluminum 27.0	14 Si Silicon 28.1	15 P Phosphorus 31.0	16 S Sulfur 32.1	17 Cl Chlorine 35.5	18 Ar Argon 39.9
Period 4	19 K Potassium 39.1	20 Ca Calcium 40.1	31 Ga Gallium 69.7	32 Ge Germanium 72.6	33 As Arsenic 74.9	34 Se Selenium 79.0	35 Br Bromine 79.9	36 Kr Krypton 83.8
Period 5	37 Rb Rubidium 85.5	38 Sr Strontium 87.6	49 In Indium 114.8	50 Sn Tin 118.7	51 Sb Antimony 121.8	52 Te Tellurium 127.6	53 I Iodine 126.9	54 Xe Xenon 131.3
Period 6	55 Cs Cesium 132.9	56 Ba Barium 137.3	81 Tl Thallium 204.4	82 Pb Lead 207.2	83 Bi Bismuth 209.0	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
Period 7	87 Fr Francium (223)	88 Ra Radium (226)	113 Uut Ununtrium (284)	114 Uuq Ununquadium (289)	115 Uup Ununpentium (288)			

A row of elements is called a *period*.

A column of elements is called a *group* or *family*.

Critical Thinking

13. Analyze Relationships Scientists can make atoms of large elements which have not been previously known. Identify an element that would have similar properties to an atom that has 118 protons.

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How Do You Read The Table?

On the previous page, the top figure shows how to read a square on the periodic table. The symbol for the element is generally the largest item on a periodic table. In this table, the atomic number is above the symbol. The name of the element and the atomic mass are below it.

Notice that for elements with one-letter symbols, the symbol is always capitalized. For elements with two-letter symbols, the first letter is capitalized and the second letter is lower case. Three-letter symbols represent elements with temporary names. ☑

The bottom figure shows part of the periodic table. In order to fit onto the page, it only shows eight groups of elements. All of the elements follow the **periodic law**. The periodic law states that the repeating chemical and physical properties change periodically with the elements' atomic numbers. An atomic number is the number of protons in an atom of the element.

Although the atomic number increases from left to right in every period, the atomic mass does not necessarily do so. There are several places where the atomic mass of an element is greater than that of the element to its right. An example is tellurium and iodine in Period 5.

Most tellurium atoms have at least two more neutrons than iodine atoms have. That is why the atomic mass of tellurium is higher than the atomic mass of iodine, even though iodine has one more proton.

READING CHECK

14. Identify What does a three-letter chemical symbol show?

____

____

Finding the Atomic Number

14
Si
Silicon
28.1

Atomic Number: ______
Number of protons: ______

86
Rn
Radon
(222)

Atomic Number: ______
Number of protons: ______

92
U
Uranium
238.0

Atomic Number: ______
Number of protons: ______

TAKE A LOOK

15. Identify Use the information from the periodic table boxes to write the atomic number and number of protons for each element. Fill in the blanks in the figure to the left.

Name ______________________ Class ______________ Date ______________

Section 1 Review

NSES PS 1b

SECTION VOCABULARY

group a vertical column of elements in the periodic table; elements in a group share chemical properties

period in chemistry, a horizontal row of elements in the periodic table

periodic describes something that occurs or repeats at regular intervals

periodic law the law that states that the repeating chemical and physical properties of elements change periodically with the atomic numbers of the elements

1. **Compare** Which elements would likely have similar properties: two elements in the same group, or two elements in the same period?

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2. **Organize** Fill in the table below with the correct classification of element.

Location	Classification
Left side and center of periodic table	
Right side of periodic table	
Zigzag line toward right side of periodic table	

3. **Identify Relationships** Use the periodic table to answer this question: Are the properties of rubidium (Rb) more similar to those of cesium (Cs) or those of strontium (Sr)? Explain your answer.

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4. **Apply Concepts** Use the periodic table on page 218 to identify the elements in the following compounds: PbS, KBr, RaO

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5. **Apply Concepts** Use the periodic table to determine whether each element is a metal or a nonmetal: sodium (Na), krypton (Kr), phosphorus (P)

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Name ______________________ Class ______________ Date ______________

CHAPTER 12 The Periodic Table

SECTION 2

Grouping the Elements

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- Why do elements in a group have similar properties?
- What are the different groups on the periodic table?
- How does hydrogen differ from other elements?

National Science Education Standards

PS 1b, 3e

Why Are Elements in a Group Similar?

The elements in a group on the periodic table have similar properties. The properties are similar because the elements within a group have the same number of electrons in their outer energy level. Atoms often take, give, or share electrons with other atoms. Elements whose atoms have similar outer energy levels tend to react in similar ways. ☑

STUDY TIP

Graphic Organizer In your notebook, make a Venn Diagram of metals and nonmetals. Read about each group of the periodic table. Indicate on the Venn Diagram whether the group includes all metals, all nonmetals, or a combination of metals and nonmetals.

READING CHECK

1. Explain Why do the elements within a group of the periodic table have similar chemical properties?

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GROUP 1: ALKALI METALS

3	Li, Lithium
11	Na, Sodium
19	K, Potassium
37	Rb, Rubidium
55	Cs, Cesium
87	Fr, Francium

Group contains: metals
Electrons in the outer level: 1
Reactivity: very reactive
Other shared properties: softness; color of silver; shininess; low density

Alkali metals are elements in Group 1 of the periodic table. Alkali metals are the most reactive metals, which means they form compounds with other elements most easily. Their atoms tend to give away one of their outer-level electrons when they form compounds.

Alkali metals react with water and with oxygen in the air. In fact, they can cause a violent explosion when put into water. Alkali metals are so reactive that they are found in nature only combined with other elements. Compounds formed from alkali metals have many uses. One such compound, sodium chloride (table salt), is necessary in your diet.

TAKE A LOOK

2. List What are the names and atomic numbers of the alkali metal elements?

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GROUP 2: ALKALINE-EARTH METALS

4	Be	Beryllium
12	Mg	Magnesium
20	Ca	Calcium
38	Sr	Strontium
56	Ba	Barium
88	Ra	Radium

Group contains: metals
Electrons in the outer level: 2
Reactivity: very reactive but less reactive than alkali metals
Other shared properties: color of silver; higher densities than alkali metals

Alkaline-earth metals are less reactive than alkali metals. Atoms of alkaline-earth metals have two outer-level electrons. It is more difficult for atoms to lose two electrons than to lose one. That means alkaline-earth metals tend to react more slowly than alkali metals, but they are still very reactive. ☑

Group 2 elements and their compounds have many uses. For example, magnesium can be mixed with other metals to make low-density materials for airplanes. Compounds of calcium are found in chalk, cement, and even in your bones and teeth.

READING CHECK

3. Explain Why are the alkaline-earth metals less reactive than the alkali metals?

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GROUPS 3 TO 12: TRANSITION METALS

21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 C	30 Zn
39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 R	45 Rh	46 Pd	47 Ag	48 Cd
57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 A	80 Hg
89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 U	112 U b

TAKE A LOOK

4. Identify How many protons does the largest transition metal have in its nucleus?

____

Group contains: metals
Electrons in the outer level: 1 or 2
Reactivity: less reactive than alkaline-earth metals
Other shared properties: shininess; good conduction of thermal energy and electric current; higher densities and melting points than elements in Groups 1 and 2 (except for mercury)

Elements of Groups 3-12 are called *transition metals*. The atoms of transition metals do not give away their electrons as easily as atoms of Group 1 or Group 2 metals.

PROPERTIES OF TRANSITION METALS

The number of outer-level electrons in atoms of transition metals can vary. The properties of these metals also vary widely. For example, iron forms rust when exposed to air and water. Gold and platinum, however, are very unreactive. Jewelry and other gold objects that are thousands of years old still look new.

Transition metals all share the common properties of metals. They tend to be shiny, malleable, and ductile. They conduct thermal energy and electric current well. Many of the transition metals have very high melting points compared to other elements. One exception is mercury, which is a liquid at room temperature. Many of the transition metals are made into structural materials, coins, and jewelry. ☑

READING CHECK

5. Identify Which transition metal has the lowest melting point?

____

GROUP 13: BORON GROUP

5	B	Boron
13	Al	Aluminum
31	Ga	Gallium
49	In	Indium
81	Tl	Thallium
113	Uut	Ununtrium

Group contains: one metalloid and five metals
Electrons in the outer level: 3
Reactivity: reactive
Other shared properties: solids at room temperature

The most common element from Group 13 is aluminum. In fact, aluminum is the most common metal in Earth's crust. Until the 1880s, however, aluminum was considered a precious metal. Today, making pure aluminum is easier and cheaper than it was in the 1800s.

Aluminum is useful because it is such a lightweight, but strong, metal. It is used in aircraft parts lightweight automobile parts, foil, cans, and garage doors. ☑

Like other elements in the boron group, aluminum is reactive. However, when aluminum reacts with oxygen in the air, a thin layer of aluminum oxide quickly forms on aluminum's surface. This layer prevents further reaction of aluminum.

TAKE A LOOK

6. List What are the atomic numbers of the elements in Group 13?

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READING CHECK

7. Explain Why is aluminum a good choice of metal for airplane bodies?

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GROUP 14: CARBON GROUP

6	C	Carbon
14	Si	Silicon
32	Ge	Germanium
50	Sn	Tin
82	Pb	Lead
114	Uuq	Ununquadium

Group contains: one nonmetal, two metalloids, and three metals
Electrons in the outer level: 4
Reactivity: varies among elements
Other shared properties: solids at room temperature

Group 14 includes several well-known and useful elements. The nonmetal carbon can be found in nature as diamonds and as soot from burning wood, oil, or coal.

Carbon also forms a wide variety of compounds. Some of these compounds, such as proteins, fats, and carbohydrates, are necessary for all living things.

The metalloids, silicon and germanium, are used in semiconductors. These are important components of computers and other electronic devices. Tin and lead are soft, relatively unreactive metals. A layer of tin keeps steel cans from rusting. Lead is used in automobile batteries.

TAKE A LOOK
8. Identify Which element in Group 14 is classified as a nonmetal?

____

GROUP 15: NITROGEN GROUP

7	N	Nitrogen
15	P	Phosphorus
33	As	Arsenic
51	Sb	Antimon
83	Bi	Bismuth
115	Uup	Ununpentium

Group contains: two nonmetals, two metalloids, and two metals
Electrons in the outer level: 5
Reactivity: varies among elements
Other shared properties: solids at room temperature (except for nitrogen)

Nitrogen, which is a gas at room temperature, makes up about 80% of the air that you breathe. In general, nitrogen is fairly unreactive. Nitrogen can react with hydrogen to make ammonia for fertilizers.

Phosphorus is an extremely reactive nonmetal. In nature, it is always found combined with other elements. Because it is so reactive, phosphorus is used to make matches. The heat of friction against the box provides the energy to cause phosphorus to start burning.

TAKE A LOOK
9. Identify What are the chemical symbols for the elements nitrogen and phosphorus?

____

GROUP 16: OXYGEN GROUP

8	O	Oxygen
16	S	Sulfur
34	Se	Selenium
52	Te	Tellurium
84	Po	Polonium

Group contains: three nonmetals, one metalloid, and one metal
Electrons in the outer level: 6
Reactivity: reactive
Other shared properties: all but oxygen are solids at room temperature

Oxygen makes up about 20% of air. Oxygen is necessary for substances to burn. It is also important to most living things. Dissolved oxygen in water is necessary for fish to live. People need to breathe oxygen to live.

Sulfur is another common member of Group 16. Sulfur can be found in natural deposits as a brittle yellow solid. It is used to make sulfuric acid, which is the most widely used compound in the chemical industry. ☑

READING CHECK

10. Describe What are two physical properties of the element sulfur?

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GROUP 17: HALOGENS

9	F	Fluorine
17	Cl	Chlorine
35	B	Bromine
53	I	Iodine
85	At	Astatine

Group contains: nonmetals
Electrons in the outer level: 7
Reactivity: very reactive
Other shared properties: poor conductors of electric current; violent reaction with alkali metals to form salts; never in uncombined form in nature

Halogens are very reactive nonmetal elements. They need to gain only one electron to have a complete outer-electron level. The atoms of halogens combine easily with other atoms, especially metals, to gain the extra electron. The reaction of a halogen with a metal makes a salt, such as sodium chloride.

Both chlorine and iodine are used to kill germs. Chlorine is used to treat water for drinking and swimming. Iodine is mixed with alcohol and used in hospitals.

Although the chemical properties of halogens are similar, their physical properties can be quite different. For example, at room temperature, fluorine and chlorine are gases, bromine is a liquid, and iodine is a solid. Astatine is a very rare element.

TAKE A LOOK

11. List What are the names and atomic numbers of the halogens?

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STANDARDS CHECK

PS 1b Substances react chemically in characteristic ways with other substances to form new substances (compounds) with different characteristics. In chemical reactions, the total mass is conserved. Substances are often placed in categories or groups if they react in similar ways; metals is an example of such a group.

Word Help: chemical
of or having to do with properties or actions of substances

Word Help: reaction
a response or change

12. Identify What family of elements are grouped together because they do not usually react with other elements?

____

Critical Thinking

13. Evaluate Models
According to the current model of the atom, the atoms are most stable when they have filled outer energy levels. How do the properties of noble gases support this model?

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GROUP 18: NOBLE GASES

2 He Helium
10 Ne Neon
18 Ar Argon
36 Kr Krypton
54 Xe Xenon
86 Rn Radon

Group contains: nonmetals
Electrons in the outer level: 8 (except helium, which has 2)
Reactivity: unreactive
Other shared properties: colorless, odorless gases at room temperature

Noble gases are unreactive gases found in Group 18 of the periodic table. The atoms of the noble gases have completely filled outer levels. This means they do not need to gain or lose electrons to become stable.

Under normal conditions, these elements do not react with other elements. In fact, they are sometimes called inert gases because scientists once believed that they do not react at all. However, scientists have made compounds with some of the Group 18 elements. This is why they are usually called noble gases instead of inert gases.

Because the noble gases are so unreactive, they are very difficult to detect. None of them was known when Mendeleev put together his first periodic table. In fact, the first noble gas was discovered not on Earth, but in the sun. Helium was first detected by its effect on light from the sun. *Helios* is the Greek word for sun.

Argon is the most common noble gas on Earth, making up about 1% of the atmosphere. All of the noble gases are found in small amounts.

The unreactivity of the Group 18 elements makes them useful. For example, ordinary light bulbs last longer when they are filled with argon. Because argon is unreactive, it does not react with the hot metal filament of the bulb. A more reactive gas could react with the filament and cause the bulb to burn out sooner.

Noble gases are also used in colorful light tubes. They glow in bright colors when exposed to a strong electric charge. These lights are often called “neon lights.” This is because the first tubes used the noble gas neon to produce a bright red glow.

HYDROGEN

1
H
Hydrogen

Electrons in the outer level: 1
Reactivity: reactive
Other properties: colorless, odorless gas at room temperature; low density; explosive reaction with oxygen

Hydrogen is the most abundant element in the universe. It is found in large amounts in stars. Atoms of hydrogen can give away one electron when they join with other atoms. Hydrogen reacts with many elements and is found in many familiar compounds. Hydrogen is so reactive that it can be used as fuel for rockets.

The properties of hydrogen do not match any group of the periodic table. Therefore, it is set apart from the rest of the elements on the table. It is shown above Group 1 because the atoms of alkali metals also lose one electron in chemical reactions. However, the physical properties of hydrogen are more like those of nonmetals than of metals. Hydrogen is in a group all by itself. ☑

READING CHECK

14. Explain Why is hydrogen not included in any group of the periodic table?

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LANTHANIDES AND ACTINIDES

These metals are part of the transition metals. They have not been shown on the periodic table in this chapter. However, many periodic tables show them as two rows at the bottom of the table as shown below. Each row has 15 metal elements, which tend to have very similar properties. Elements in the first row are called *lanthanides*. The lanthanides are often mixed with other metals to make them stronger.

Elements in the second row are called the *actinides*. The best known actinide is uranium, which is used in nuclear power plants. All of the actinides are radioactive. Most actinides are not found in nature, but are made in laboratories.

Say It

Research Scientists in laboratories can make new elements by forcing particles together. Research how actinide elements such as plutonium and californium are made by scientists. Report your results to the class.

57
La
Lanthanum

89
Ac
Actinium

Lanthanides	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
Actinides	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

Name ______________________ Class ______________ Date ______________

Section 2 Review

NSES PS 1b, 3e

SECTION VOCABULARY

alkali metal one of the elements of Group 1 of the periodic table (lithium, sodium, potassium, rubidium, cesium, and francium)

alkaline-earth metal one of the elements of Group 2 of the periodic table (beryllium, magnesium, calcium, strontium, barium, and radium

halogen one of the elements of Group 17 of the periodic table (fluorine, chlorine, bromine, iodine, and astatine); halogens combine with most metals to form salts.

noble gas one of the elements of Group 18 of the periodic table (helium, neon, argon, krypton, xenon, and radon); noble gases are unreactive.

1. **Explain** Why are the alkali metals and the halogens among the most reactive elements on the periodic table?

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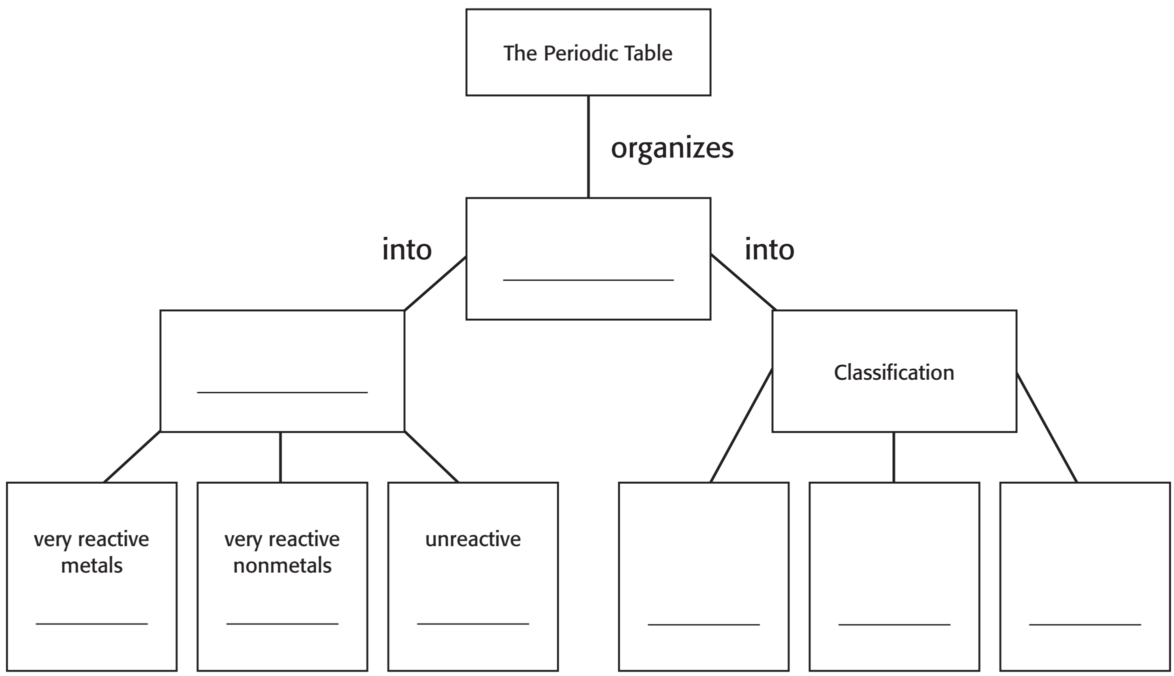
2. **Recall** Complete the Concept Diagram below with words from this section.



3. **Apply Concepts** Why were the noble gases among the last of the naturally occurring elements to be discovered?

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4. **Identify Relationships** How are all of the nonmetal elements on the periodic table related in terms of ability to lose electrons?

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Name ______________________ Class ______________ Date ____________

CHAPTER 13 Chemical Bonding

SECTION 1

Electrons and Chemical Bonding

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is chemical bonding?
- What are valence electrons?
- How do valence electrons affect bonding?

National Science Education Standards
PS 1b, 1c

What Is a Chemical Bond?

All things are made of atoms. A few substances are made of single atoms, but most are made of two or more atoms joined together. **Chemical bonding** is the joining of atoms to form a new substance. The bond that forms when two atoms join is called a **chemical bond**. Chemical bonds form when electrons in atoms interact. Atoms can gain, lose, or share electrons to form a chemical bond. ☑

In some cases, the atoms that join together are atoms of the same element. Oxygen gas, for example, is made of two oxygen atoms bonded together. In other cases, atoms of different elements bond. For example, hydrogen and oxygen atoms bond to form water.

STUDY TIP

Clarify Concepts Take turns reading this section out loud with a partner. Stop to discuss ideas that seem confusing.

READING CHECK

1. Explain What can happen to electrons in an atom when a chemical bond forms?

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ELECTRONS IN ATOMS

Remember that electrons are found outside the nucleus in layers called energy levels. Each energy level can hold a certain number of electrons. The first energy level is closest to the nucleus. It can hold up to two electrons. The second energy level can hold up to eight electrons. The third energy level can also hold up to eight electrons. ☑

READING CHECK

2. Describe Where are electrons found in an atom?

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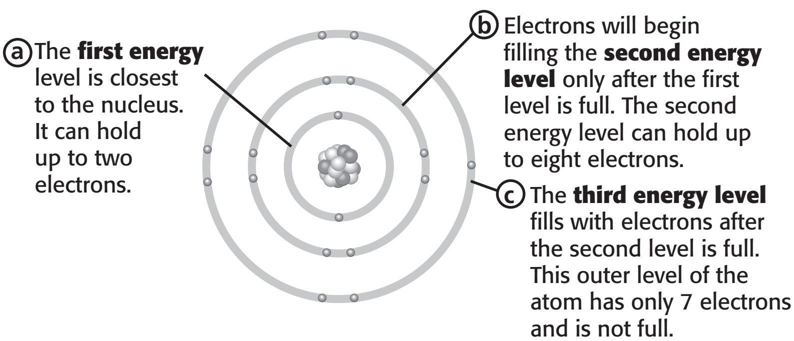
Electron Arrangement in an Atom of Chlorine



Which Electrons Affect Bonding?

Atoms form chemical bonds when their electrons interact with one another. However, not all of the electrons in an atom interact to form bonds. In most cases, only the electrons in the outermost energy level are able to form bonds. Electrons in the outermost energy level are called **valence electrons**. An atom can form different kinds of bonds depending on how many valence electrons it has. ☑

READING CHECK

3. Explain Where are the valence electrons found in an atom?

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DETERMINING THE NUMBER OF VALENCE ELECTRONS

The *atomic number* of an element tells you how many protons are in an atom of the element. No two elements have the same number of protons in their atoms. As a result, no two elements have the same atomic number. The number of protons in an atom equals the number of electrons in the atom. Therefore, the atomic number also tells how many electrons are found in an atom of an element.

You can use an element's atomic number to learn how many valence electrons its atoms have. In order to do this, you need to draw a model of the atom. Remember that valence electrons are in the outermost level. For example, the figures below show models of two atoms.

Math Focus

4. Determine The atomic number of carbon is 6. How many protons does an atom of carbon have? How many electrons?

____

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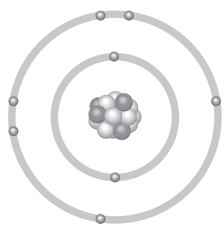
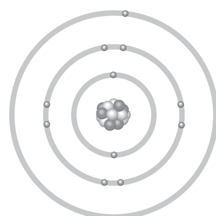
Model of an Oxygen Atom



Model of a Sodium Atom



In the illustration above, the figure on the left shows a model of an atom of oxygen. Oxygen's atomic number is 8. Therefore, its atoms have 8 electrons in them. The first energy level holds 2 electrons. The second, outermost energy level has 6 electrons in it. Therefore, oxygen has 6 valence electrons.

In the illustration above, the figure on the right shows a model of a sodium atom. Sodium's atomic number is 11. Its atoms have 11 electrons in them. The first energy level holds 2 electrons. The second energy level holds 8 electrons. The third, outermost energy level holds 1 electron. Therefore, sodium has 1 valence electron.

STANDARDS CHECK

PS 1b Substances react chemically in characteristic ways with other substances to form new substances (compounds) with different characteristics. In chemical reactions, the total mass is conserved. Substances are often placed in categories or groups if they react in similar ways; metals is an example of such a group.

Word Help: chemical
of or having to do with properties or actions of substances

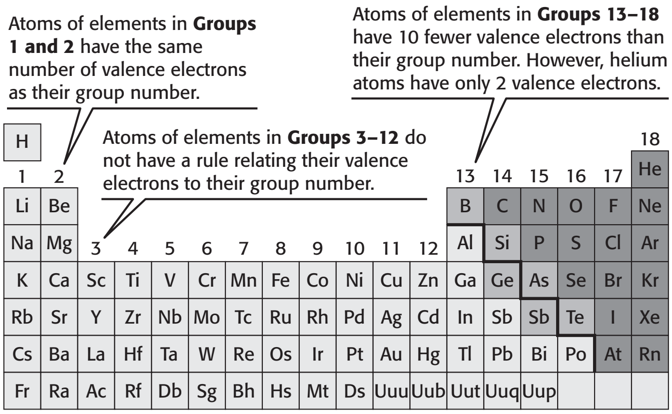
Word Help: reaction
a response or change

5. Determine When oxygen reacts, how many more electrons are needed to fill its outermost energy level?

____

USING THE PERIODIC TABLE TO FIND VALENCE ELECTRONS

You can also use the periodic table to find the number of valence electrons in an atom. Each column in the table is a group. The atoms of all of the elements in a group have the same number of valence electrons. The only exception to this rule is helium. Helium has two valence electrons. All of the other atoms in its group have eight valence electrons.



Math Focus

6. Analyze Data Use the periodic table to figure out how many valence electrons the elements in Group 16 have.

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Why Do Atoms Bond?

Some atoms form bonds easily. Others don't. How an atom bonds depends on how many valence electrons it has. An atom forms a bond with another atom in order to complete, or fill, its outermost energy level. An atom is most stable when its outermost energy level is full. ☑

The atoms in Group 18 (at the far right) have full outermost energy levels. Therefore, they do not usually form bonds. However, atoms in the other groups have outermost energy levels that are not full. These atoms fill their outermost energy levels by forming bonds. For most atoms, eight electrons will fill the outermost energy level

READING CHECK

7. Explain Why do atoms bond with one another?

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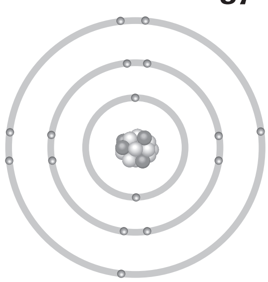
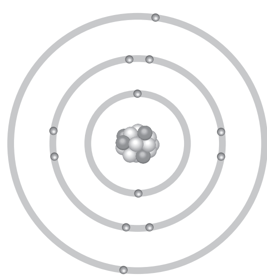
Filling Outermost Energy Levels



Sulfur An atom of sulfur has six valence electrons. It can have eight valence electrons by sharing two electrons with or gaining two electrons from other atoms.



Magnesium An atom of magnesium has two valence electrons. It can have a full outer level by losing two electrons. The second energy level becomes the outermost energy level and has eight electrons.

TAKE A LOOK

8. Apply Concepts Calcium (Ca) is in the same group as magnesium. Does it tend to gain or lose electrons when it bonds?

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Name ______________________ Class ______________ Date ____________

Section 1 Review

NSES PS 1b, 1c

SECTION VOCABULARY

chemical bonding the combining of atoms to form molecules or ionic compounds **chemical bond** an interaction that holds atoms or ions together	**valence electron** an electron that is found in the outermost shell of an atom and that determines the atom's chemical properties

1. Identify How do atoms form chemical bonds?

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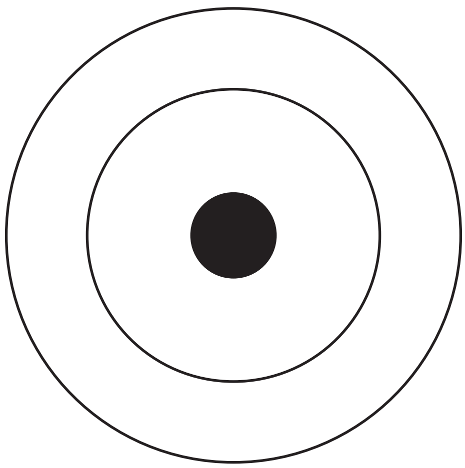
2. Use Models Fluorine (F) is an atom with two electrons in its innermost energy level and seven in its outermost level. Draw the electrons around the nucleus. Color the valence electrons in a different color.



3. Apply Concepts How can an atom that has seven valence electrons complete its outermost level?

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4. Apply Concepts Magnesium (Mg) has two electrons in its outermost energy level. Oxygen (O) has six. How can a Mg atom bond with an O atom?

____

5. Interpret Graphics Each box in the periodic table contains an element symbol and the element's atomic number. Using the box below, answer the questions about sulfur (S) next to the box.

16
S

How many protons does an atom of sulfur have? ______________

How many electrons does an atom of sulfur have? ______________

Name ______________________ Class ______________ Date ____________

CHAPTER 13 Chemical Bonding

SECTION 2

Ionic Bonds

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is ionic bonding?
- What happens to atoms that gain or lose electrons?
- What kinds of solids are formed from ionic bonds?

National Science Education Standards
PS 1b, 3a, 3e

How Do Ionic Bonds Form?

There are several types of chemical bonds. An ionic bond is one type. **Ionic bonds** form when valence electrons are transferred from one atom to another.

Like other bonds, ionic bonds form so that the outermost energy levels of the atoms are filled. To understand why ionic bonds form, you need to learn what happens when atoms gain or lose electrons. ☑

STUDY TIP

Ask Questions As you read, make a list of things you don't understand. Talk about your questions in a small group.

READING CHECK

1. Explain How does an ionic bond form?

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CHARGED PARTICLES

An electron has a negative electrical charge. A proton has a positive electrical charge. An atom is neutral, or not charged, when it has an equal number of electrons and protons. The electrical charges cancel out each other.

When atoms gain or lose electrons, the numbers of protons and electrons are no longer equal. When this happens, atoms become charged particles called **ions**. ☑

READING CHECK

2. Explain How are ions different from atoms?

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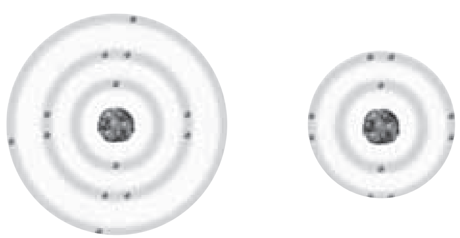
How Do Positive Ions Form?

Ions form when atoms gain or lose electrons. The atoms that lose electrons have more protons than electrons. That means they have positive charges as shown in the figure.

Forming a Positive Ion



Aluminum atom (Al)

13+	protons
13–	electrons
0	charge

Aluminum ion (Al^{3+})

13+	protons
10–	electrons
3+	charge

Here's How It Works: During chemical changes, an aluminum atom can lose its 3 electrons in the third energy level to another atom. The filled second level becomes the outermost level, so the resulting aluminum ion has 8 valence electrons.

METAL ATOMS LOSE ELECTRONS

Most metal atoms have few valence electrons. As shown in the figure on the previous page, metal atoms form positive ions. Notice that the symbol for a metal ion has the charge at the upper right of the chemical symbol.

ENERGY AND LOSING ELECTRONS

For an atom to lose an electron, the attraction between the electron and the protons has to be broken. Breaking the attraction takes energy. ☑

Compared with other elements, only a small amount of energy is needed for metals to lose their valence electrons. Therefore, metals are much more likely to form positive ions than nonmetals are. In the periodic table, the elements in Groups 1 and 2 are all metals. They need little energy to lose their valence electrons. Therefore, the metals in Groups 1 and 2 form ions very easily. The energy needed to make positive ions comes from forming negative ions during ionic bonding.

How Do Negative Ions Form?

What happens to the electrons that metal atoms lose? Atoms of nonmetals gain electrons during ionic bonding. This forms ions that have more electrons than protons. These ions have a negative charge.

Forming a Negative Ion

Here's How It Works: During chemical changes, an oxygen atom gains 2 electrons in the second energy level from another atom. An oxide ion that has 8 valence electrons is formed. Thus, its outermost energy level is filled.

Oxygen atom (O)

8+	protons
8−	electrons
0	charge

Oxide ion (O^{2-})

8+	protons
10−	electrons
2−	charge

NONMETAL ATOMS GAIN ELECTRONS

The outermost energy level of a nonmetal is almost full. It is easier for it to fill its outer energy level by gaining electrons than by losing electrons. As a result, atoms of nonmetals tend to gain electrons from other atoms. The name of a negative ion formed from an element ends with *–ide*. ☑

Its charge is shown as at the upper right of the symbol. As shown in figure, an oxygen atom gains two electrons and becomes an oxide ion. The charge on an oxide ion is −2 because it has two more electrons than protons.

Critical Thinking

3. Apply Concepts What is the charge of a nickel atom that has lost two electrons?

____

READING CHECK

4. Explain What has to happen in order for an atom to lose an electron?

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STANDARDS CHECK

PS 3e In most chemical and nuclear reactions, energy is transferred into or out of a system. Heat, light, mechanical motion, or electricity might be involved in such transfers.

Word Help: chemical
of or having to do with the properties or actions of substances

Word Help: reaction
a response or change

Word Help: involve
to have as a part of

5. Identify Where does the energy needed to form positive ions come from during ionic bonding?

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READING CHECK

6. Identify What kinds of atoms tend to gain electrons?

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ENERGY AND GAINING ELECTRONS

When atoms of most nonmetals gain electrons, they give off energy. The more easily an atom gains electrons, the more energy it releases. The elements in Group 17 (the halogens) are all nonmetals. Their atoms give off a lot of energy when they gain electrons. ☑

READING CHECK

7. Describe What does a halogen atom give off when it gains an electron?

____

How Do Ionic Compounds Form?

Ionic bonds form because positive ions are attracted to negative ions. When ionic bonds form, the number of electrons lost by metal atoms equals the number of electrons gained by nonmetal atoms. ☑

READING CHECK

8. Explain Why do ionic bonds form?

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The ions that form an ionic compound are charged, but the compound they form is neutral. That is because the charges of the two kinds of ions cancel out.

Ionic compounds form hard solids with flat faces and straight edges. These solids are called *crystals*. In a crystal, the positive and negative ions are found in a repeating three-dimensional pattern. This arrangement of ions is called a **crystal lattice**. The figure below shows an example of a crystal lattice in sodium chloride, or table salt.

This model shows a crystal lattice of sodium chloride. The sodium ions are dark gray and the chloride ions are light gray.

Say It

Share Observations Spread several grains of salt on a sheet of dark construction paper. Use a magnifying lens to examine the salt grains. Try to crush the grains with your fingers. Talk to your class about your observations.

PROPERTIES OF IONIC COMPOUNDS

Ionic compounds form brittle solids. Something that is *brittle* breaks apart when it is hit with another object. They also have high melting points. This means they have to be heated to very high temperatures before they become liquids. Many ionic compounds also dissolve easily in water. For example, seawater tastes salty because sodium chloride and other ionic compounds are dissolved in it.

Name ______________________ Class ______________ Date ______________

Section 2 Review

NSES PS 1b, 3a, 3e

SECTION VOCABULARY

crystal lattice the regular pattern in which a crystal is arranged **ion** a charged particle that forms when an atom or group of atoms gains or loses one or more electrons	**ionic bond** the attractive force between oppositely charged ions, which form when electrons are transferred from one atom to another

1. **Apply Concepts** Magnesium is a metal with two electrons in its outermost energy level. When it becomes an ion, what happens to its valence electrons? What happens to its charge?

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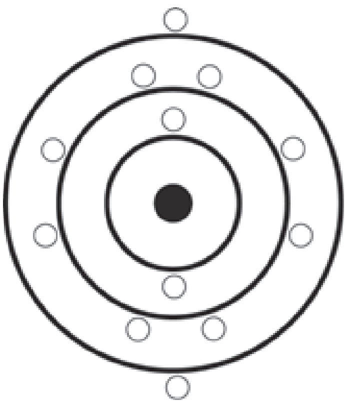
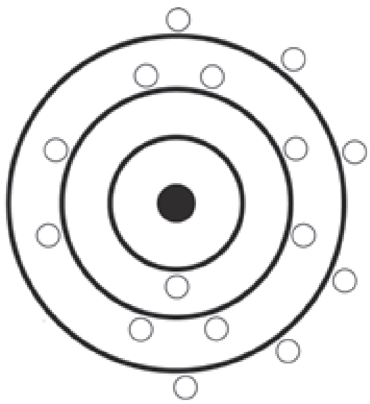
2. **Interpret Graphics** Sulfur is a nonmetal that has six electrons in its outermost level. Using the models of a magnesium (Mg) atom and a sulfur (S) atom below, draw arrows to show the transfer of electrons.



Magnesium



Sulfur

3. **Predict Consequences** Potassium (K) is found in Group 1. Fluorine (F) is found in Group 17. When these atoms bind, which will form the positive ion, and which will form the negative ion? Why? Hint: Refer back to the periodic table.

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4. **Name** What is the name given to the regular pattern in which an ionic compound is arranged?

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Name ______________________ Class ______________ Date ____________

CHAPTER 13 Chemical Bonding

SECTION 3

Covalent and Metallic Bonds

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What are covalent bonds?
- What are molecules?
- What are metallic bonds?
- How does bonding affect a metal's properties?

National Science Education Standards

PS 1b

What Are Covalent Bonds?

Another type of bond is a covalent bond. A **covalent bond** forms when atoms share electrons. Covalent bonds most often form between atoms of nonmetals. Remember that most nonmetals can fill the outermost energy level by gaining an electron. When a covalent bond forms, both atoms are able to fill their outermost energy level. They do this by sharing electrons between the two atoms. ☑

Hydrogen is one example of an atom that bonds covalently. A hydrogen atom has one electron in its outermost level. Two hydrogen atoms can come together and share their electrons. This fills the first energy level of both atoms. The electrons move around both hydrogen nuclei. The protons and the shared electrons attract one another. This attraction holds the atoms together.

STUDY TIP

Compare As you read, make a chart comparing covalent bonds and metallic bonds.

READING CHECK

1. Explain How do electrons behave in covalent bonds?

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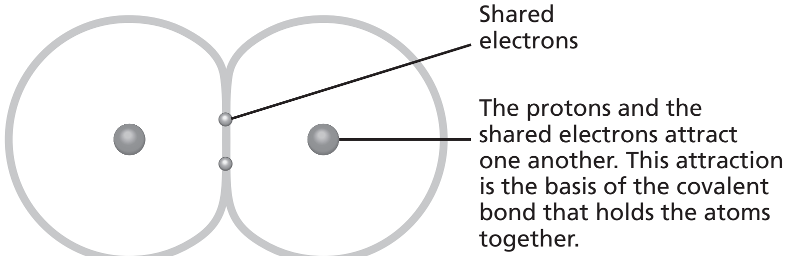

By sharing electrons in a covalent bond, each hydrogen atom (the smallest atom) has a full outermost energy level containing two electrons.

What Are Molecules?

Atoms that join with each other by covalent bonds form particles called **molecules**. Most molecules are made of atoms of two or more elements. The atoms share electrons. In the figure above, two hydrogen atoms have formed a covalent bond. The result is a hydrogen molecule. ☑

READING CHECK

2. Identify What type of bond joins the atoms in molecules?

____

PROPERTIES OF MOLECULES

Remember that an atom is the smallest piece of an element that still has the properties of that element. In the same way, a molecule is the smallest piece of a covalent compound that has the properties of that compound. This means that if a molecule is broken down, it will no longer have the properties of that compound.

Most covalently bonded substances have low melting and boiling points (water is an exception to this). Many are gases at room temperature. When a substance with covalent bonds forms a solid, the solid tends to be soft.

How Can You Model a Covalent Bond?

An *electron-dot diagram* is a model that shows only the valence electrons of an atom. The figure below shows the electron-dot diagrams for the elements in the second row of the periodic table.

TAKE A LOOK

3. Apply Concepts Hydrogen has one valence electron. Draw an electron-dot diagram of a hydrogen atom.

____

Electron-Dot Diagrams	Li·	Be·	B·	·C·	:N·	:O·	:F·	:Ne:

Electron-dot diagrams are used to show how atoms bond in molecules. In the diagram below, you can see the pairs of electrons that form the covalent bonds in a water molecule.

Critical Thinking

4. Apply Concepts Draw the electron-dot diagram that shows how two hydrogen atoms bond with a covalent bond.

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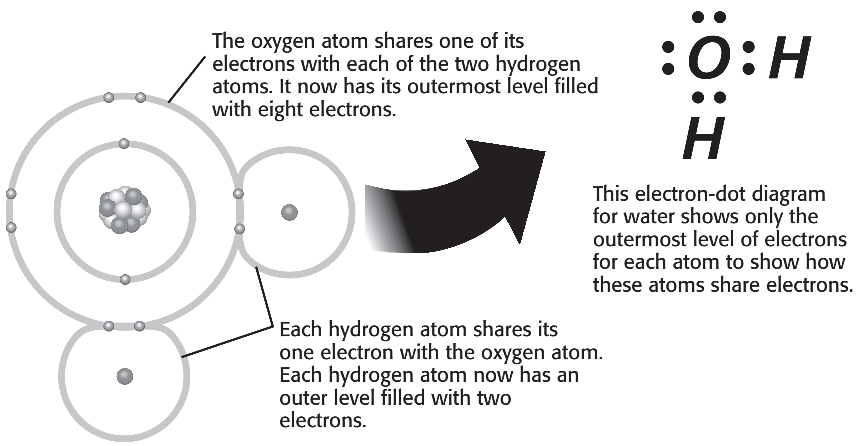

What Kinds of Molecules Can Form?

Molecules contain at least two atoms bonded by covalent bonds. The simplest molecules are made up of only two bonded atoms. They are called *diatomic molecules*. If the two atoms are of the same element, the substance is known as a *diatomic element*. The oxygen and nitrogen in the air that we breathe are both diatomic elements. ☑

In any diatomic molecule, each of the shared electrons is counted as a valence electron for both atoms. As a result, both atoms of the molecule have filled outermost energy levels.

READING CHECK

5. Identify What type of molecule is made of only two bonded atoms?

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Electron-Dot Diagrams for Chlorine, Oxygen, and Nitrogen Gas

Chlorine Oxygen Nitrogen

TAKE A LOOK

6. Count How many electrons are around each chlorine atom, each oxygen atom, and each nitrogen atom? (Remember, the electrons that are shared count for each atom.)

Chlorine: ______________

Oxygen: ______________

Nitrogen: ______________

7. Count How many pairs of electrons are shared in each molecule?

Chlorine: ______________

Oxygen: ______________

Nitrogen: ______________

COUNTING COVALENT BONDS

We have seen how atoms can share one or more pairs of electrons. The oxygen atom in water shares two pairs of electrons, one pair with each hydrogen atom. This means that the oxygen atom in a water molecule forms two covalent bonds.

The number of shared pairs of electrons tells you the number of covalent bonds in a molecule. In the figure above, you counted the number of electron pairs shared in molecules of chlorine, oxygen, and nitrogen. In a chlorine molecule, there is one covalent bond. There are two covalent bonds in an oxygen molecule and three in a nitrogen molecule.

Many molecules are more complex than the molecules in the figure. As you may suspect, some molecules have many covalent bonds.

Critical Thinking

8. Apply Concepts How many covalent bonds does phosphorus (P) form in the molecule shown below:

____

MORE COMPLEX MOLECULES

Many molecules are much larger and more complex than diatomic molecules or water. Complex molecules have many atoms joined by covalent bonds. Complex molecules make up many important and familiar substances, such as gasoline, soap, plastics, proteins, and sugars. In fact, most of the substances that make up your body are complex molecules!

Carbon (C) atoms are the basis of many complex molecules. Carbon has four valence electrons. To fill its outer energy level, a carbon atom needs to gain four electrons. Therefore, carbon atoms can form four covalent bonds. Carbon atoms can form bonds with other carbon atoms. They also can bond to atoms of other elements, such as oxygen, hydrogen, and nitrogen. Most of the molecules that carbon forms are very complex.

TAKE A LOOK

9. Count How many covalent bonds does an atom of carbon form in this molecule?

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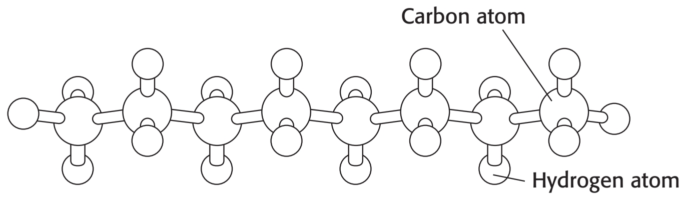
Model of an Octane Molecule Found in Gasoline



What Are Metallic Bonds?

The bonding in metals is different from the bonding we have discussed. Metals are substances like copper, iron, silver, and nickel. A **metallic bond** is formed by the attraction between positively charged metal ions and the electrons around the ions. ☑

READING CHECK

10. Describe How is a metallic bond formed?

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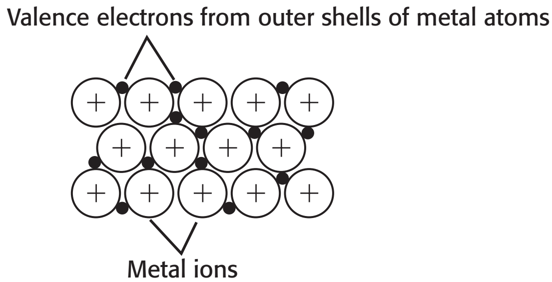
Model Showing Metallic Bonding



READING CHECK

11. Explain What can valence electrons do in a metallic bond?

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The bonding in metals is a result of the closeness of many metal atoms. Their outermost energy levels overlap. Because of the overlapping, metallic bonds form and extend throughout the metal in all directions. The valence electrons can move throughout the metal. The electrons keep the ions together and cancel the positive charge of the ions. ☑

What Are the Properties of Metals?

You probably know if something is metal as soon as you look at it. Most metals are very shiny, like gold, silver, copper, nickel, and platinum. Metals have other properties that identify a substance as a metal.

CONDUCTING ELECTRIC CURRENT

Metallic bonding allows metals to conduct electricity. Metals are used to make wires. When the wire is attached to an electrical source, the valence electrons are free to move throughout the wire. They can light a bulb or power a radio. ☑

READING CHECK

12. Explain Why can a wire conduct an electric current when it is connected to an electrical source?

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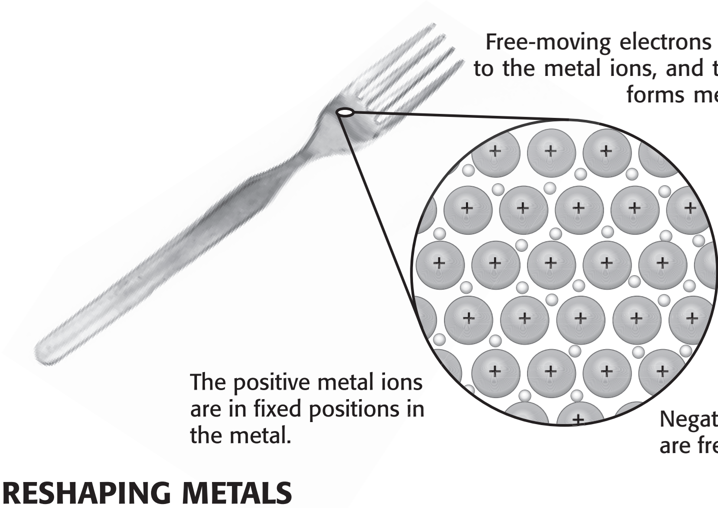

RESHAPING METALS

The atoms in metals can be rearranged easily because the electrons move around freely. The valence electrons of metals are constantly moving around the metal ions. This movement maintains the metallic bonds. As a result, no matter how the shape of the metal is altered, it won't break. This is why metals can so easily change their shape. Two properties describe a metal's ability to be reshaped:

- *Ductility* is the ability to be shaped into long, thin wires.
- *Malleability* is the ability to be hammered into thin sheets. ☑

READING CHECK

13. Define What does ductility mean? What does malleability mean?

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Ductility and malleability are the properties that make many metals useful for people. Copper can be stretched to make electrical wires. Aluminum can be pounded to form sheets of foil. Silver and gold can be mixed with other metals and bent to form jewelry or fill cavities in teeth.

Name ______________________ Class ______________ Date ______________

Section 3 Review

NSES **PS 1b**

SECTION VOCABULARY

covalent bond a bond formed when atoms share one or more pairs of electrons

metallic bond a bond formed by the attraction between positively charged metal ions and the electrons around them

molecule a group of atoms that are held together by chemical forces; a molecule is the smallest unit of matter that can exist by itself and retain all of a substance's chemical properties

1. Apply Ideas The following is a list of elements: gold, carbon, oxygen, aluminum, copper, and fluorine. In the table below, list each under the correct heading.

Forms covalent bonds	Forms metallic bonds

2. Apply Concepts Nitrogen has five valence electrons, and hydrogen has one. An ammonia molecule has one nitrogen atom and three hydrogen atoms. Draw an electron-dot diagram for a molecule of ammonia.

3. Apply Concepts In addition to conducting electricity, metals conduct heat quickly. Substances with covalent bonds are not good conductors of heat or electricity. Which type of substance would you use as insulating material for a hot mitt?

____

Which type of substance would you use as a heating coil in an electric toaster?

____

4. Make Inferences What happens to the properties of oxygen when oxygen bonds with hydrogen to form water?

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5. Identify List three properties of metals that are caused by metallic bonding.

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Name ______________________ Class ______________ Date ____________

CHAPTER 14 Chemical Reactions

SECTION 1

Forming New Substances

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is a chemical reaction?
- What can you tell that a chemical reaction is happening?
- What happens during a chemical reaction?

National Science Education Standards

PS 1b, 3a, 3e

What Is a Chemical Reaction?

Chemical reactions happen around you all the time. Wood burns and turns to ash. Rust forms on iron. Bread dough rises. These are all chemical reactions.

A **chemical reaction** happens when substances break apart or combine to form one or more new substances. New substances form when bonds break and new bonds form. The chemical properties of the new substances are different from those of the original substances. ☑

STUDY TIP

Construct Make a Concept Map for chemical reactions. Your map should show the signs of a chemical reaction happening and what happens to chemical bonds during a reaction.

READING CHECK

1. Describe What happens in a chemical reaction?

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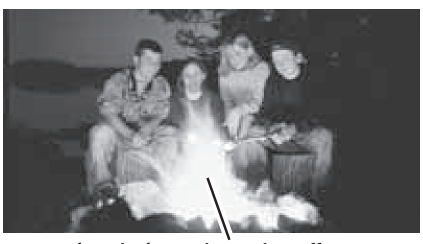
What Are the Signs of a Chemical Reaction?

There are several ways to tell that a chemical reaction has happened. Sometimes, you can see the new substance that forms during the reaction. For example, during some chemical reactions, a precipitate forms. A **precipitate** is a solid substance that forms in a solution. The figure below shows some of the signs that a chemical reaction is happening.

Some chemical reactions produce gas. For example, nitrogen dioxide gas is produced when copper reacts with nitric acid.

Some chemical reactions produce a precipitate. For example, solid silver chromate forms when potassium chromate solution is added to silver nitrate solution.



Some chemical reactions give off energy. For example, burning wood gives off light and heat energy. Other chemical reactions take in energy.

During some chemical reactions, a color change happens. For example, the chemical reaction between the blue dye in jeans and bleach will cause the jeans to change color.

TAKE A LOOK

2. Describe How can you tell that a precipitate has formed?

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CHANGING CHEMICAL PROPERTIES

Seeing signs of a chemical reaction does not always mean that a reaction is happening. For example, a gas (water vapor) is given off when water boils. Recall that boiling is a physical change, not a chemical reaction. You can tell that it is a physical change because water vapor can condense to form liquid water. In a chemical change, a new substance must be produced. ☑

READING CHECK

3. Explain Does seeing a gas produced always mean a chemical reaction is occurring? Explain.

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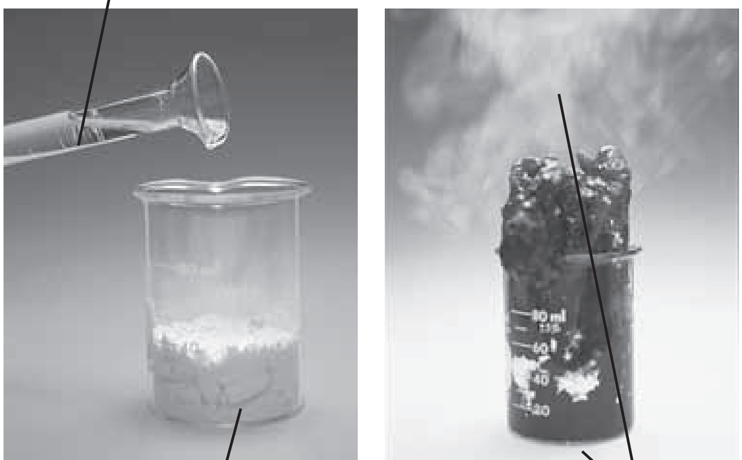
How can you be sure that a chemical reaction is happening? The best way is to look at the chemical properties of the substance that forms. The new substances that form during chemical reactions always have different chemical properties than the original substances. The figure below shows an example of how chemical properties change during a chemical reaction.

This sulfuric acid is a clear liquid.



This sugar is a white solid.

When sulfuric acid reacts with sugar, new substances with different properties form. Carbon is a black solid. Water vapor is a colorless gas.

The starting materials in this reaction are sugar and sulfuric acid. There are signs that a chemical reaction occurs. Bubbles form, a gas is given off, and the beaker gets very hot.

The most important sign that a chemical reaction occurs is the formation of new substances. The new substances are carbon, a brittle black solid, and water vapor, a colorless gas. The properties of these new substances are not at all like the properties of sugar and sulfuric acid.

STANDARDS CHECK

PS 1b Substances react chemically in characteristic ways with other substances to form new substances (compounds) with different characteristic properties. In chemical reactions, the total mass is conserved. Substances often are placed in categories or groups if they react in similar ways; metals is an example of such a group.

Word Help: chemical
of or having to do with the properties or actions of substances

4. Explain What happens to the chemical properties of substances during a chemical reaction?

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How Do New Substances Form?

Chemical reactions happen when chemical bonds are broken and formed. A *chemical bond* is a force that holds two atoms together in a molecule. During a chemical reaction, some of the bonds in the original molecule break. New bonds form to produce a new substance. ☑

Remember that molecules are always moving. If the molecules in a substance bump into each other with enough energy, some of the bonds in the molecules can break. The atoms can form new bonds with different atoms. A new substance forms. The figure below shows an example of how new substances can form.

READING CHECK

5. Describe What happens to chemical bonds during a chemical reaction?

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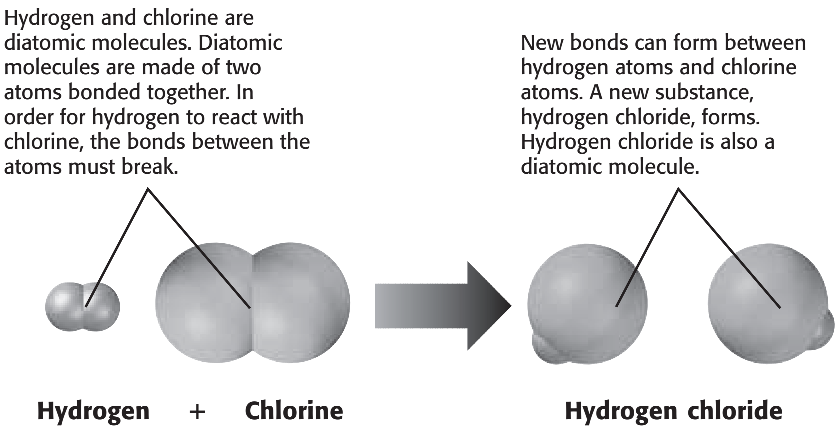

TAKE A LOOK

6. Identify Hydrogen and chlorine react to produce hydrogen chloride. What bonds are broken and what bonds are formed during this reaction?

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In this example, both elements exist as diatomic molecules. Chlorine is a greenish-yellow gas and hydrogen is a colorless gas that is flammable. When they react, the bond between the hydrogen atoms breaks and the bond between the chlorine atoms breaks.

New bonds form between hydrogen and chlorine atoms. The product of the reaction is hydrogen chloride. Hydrogen chloride is a nonflammable, colorless gas. Its properties are very different from those of hydrogen or chlorine.

Let's look at another example. Sodium is a metal that reacts violently with water. When sodium and chlorine react, they make a new substance, sodium chloride. You use sodium chloride as table salt. Sodium and chlorine are both toxic substances, but sodium chloride is not.

Name ____________________ Class ____________ Date ____________

Section 1 Review

NSES PS 1b, 3a, 3e

SECTION VOCABULARY

chemical reaction the process by which one or more substances change to produce one or more different substances	**precipitate** a solid that is produced as a result of a chemical reaction in solution

1. **Identify** Why is the formation of a precipitate a possible indication of a chemical reaction?

____

____

2. **Identify** Complete the table to identify the four possible signs of a chemical change.

Observed during a chemical reaction	Sign of a chemical reaction
a precipitate forms in a solution	
heat given off	
green gas observed	
colorless solution turned blue	

3. **Identify** What is the force that holds two atoms together in a molecule?

____

4. **Apply Concepts** Explain why water boiling is not a chemical reaction, even though it releases a gas.

____

____

5. **Infer** A scientist mixes substance A and substance B in a beaker. Neither substance A nor substance B can conduct electricity. The material in the beaker changes color, and the beaker becomes very hot. The material left in the beaker conducts electricity. Has a chemical reaction occurred? Explain your answer.

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SECTION 2

Chemical Formulas and Equations

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What are chemical formulas?
- What are chemical equations?
- How do you balance a chemical equation?

National Science Education Standards

PS 1b

What Is a Chemical Formula?

We use letters to form words. We put words together to form sentences. In the same way, scientists use symbols to form chemical formulas that describe different substances. They put chemical formulas together to show how chemical reactions happen.

Remember that substances are formed from different elements. Each element has its own chemical symbol. You can find the symbol for an element in the periodic table. Scientists combine the symbols for different elements when they write chemical formulas. A **chemical formula** shows which elements are found in a substance. It also shows how many atoms of each element are found in a molecule of the substance. ☑

In order to learn how chemical formulas work, let's look at an example. The chemical formula for water is H_2O. This formula means that a molecule of water is made of two hydrogen (H) atoms and one oxygen (O) atom.

The small 2 in the formula is a subscript. A *subscript* is a number that tells you how many atoms of an element are in a molecule. Subscripts are always written below and to the right of the symbol for an element. No subscript with an element's chemical symbol means the substance has only one atom of the element.

Water

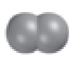
H_2O

Water A molecule of water contains 2 hydrogen (H) atoms and 1 oxygen (O) atom.

Oxygen

O_2

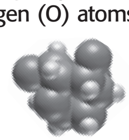
Oxygen A molecule of oxygen is made of 2 oxygen (O) atoms.



Glucose

$C_6H_{12}O_6$

Glucose A molecule of glucose cotains 6 carbon (C) atoms, 12 hydrogen (H) atoms and 6 oxygen (O) atoms.



STUDY TIP

Ask Questions As you read this section, make a list of questions that you have. Talk about your questions with a small group. When you figure out the answers to your questions, write them in your notebook.

READING CHECK

1. Identify What are two things that are shown by a chemical formula?

____

____

____

____

Math Focus

2. Calculate How many oxygen atoms are in three molecules of water?

____

FORMULAS FOR COVALENT COMPOUNDS

In many cases, the name of a covalent compound tells you how to write its chemical formula. This is because the names of many covalent compounds use prefixes. Prefixes represent numbers. For example, the prefix di- means "two." The prefixes tell you how many atoms of an element are found in a substance. The table below shows the meanings of different prefixes.

Critical Thinking

3. Apply Concepts Write the formula for the covalent compound whose name is phosphorus trichloride.

____

Prefix	Number
mono-	1
di-	2
tri-	3
tetra-	4
penta-	5

Prefix	Number
hexa-	6
hepta-	7
octa-	8
nona-	9
deca-	10

Carbon dioxide

CO_2

The ***absence of a prefix*** indicates one carbon atom.

The prefix ***di-*** indicates two oxygen atoms.

Dinitrogen monoxide

N_2O

The prefix ***di-*** indicates two nitrogen atoms.

The prefix ***mono-*** indicates one oxygen atom.

FORMULAS FOR IONIC COMPOUNDS

If the name of a compound contains the name of a metal and a nonmetal, the compound is ionic. To write the name of an ionic compound, make sure the compound's charge is 0. Therefore, the formula must have subscripts that cause the charges of the ions to cancel. The figure below shows some examples of how to name ionic compounds.

Math Focus

4. Identify What is the charge on the Fe ion in the ionic compound $FeCl_3$? Hint: find the charge of a chloride ion.

____

Sodium chloride

$NaCl$

A sodium ion has a **1+ charge.**

A chloride ion has a **1– charge.**

One sodium ion and one chloride ion have an **overall charge of (1+) + (1–) = 0.**

Magnesium chloride

$MgCl_2$

A magnesium ion has a **2+ charge.**

A chloride ion has a **1– charge.**

One magnesium ion and two chloride ions have an **overall charge of (2+) + 2(1–) = 0.**

How Are Chemical Formulas Used to Write Chemical Equations?

Scientists use chemical equations to describe reactions. A **chemical equation** uses chemical symbols and formulas as a short way to show what happens in a chemical reaction. A chemical equation shows that atoms are only rearranged in a chemical reaction. No atoms are gained or lost in a chemical reaction. ☑

The starting materials in a chemical reaction are the **reactants**. The substances that form during the reaction are the **products**. In a chemical equation, the reactants and products are written using chemical formulas. Scientists use a plus sign to separate the formulas of two or more reactants or products. An arrow points from the formulas of the reactants to the formulas of the products.

READING CHECK

5. Define What is a chemical equation?

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Carbon is the main element in charcoal. When charcoal burns, it reacts with oxygen in the air. The reaction produces heat, light, and carbon dioxide.

The formulas of the reactants are written before the arrow.

The formulas of the products are written after the arrow.

$$C + O_2 \rightarrow CO_2$$

A **plus sign** separates the formulas of two or more reactants or the formulas of two or more products.

The **arrow,** also called the *yields sign,* separates the formulas of the reactants from the formulas of the products.

TAKE A LOOK

6. Identify List the reactants and the products of the reaction in the figure. Use chemical symbols and chemical formulas in your answer.

reactants: ____________

products: ____________

CHECKING SYMBOLS

When you write a chemical formula, it is important that you check to make sure that it is correct. If you use the wrong formula or symbol in an equation, the equation will not describe the correct reaction. Even a small mistake can make a big difference. ☑

READING CHECK

7. Explain Why is it important to check to make sure that your chemical formulas are correct?

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As an example, consider the three formulas Co, CO, and CO_2. These formulas look very similar. However, the substances they represent are very different. Co is the symbol for the element cobalt, a hard, bluish-grey metal. CO is the formula for carbon monoxide, a colorless, poisonous gas. CO_2 is the formula for carbon dioxide, a colorless gas that living things give off when they breathe.

Examples of Similar Symbols and Formulas

CO_2	CO	Co
The chemical formula for the compound **carbon dioxide** is CO_2. Carbon dioxide is a colorless, odorless gas that you exhale.	The chemical formula for the compound **carbon monoxide** is CO. Carbon monoxide is a colorless, odorless, and poisonous gas.	The chemical symbol for the element **cobalt** is Co. Cobalt is a hard, bluish gray metal.

STANDARDS CHECK

PS 1b Substances react chemically in characteristic ways with other substances to form new substances (compounds) with different characteristic properties. In chemical reactions, the total mass is conserved. Substances often are placed in categories or groups if they react in similar ways; metals is an example of such a group.

Word Help: chemical
of or having to do with the properties or actions of substances

8. Explain How does a balanced chemical equation show the law of conservation of mass?

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CONSERVING MASS

The **law of conservation of mass** states that mass cannot be lost or gained during a chemical reaction. The total mass of the reactants in a chemical reaction is the same as the total mass of the products. You can use this law to help you figure out how to write a chemical equation.

During a chemical reaction, atoms are not lost or gained. Every atom in the reactants becomes part of the products. Therefore, in a chemical equation, the numbers and kinds of atoms in the reactants and products must be equal. In other words, the chemical equation must be balanced.

HOW TO BALANCE A CHEMICAL EQUATION

To balance an equation, you must use coefficients. A *coefficient* is a number that is placed in front of a chemical formula. For example, 2CO represents two carbon monoxide molecules. The number 2 is the coefficient. ☑

For an equation to be balanced, all atoms must be counted. So you must multiply the subscript for each element in a formula by the formula's coefficient. For example, $2H_2O$ contains a total of four hydrogen atoms and two oxygen atoms. Only coefficients, not subscripts, may be changed when balancing equations. The figure below shows you how to use coefficients to balance an equation. ☑

READING CHECK

9. Describe What is a coefficient?

____

____

____

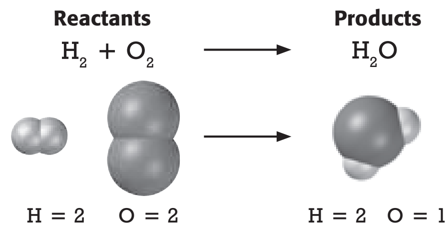
READING CHECK

10. Identify What can't be changed when balancing a chemical equation?

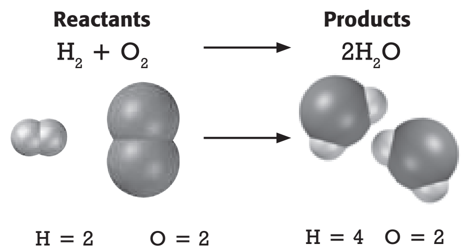
____

Follow these steps to write a balanced equation for $H_2 + O_2 \longrightarrow H_2O$.

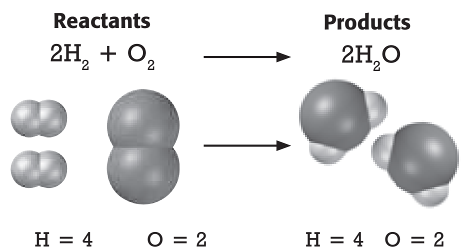
❶ **Count the atoms** of each element in the reactants and the products. Here, you can see that there are more oxygen atoms in the reactants than in the products. Therefore, the chemical equation is not balanced.



❷ **Add coefficients to balance the atoms** of oxygen. There are two atoms of oxygen in the reactants. Place the coefficient 2 in front of the products to give two atoms of oxygen in the products. Then, count the atoms again. Now, the hydrogen atoms are not balanced.



❸ **Add coefficients to balance the atoms** of hydrogen. Add the coefficient 2 to the H_2 reactant to give four atoms of hydrogen in the reactants. Then, count the atoms again to double-check your work.



Math Focus

11. Applying Concepts Balance the equation:

___Na + ___$Cl_2 \longrightarrow$ ___NaCl

by putting coefficients where needed.

Name ______________________ Class ______________ Date ______________

Section 2 Review

NSES PS 1b

SECTION VOCABULARY

chemical equation a representation of a chemical reaction that uses symbols to show the relationship between the reactants and the products **chemical formula** a combination of chemical symbols and numbers to represent a substance	**law of conservation of mass** the law that states the mass cannot be created or destroyed in ordinary chemical and physical changes **product** a substance that forms in a chemical reaction **reactant** a substance or molecule that participates in a chemical reaction

1. Compare How is a chemical equation different from a chemical formula?

____

____

2. Identify Fill in the blank spaces in the table.

Chemical equation	Number of atoms in the reactants	Number of atoms in the products	Is the equation balanced?
$Na + Cl_2 \rightarrow NaCl$	Na = Cl =	Na = Cl =	
$HCl + NaOH \rightarrow NaCl + H_2O$	H = Cl = Na = O =	H = Cl = Na = O =	
$2Sb + 3I_2 \rightarrow 2SbI_3$	Sb = I =	Sb = I =	

3. Describe Give the names of the covalent compounds listed below.

SiO_2 ____

SbF_3 ____

4. Explain Why can't you change the subscripts in a formula in order to balance a chemical equation?

____

____

5. Applying Concepts Balance the equation:

____Mg + ____$N_2 \rightarrow$ ____Mg_3N_2 by putting coefficients where needed.

SECTION 3

Types of Chemical Reactions

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is a synthesis reaction?
- What is a decomposition reaction?
- What is a displacement reaction?

National Science Education Standards

PS 1b

Organizing Chemical Changes

There are thousands of different chemical reactions. It would be impossible to remember them all. However, reactions can be put in groups based on what happens during the reaction.

Most reactions fall into one of four types: synthesis, decomposition, single-displacement, and double displacement. Each type has a pattern that shows how reactants become products. In this section, drawings of students at a dance will show how each reaction works.

STUDY TIP

Construct Make a table listing each type of reaction and the pattern that shows how reactants become products.

Synthesis Reactions

A **synthesis reaction** is a reaction in which two or more substances combine to form a new compound. The substances that react can be elements or compounds. An example of a synthesis reaction is shown in the figure below. Sodium and chlorine react to make sodium chloride, which you know as table salt. The synthesis reaction is modeled by two people becoming a dancing couple. ☑

READING CHECK

1. Describe What is a synthesis reaction?

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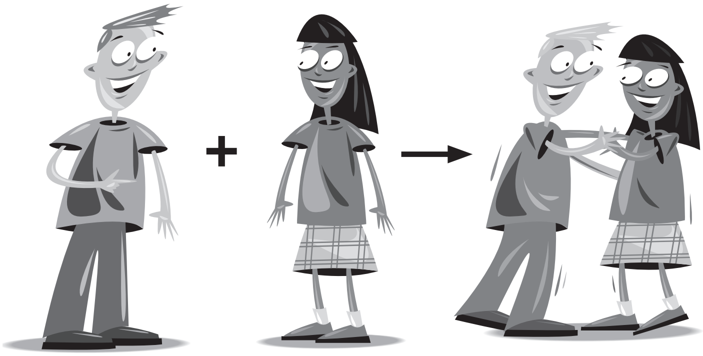
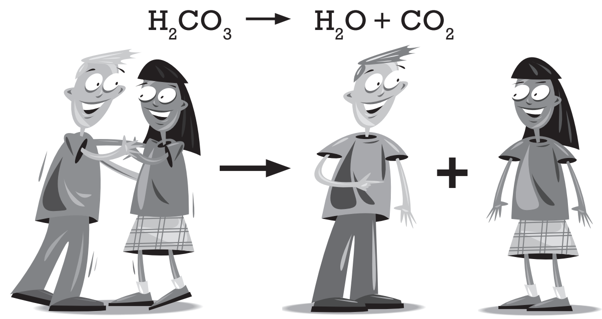
$$2Na + Cl_2 \longrightarrow 2NaCl$$



Sodium reacts with chlorine to form sodium chloride in this synthesis reaction.

Decomposition Reactions

A **decomposition reaction** is a reaction in which a single compound breaks down to form two or more simpler substances. These substances can be elements or other compounds. Decomposition is the reverse of synthesis. A decomposition reaction is shown in the figure as two dance partners separating at the end of the dance. In the reaction, carbonic acid (the acid in soft drinks) breaks down into water and carbon dioxide.



In this decomposition reaction, carbonic acid, H_2CO_3, decomposes to form water and carbon dioxide.

Critical Thinking

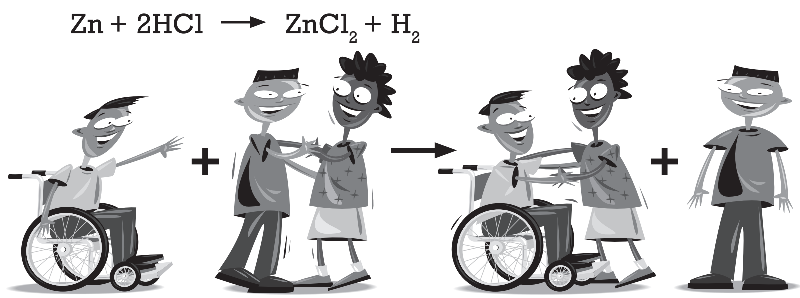
2. Applying Concepts Synthesis can be represented by the equation: $A + B \rightarrow C$. A and B can be elements or compounds and C is a compound. What equation could be used to represent a decomposition reaction?

____

Single Displacement Reactions

In some reactions, one element replaces another element in a compound. This type of reaction is called a **single-displacement reaction**. The products of a single displacement reaction are a new compound and the replaced element. ☑

The figure below models a single-displacement reaction. A third person cuts into the dance, making a new couple and one of the original dancers standing alone. The reaction shows zinc replacing hydrogen in a hydrogen chloride solution, or hydrochloric acid.



Zinc replaces the hydrogen in hydrochloric acid to form zinc chloride and hydrogen gas in this single replacement reaction.

READING CHECK

3. Identify What are the products of a single-displacement reaction?

____

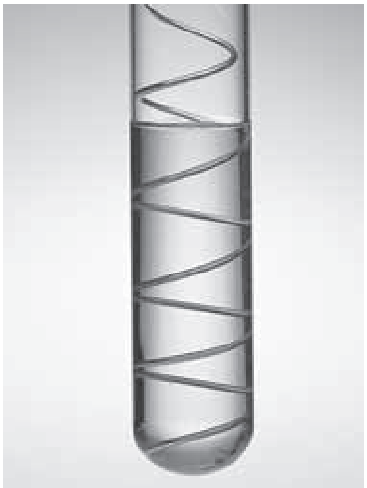
____

HOW ELEMENTS REACT

In a single-displacement reaction, a more reactive element replaces a less reactive element in the compound. The figure below shows a copper wire in silver nitrate and a silver wire in copper nitrate. Copper is more reactive than silver, so copper will displace silver from its compound. However, silver, being less reactive than copper, will not displace copper from its compound.

$Cu + 2AgNO_3 \rightarrow 2Ag + Cu(NO_3)_2$
Copper is more reactive than silver. When it takes the place of silver in the compound, silver coats the wire.

$Ag + Cu(NO_3)_2 \rightarrow$ no reaction
Silver is less reactive than copper, so no reaction occurs.



Critical Thinking

4. Applying Concepts If iron replaces copper in $Cu(NO_3)_2$, is it more or less reactive than copper?

____

STANDARDS CHECK

PS 1b Substances react chemically in characteristic ways with other substances to form new substances (compounds) with different characteristic properties. In chemical reactions, the total mass is conserved. Substances often are placed in categories or groups if they react in similar ways; metals is an example of such a group.

Word Help: chemical
of or having to do with the properties or actions of substances

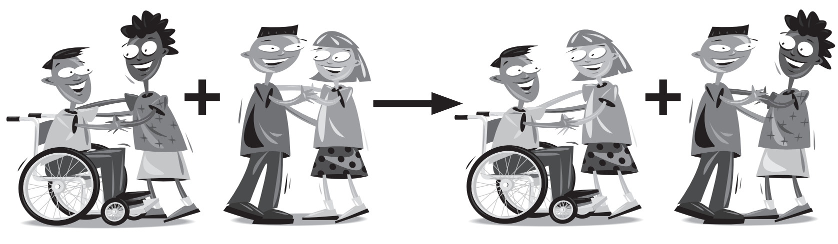
5. Identify What are four ways substances react?

____
____
____
____
____

Double-Displacement Reactions

A **double-displacement reaction** is a reaction in which two ions from two different compounds trade places. Often, one of the products is a precipitate. The figure below models a double displacement reaction as two pairs of dancers change partners. The equation shows the reaction between sodium chloride and silver fluoride.

$$NaCl + AgF \rightarrow NaF + AgCl$$



Sodium chloride reacts with silver fluoride to produce sodium fluoride and silver chloride (a precipitate). This is a double-displacement reaction.

Name ______________________ Class ______________ Date ______________

Section 3 Review

NSES **PS 1b**

SECTION VOCABULARY

decomposition reaction a reaction in which a single compound breaks down to form two or more simpler substances

double-displacement reaction a reaction in which a gas, solid precipitate, or a molecular compound forms from the exchange of ions between two compounds

single-displacement reaction a reaction in which one element takes the place of another element in a compound

synthesis reaction a reaction in which two or more substances combine to form a new compound

1. **Compare** Which two reaction types can be considered the opposite of one another?

____

2. **Explain** Why can the product of a synthesis reaction never be an element?

____

____

3. **Identify** What type of reaction is represented by the following equations?

$FeS + 2HCl \rightarrow FeCl_2 + H_2S$ ______________________

$2Ag_3N \rightarrow 6Ag + N_2$ ______________________

$P_4 + 5O_2 \rightarrow 2P_2O_5$ ______________________

4. **Analyzing Processes** The equation below shows a combination of an element and a compound, but no single-displacement reaction occurs. What is the most likely reason this combination does not react?

$$CaS\ 1\ Al \rightarrow \text{no reaction}$$

____

____

5. **Infer** Two clear solutions are poured together and a blue precipitate forms. What type of reaction appears to have taken place? Explain your answer.

____

____

____

SECTION 4

Energy and Rates of Chemical Reactions

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- How is energy involved in a chemical reaction?
- What are exothermic and endothermic reactions?
- How fast do chemical reactions occur?

National Science Education Standards

PS 3a, 3e

What Happens to Energy During a Reaction?

Chemical energy is part of all chemical reactions. Energy is needed to break chemical bonds in reactants. Energy is released as new bonds form. You can find out if more energy is absorbed or released in the reaction. You do this by comparing the chemical energy of the products to the chemical energy of the reactants.

STUDY TIP

Describe Make a list of the factors that affect the rate of chemical reactions and how they affect them.

EXOTHERMIC REACTIONS

A reaction that gives off energy is an **exothermic reaction**. *Exo* means "go out" or "exit." *Thermic* means "heat" or "energy." During an exothermic reaction, energy is released into the surroundings. Exothermic reactions can give off energy in several forms, such as light, heat, and electricity. The energy released by a reaction is sometimes included in the chemical equation. For example,

$$2Na\ 1\ Cl_2 \longrightarrow 2NaCl + \textit{energy}$$

READING CHECK

1. Describe What happens to the energy involved in an exothermic reaction?

____

____

Types of Energy Released in Exothermic Reactions

Light energy is released in the exothermic reaction that is taking place in these light sticks.

Electrical energy is released in the exothermic reaction that will take place in this battery.

Light and thermal energy are released in the exothermic reaction taking place in this campfire.

ENDOTHERMIC REACTIONS

A reaction that takes in energy is an **endothermic reaction**. *Endo* means "go in." During an endothermic reaction, energy is taken in from the surroundings. ☑

READING CHECK

2. Describe What happens to energy during an endothermic reaction?

____

____

The energy in endothermic reactions can be in several forms. Some reactions take in light energy. For example, plants use light energy to make food during the process of *photosynthesis*. Photosynthesis is an endothermic reaction.

$$6CO_2 + 6H_2O + \textit{energy} \rightarrow C_6H_{12}O_6 + 6O_2$$

Electric energy is used to decompose water. An electric current is passed through water producing hydrogen and oxygen gases.

Some endothermic reactions take in heat energy. In the figure, the reaction in the flask is endothermic. The reaction in the flask absorbs energy from the water between the wood and the flask, causing it to freeze.

STANDARDS CHECK

PS 3e In most chemical and nuclear reactions, energy is transferred into or out of a system. Heat, light, mechanical motion, or electricity might all be involved in such transfers.

Word Help: chemical
of or having to do with the properties or actions of substances

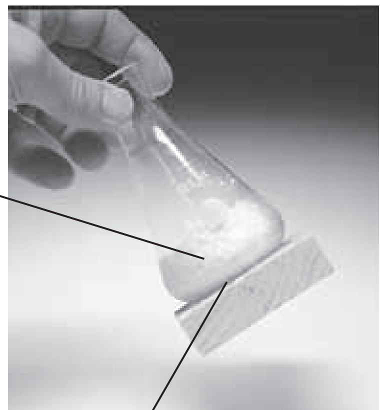
Word Help: involve
to have as a part of

3. Identify What are three types of energy that may be absorbed or released in a chemical reaction?

____

____

The chemical reaction happening in the flask is endothermic. It absorbs energy from the flask, the wood, and the air.



There were a few drops of water between the wood and the flask. The reaction in the flask absorbed energy from the water and caused it to freeze.

Where Does the Energy Go?

The **law of conservation of energy** states that energy cannot be created or destroyed. However, energy can change forms. Energy can move from one object to another. For example, the chemical reaction between gasoline and oxygen in a car engine makes parts of the engine move. The energy changes from chemical energy to *kinetic energy*, the energy of motion. ☑

READING CHECK

4. Describe What is the law of conservation of energy?

____

____

The energy given off in an exothermic reaction was once contained in the chemical bonds in the original substances. The energy taken in during an endothermic reaction is stored in the bonds in the new substances.

How Fast Do Reactions Occur?

A chemical reaction happens only if reactant particles collide. Even when they do collide, a reaction can occur only if there is enough energy to break chemical bonds. How fast reactants break apart and products form is called the *rate of a reaction*. ☑

A boost of energy is necessary to start a reaction. This boost is called activation energy. **Activation energy** is the smallest amount of energy that molecules need to react.

An example of activation energy is striking a match. The match contains all of the reactants needed to cause the match to start burning. A match can be kept for many years, but it does not start burning by itself. As soon as you strike it against a surface, a chemical reaction starts. Striking the match on the box causes friction. Heat from this friction provides activation energy to start the reaction.

The figure below shows energy diagrams for an exothermic and an endothermic reaction. See that the reactants gain the activation energy and form the products of the reaction. Also see that the energy change, energy given off or absorbed, is the difference in energy between reactants and products.

READING CHECK

5. Describe What must happen to reactant particles for a reaction to occur?

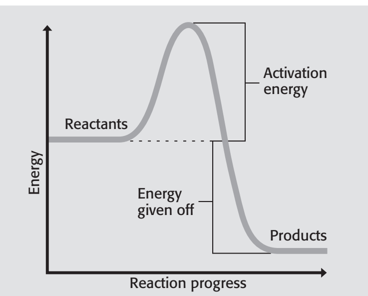
____

Say It

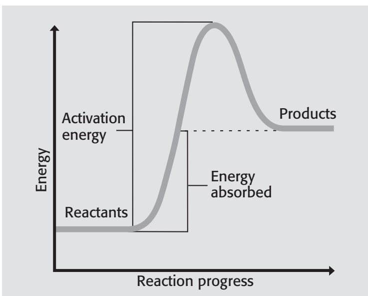
Discuss With a partner, discuss chemical reactions you both are familiar with and identify the source of the activation energy for each.

Energy Diagrams

Exothermic Reaction After the activation energy is supplied, an exothermic reaction continues. The energy given off by the reaction continues to supply more activation energy.



Endothermic Reaction The reaction keeps absorbing energy. Energy must be constantly supplied to keep the reaction going.



TAKE A LOOK

6. Describe The activation energy is always the energy gain between what two points on an energy diagram?

____

____

____

7. Identify For an endothermic reaction, do reactants or products have more energy?

____

What Factors Affect Reaction Rates?

The rate of a reaction measures how fast the reaction takes place. It depends on how fast particles break apart and how fast new particles form. There are four factors that affect the rate of a reaction:

- temperature
- surface area
- concentration
- inhibitors or catalysts

TEMPERATURE

Higher temperature causes a faster rate of reaction. At higher temperatures, particles of the reactant move faster. That means that they collide more often and they have more energy. Because the particles have more energy, more collisions provide the activation energy to react. As temperature goes up, more reactants change to products in a shorter time. ☑

The figure shows the effect of temperature on a reaction. The chemical reaction inside the light stick produces energy as light. A faster reaction makes a brighter light.

READING CHECK

8. Describe What is the effect of temperature on reaction rate?

____

____

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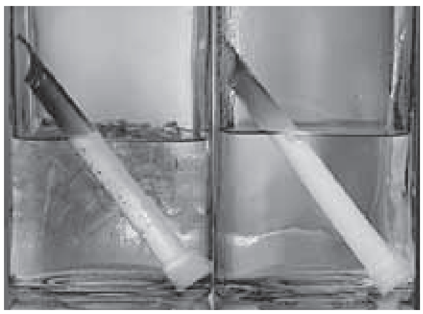

The light stick on the left is in cool water. The light stick on the right is in warm water. The higher temperature causes a faster reaction rate that produces more light.

SURFACE AREA

Surface area is the amount of exposed surface of a substance. Increasing the surface area of solid reactants increases the rate of a reaction. For example, cutting wood into small pieces or grinding it into a powder increases surface area. Small pieces of wood or sawdust burn fast. ☑

A larger surface area means that more particles of the reactant are exposed to particles of other reactants. As a result, there are more collisions between particles. More collisions increase the rate of reaction.

READING CHECK

9. Describe What does increasing surface area do to the rate of a reaction?

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CONCENTRATION

Concentration is the amount of one substance dissolved in another. The figure below shows the difference in the number of particles at different concentrations.

Concentration of Solutions

▼ When the concentration is low, the average distance between ions from copper sulfate is large.

▼ When the concentration is high, the average distance between ions from copper sulfate is small.

Usually, a high concentration of reactants causes a faster rate of reaction. The distance between particles is smaller, so collisions happen more often. The particles collide more often and react faster. ☑

READING CHECK

10. Describe What is the effect of higher concentration of reactants on reaction rate?

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INHIBITORS

Sometimes, it is useful to slow a chemical reaction. For example, it can be helpful to slow a reaction that causes iron to rust. An **inhibitor** is a substance that slows down or stops a chemical reaction.

Preservatives are inhibitors that are added to foods to slow down the growth of bacteria and fungi. The preservatives slow down reactions in cells and keep them from making substances that spoil food. Some antibiotics are inhibitors.

CATALYSTS.

Some reactions are more useful if they can be made to occur faster. A **catalyst** is a substance that speeds up a reaction without being permanently changed. That means that a catalyst is not a reactant. ☑

A catalyst works by lowering the activation energy of a reaction. Lower activation energy means that the reaction will occur more quickly. Catalysts called *enzymes* speed up reactions inside your body. The catalytic converter in a car speeds up reactions that destroy harmful products from the car engine.

READING CHECK

11. Compare How do catalysts differ from inhibitors?

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Name ______________________ Class ______________ Date ______________

Section 4 Review

NSES PS 3a, 3e

SECTION VOCABULARY

activation energy the minimum amount of energy required to start a chemical reaction **catalyst** a substance that changes the rate of a chemical reaction without being used up or changed very much **endothermic reaction** a chemical reaction that requires heat	**exothermic reaction** a chemical reaction in which heat is released to the surroundings **inhibitor** a substance that slows down or stops a chemical reaction **law of conservation of energy** the law that states that energy cannot be created or destroyed but can be changed from one form to another

1. **Compare** How are exothermic reactions different from endothermic reactions?

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2. **Explain** What happens to energy when a chemical bond forms? What happens to energy when a chemical bond is broken?

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3. **List** Give one example of an exothermic reaction and one example of an endothermic reaction.

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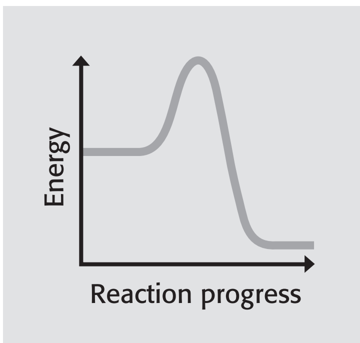
4. **Interpret Graphics** Does this energy diagram show an exothermic reaction or an endothermic reaction? How can you tell?



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5. **Apply Concepts** How does chewing your food well speed up the reactions in your digestive system?

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SECTION 1

Ionic and Covalent Compounds

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What are ionic compounds?
- What are covalent compounds?

National Science Education Standards

PS 1a, 1b

What Are Ionic and Covalent Compounds?

Many things are made of combinations of elements called *compounds*. Sugar, salt, gasoline, and chalk are all compounds. They have atoms of more than one element joined together. How are the compounds alike and how are they different?

Scientists *classify*, or group, chemical compounds by the kinds of chemical bonds they have. A **chemical bond** joins atoms together to form compounds. The compounds are grouped by their bonding as either *ionic* or *covalent*.

Bonding happens between valence electrons of different atoms. *Valence electrons* are electrons in the outermost energy level of an atom. The type of compound that forms depends on what happens to the valence electrons. ☑

STUDY TIP

Work in Pairs Make flash cards with all of the vocabulary words in this section. Also make flash cards of the words in *italics* in this section.

On the other side of the card, write the definition of the word. Practice saying the words and their definitions.

READING CHECK

1. Identify What determines the type of compound that forms when atoms bond?

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What Makes a Compound Ionic?

An ionic bond is an attraction between ions that have opposite charges. Compounds that have ionic bonds are called **ionic compounds**.

Ionic compounds can be formed by the chemical reaction between a metal and a nonmetal. Metal atoms become positively charged ions when electrons move from the metal atoms to the nonmetal atoms. The nonmetal atoms become negatively charged ions. ☑

READING CHECK

2. Describe What kind of ions do metals form? What kind of ions do nonmetals form?

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Na^{1+} Cl^{1-}

A sodium atom has lost an electron to a chlorine atom. The result is a positively charged sodium ion and a negatively charged chlorine ion. The attraction of the ions is called an ionic bond.

What Are the Properties of an Ionic Compound?

Ionic compounds form strong bonds because of the attraction between oppositely charged ions. There are several properties that tell you a compound is ionic.

IONIC COMPOUNDS ARE BRITTLE

Ionic compounds tend to be brittle at room temperature. That means they break apart when hit. They break because their ions are arranged in a pattern that happens over and over again. The pattern is called a *crystal lattice*. Each ion in a lattice bonds to the ions around it that have the opposite charge. ☑

READING CHECK

3. Describe What is a crystal lattice?

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When you hit an ionic compound, the ions move and the pattern changes. Ions that have the same charge line up and repel each other. That makes the crystals break.

Sodium chloride crystals (shown below) all have a regular cubic shape. The shape is due to the way sodium and chloride ions are arranged in the crystal lattice.

Sodium chloride crystals all have a regular cubic shape because of the way sodium and chloride ions are arranged.

IONIC COMPOUNDS HAVE A HIGH MELTING POINT

Because of the strong bonds that hold ions together, ionic compounds don't melt easily. They have a high melting point. For example, sodium chloride must be heated to 801°C before it will melt. ☑

READING CHECK

4. Explain What causes ionic compounds to have high melting points?

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IONIC COMPOUNDS ARE SOLUBLE

Many ionic compounds are highly *soluble* in water. That means they dissolve easily in water. Water molecules attract each of the ions of an ionic compound and pull them away from each other.

IONIC COMPOUNDS CONDUCT ELECTRICITY

When an ionic compound dissolves in water, it forms a solution that can conduct an electric current. It conducts electricity because its ions are now free to move to complete an electric circuit. When ionic compounds are solids, their ions are not free to move. They will not conduct an electric current. ☑

READING CHECK

5. Explain Why do ionic compounds dissolved in water conduct an electric current?

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What Makes A Compound Covalent?

Many of the compounds in your body are covalent compounds. **Covalent compounds** form when atoms share electrons. The bond that forms when atoms share electrons is called a *covalent bond*. Atoms share electrons to fill their outermost energy level. This forms a group of atoms, each having a full valence shell.

The group of atoms that make up a covalent compound is called a *molecule*. A molecule is the smallest particle that you can divide a compound into and still have the same compound. For example, if you break water down further, it isn't water anymore. It is hydrogen and oxygen.

What Are the Properties of Covalent Compounds?

The properties of covalent compounds are very different from the properties of ionic compounds. This table lists the properties of covalent compounds.

Properties of Covalent Compounds

Property	Description
Solubility in water	Some covalent compounds do not dissolve in water. For example, oil does not dissolve in water. When mixed with water, the water molecules stay together and the oil molecules stay together.
Melting point	Normally, covalent compounds have lower melting and boiling points than ionic compounds. This is due to weaker forces of attraction in a covalent compound than in an ionic compound.
Electrical conductivity	Most covalent compounds do not conduct electricity when dissolved in water. This is because most covalent compounds that dissolve in water form solutions that do not have ions.

STANDARDS CHECK

PS 1a A substance has characteristic properties, such as density, a boiling point, and solubility, all of which are independent of the amount of sample. A mixture of substances often can be separated into the original substances using one or more of the characteristic properties.

6. Identify Give three ways covalent compounds often differ from ionic compounds.

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Section 1 Review

NSES PS 1a, 1b

SECTION VOCABULARY

chemical bond an interaction that holds atoms or ions together **covalent compound** a chemical compound that is formed by the sharing of electrons	**ionic compound** a compound made of oppositely charged ions

1. **Compare** How does the melting point of ionic compounds compare to that of covalent compounds?

____

2. **Make Inferences** Examine the table below. Use the information in the table to help you decide if the compound is ionic or covalent. Write *ionic* or *covalent* in the box next to each compound

Compound	Property	Ionic or covalent
A	low melting point	
B	smallest particle is a molecule	
C	water solution conducts an electric current	
D	high melting point	

3. **Describe** Why do ionic compounds tend to be brittle?

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4. **Explain** Solid crystals of ionic compounds do not conduct an electric current. Why does the solution conduct electricity when the crystals dissolve in water?

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5. **Describe** Describe how a metal and a nonmetal can combine by forming an ionic bond.

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Name ________________ Class ________________ Date ________________

SECTION 2

Acids and Bases

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What are the properties of acids?
- What are the properties of bases?

National Science Education Standards
PS 1a, 1b

What Are Acids?

Many of the foods we eat contain acid. Lemons, vinegar, grapes, and soft drinks are examples of *acidic*, or acid-containing foods.

STUDY TIP

Graphic Organizer In your science notebook, create two Idea Wheels, one about acids and one about bases.

Foods that have a sour taste usually contain acids.

Acids are not just in foods. You can find acid in car batteries, in paper, and even in your stomach. An **acid** is any compound that increases the number of hydronium ions (H_3O^+) when dissolved in water. The figure below shows how the hydronium ion forms.

TAKE A LOOK

1. Explain How is a hydronium ion formed?

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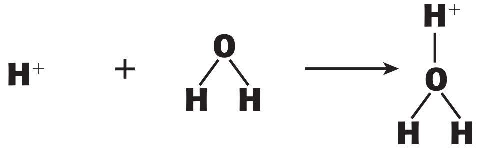
Formation of a Hydronium Ion



Hydrogen ion plus water make a hydronium ion.

What Are the Properties of Acids?

The hydronium ions formed by acids are what give acids their special properties. There are several properties that can tell us that a substance is an acid.

ACIDS HAVE A SOUR TASTE

Have you ever bitten into a lemon? It probably tasted sour and made your mouth pucker up. Foods that have a sour taste usually contain acid. In fact, the word *acid* means "sour" in Latin. The taste of lemons, limes, and other citrus fruits comes from citric acid. ☑

READING CHECK

2. Identify What kind of taste do acids have?

____

Many acids are dangerous because they are *corrosive*. That means that they destroy body tissue, clothing, and many other things. Most acids are also poisonous. Remember that you should never taste, touch, or smell an unknown chemical.

ACIDS CHANGE THE COLOR OF INDICATORS

We can use colored chemicals to tell us if a solution is an acid or a base. A substance that changes color in the presence of an acid or base is an **indicator**. For example, if you squeeze lemon juice into a cup of tea, the tea changes color. The tea shows that the lemon juice has increased the acidity of the solution.

A solution called *bromthymol blue* is an indicator used by scientists. If you add acid to bromthymol blue, it changes from pale blue to yellow. It *indicates*, or shows, the presence of acid. Scientists also use a special kind of paper called *litmus paper* as an indicator. The paper contains the substance litmus. The paper comes in blue or red. When you add acid to blue litmus paper, the paper turns red.

Detecting Acids with Indicators

The indicator, bromthymol blue, is pale blue in water.

When acid is added, the color changes to yellow because of the presence of the indicator.

TAKE A LOOK

3. Identify Use colored pencils to color the water in the beakers pale blue and yellow.

ACIDS REACT WITH METALS

Acids react with some metals to make hydrogen gas. For example, when hydrochloric acid reacts with the metal zinc, the product is hydrogen gas. This is the chemical equation for that reaction:

$$\text{Hydrochloric acid} + \text{Zinc} \longrightarrow \text{Hydrogen gas} + \text{Zinc chloride}$$

$$2HCl + Zn \longrightarrow H_2 + ZnCl_2$$

In this reaction, zinc takes the place of hydrogen in hydrochloric acid. This reaction happens because zinc is a reactive metal. But other metals, such as silver or gold, do not react easily. For example, if silver were used in the reaction above, no hydrogen gas would be produced.

TAKE A LOOK

4. Identify What forms when zinc reacts with hydrochloric acid?

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ACIDS CONDUCT ELECTRICITY

When acids dissolve in water, they break apart and form ions in the solution. The ions make it possible for the solution to conduct an electric current. ☑

A car battery is an example of how an acid can be used to produce an electric current. The acid that is in a car battery conducts an electric current to help start the car's engine.

READING CHECK

5. Identify What makes it possible for a solution to conduct an electric current?

____

How Do We Use Acids?

Acids are important chemicals because they have so many uses. Sulfuric acid is the most widely used chemical in the world. It is used to make many products, including paper, paint, and detergents. The sulfuric acid in car batteries conducts the current to help start the car's engine. You can find nitric acid in fertilizers, rubber, and plastic. ☑

READING CHECK

6. Identify Which of the following uses nitric acid: making paper, making paint, or making fertilizers?

____

Another acid, hydrochloric acid, is used to get metals from their ores. We also put it in swimming pools to keep them free of algae. In addition, hydrochloric acid helps your stomach digest the food you eat.

Food has many kinds of acid in it. For example, orange juice contains citric acid and ascorbic acid (vitamin C). The main ingredient in vinegar is acetic acid. Carbonic acid and phosphoric acid help give soft drinks a sharp taste.

STANDARDS CHECK

PS 1b Substances react chemically in characteristic ways with other substances to form new substances (compounds) with different characteristic properties. In chemical reactions, the total mass is conserved. Substances often are placed in categories or groups if they react in similar ways; metals is an example of such a group.

7. Identify What ions are used to group acids and bases?

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What Are Bases?

Bases are found in baking powder, chalk, soap, and even the saliva in your mouth. Bases are the opposite of acids. When a base meets an acid, it *neutralizes* it. That means it cancels out acidity. A **base** is any compound that makes many hydroxide ions (OH^-) when it is dissolved in water. For example, sodium hydroxide breaks apart to form sodium ions and hydroxide ions when dissolved in water.

Sodium hydroxide	⟶	Sodium ion	+ Hydroxide ion
NaOH	⟶	Na^+	+ OH^-

Bases, such as a solution of sodium hydroxide, will have many more hydroxide ions than hydronium ions.

What Are the Properties of Bases?

Hydroxide ions give bases their properties. These properties make bases very useful substances. Imagine how dirty we would be without soap and other cleaners made from base compounds. ☑

READING CHECK

8. Describe What gives bases their properties?

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BASES HAVE A BITTER FLAVOR AND FEEL SLIPPERY

The properties of a base solution include a bitter taste and a slippery feel. Have you ever tasted soap? It has a bitter taste. Soap also has the slippery feel of a base.

Never use taste, touch, or smell to identify an unknown chemical. Like acids, many bases are corrosive. If you use a base in an experiment, be very careful. If your fingers feel slippery, you may have gotten the base on your hands. You should quickly rinse your hand with large amounts of water and tell your teacher.

Critical Thinking

9. Apply Concepts Why do you think it's a bad idea to use taste, touch, or smell to identify an unknown chemical?

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BASES CHANGE THE COLOR OF INDICATORS

Like acids, bases change the color of an indicator. Bases turn most indicators a different color than acids do. For example, bases change the color of red litmus paper to blue. Bromthymol blue turns a darker blue when you add a base to it.

Detecting Bases with Indicators

The indicator, bromthymol blue, is pale blue in water.

When a base is added to the indicator, the indicator turns dark blue.

TAKE A LOOK
10. Identify Use colored pencils to color the water in the beakers pale blue and dark blue.

BASES CONDUCT AN ELECTRIC CURRENT

Like acids, solutions of bases conduct an electric current. Bases are good conductors because they contain many hydroxide ions (OH^-).

Soaps are made by using sodium hydroxide, which is a base. Soaps remove dirt and oils from skin and feel slippery when you touch them.

Baking soda is a mild base. It is used in toothpastes to neutralize acids, which can produce unpleasant odors.

TAKE A LOOK
11. Identify What color will baking soda turn litmus paper?

____

How Are Bases Used?

Like acids, bases have many uses. Companies use the base sodium hydroxide to make soap and paper. It is also used in oven cleaners and in products that unclog drains. Ammonia is found in many household cleaners and is used to make fertilizers. The antacids people use to treat heartburn contain magnesium hydroxide and aluminum hydroxide. ☑

READING CHECK
12. Identify What are two products that contain ammonia?

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Name ______________________ Class ______________ Date ______________

Section 2 Review

NSES PS 1a, 1b

SECTION VOCABULARY

acid any compound that increases the number of hydronium ions when dissolved in water **base** any compound that increases the number of hydroxide ions when dissolved in water	**indicator** a compound that can reversibly change color depending on conditions such as pH

1. **Explain** What kind of ions do acids produce when you dissolve them in water? What kind of ions do bases produce?

____

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2. **Graphic Organizer** Fill in the table below with the properties of acids and bases. Draw lines between the properties that are the same.

Property	Acids	Bases
Taste		
Color change of litmus paper		
Reaction with metals to produce hydrogen gas		
Electrical conductivity		

3. **Applying Concepts** Lemon juice is an acid. What ion is present in lemon juice that makes it an acid?

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4. **Evaluating Data** A solution conducts electric current. Can you use this property to determine if the solution is an acid or a base? Explain.

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5. **Describe** What happens to red litmus paper when it touches a household cleaner that has ammonia in it, and why?

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6. **Identify** What word is used to describe an acid or base that can destroy body tissue, clothing, and many other things?

____

7. **Identify** Suppose you are doing an experiment and your fingers feel slippery; what did you probably get on them? What should you do if this happens to you?

____

CHAPTER 15 Chemical Compounds

SECTION 3

Solutions of Acids and Bases

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What are strong and weak acids?
- What are strong and weak bases?
- What happens when an acid reacts with a base?
- What is pH?

National Science Education Standards

PS 1b

What Is a Strong Acid or Base?

Acids and bases can be strong or weak. The strength of an acid or base is not the same as their concentration. *Concentration* means the amount of acid or base dissolved in water. The strength of an acid or base depends on the number of ions formed when they dissolve in water. ☑

STUDY TIP

Discuss Read this section silently. With a partner, take turns telling what the section is about. Stop to discuss ideas and words that confuse you.

STRONG VERSUS WEAK ACIDS

As an acid dissolves in water, the acid's molecules break apart to form hydronium ions, H_3O^+. In water, all of the molecules of a *strong acid* break apart to form many ions. Sulfuric acid, nitric acid, and hydrochloric acid are all strong acids.

However, if you mix a weak acid in water, only a few of its molecules break apart. So there are only a few hydronium ions in a solution of a weak acid. Acetic acid, citric acid, and carbonic acid are all weak acids. ☑

READING CHECK

1. Explain What does the concentration of an acid or base solution tell you?

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STRONG VERSUS WEAK BASES

A base is strong if it forms many hydroxide ions, OH^-, when dissolved in water. Sodium hydroxide, calcium hydroxide, and potassium hydroxide are strong bases. When only a few ions are formed, the base is a weak base. Two weak bases are magnesium hydroxide and aluminum hydroxide.

READING CHECK

2. Explain What is the difference between a strong acid and a weak acid?

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Antacids are weak bases. They help relieve your stomachache by reacting with acid in your stomach.

What Happens When Acids and Bases Mix?

The base in an antacid reacts with the acid in your stomach. Why does your stomach feel better? Because the reaction between acids and bases makes the excess acid in your stomach neutral. This is a called a **neutralization reaction**.

In a neutralization reaction, hydrogen ions (H^+) from the acid combine with hydroxide ions (OH^-) from the base. This reaction forms water, which is neutral. The other ions in the acid and base solution combine to form a compound called a *salt*. ☑

READING CHECK

3. Describe What two things are formed by a neutralization reaction?

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THE PH SCALE

An indicator such as litmus paper can show us if a solution contains an acid or a base. We use the pH scale to describe how acidic or basic a solution is.

The **pH** of a solution is a measure of how many hydronium ions it has. A solution that has a pH of 7 is neutral. A neutral solution is not acidic and it is not basic. Pure water has a pH of 7. Basic solutions have a pH greater than 7. Acidic solutions have a pH less than 7. ☑

READING CHECK

4. Describe What is pH?

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5. Identify What kind of solution has a pH above 7? What kind has a pH below 7?

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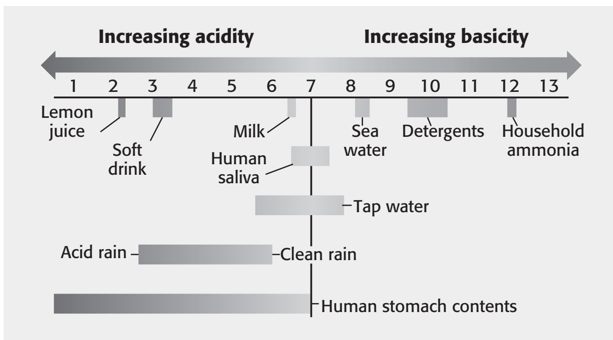
pH Values of Common Materials



USING INDICATORS TO FIND PH

There are several ways to find out how basic or acidic a solution is. For example, strips of pH paper have several different indicators on them. When you dip them into a solution, the pH paper changes color. You can compare that color to a color scale to find the pH of the solution. People use this kind of indicator to test the pH of water in swimming pools.

Another way to find the pH of a solution is to use an electronic device called a *pH meter*. These meters measure hydronium ion concentration in the solution.

PH AND THE ENVIRONMENT

Living things depend on having a steady pH in their environment. Some plants, such as pine trees, like to grow in acidic soil. The soil has a pH between 4 and 6. Other plants, such as lettuce, need basic soil that has a pH between 8 and 9. Many plants and animals that live in lakes and streams need a neutral pH to survive.

Some plants show different traits with different kinds of soil. For example, the flowers of the hydrangea plant act as a natural indicator. The color of the flowers changes when the plants are grown in soils that have different pH values.

Most rain is slightly acidic and has a pH between 5.5 and 6. Acids form when rainwater reacts with compounds in polluted air, causing the rainwater's pH to decrease. In the United States, most acid rain has a pH between 4 and 4.5. However, some acid rain has a pH as low as 3. Water with low pH can harm fish and other animals.

STANDARDS CHECK

PS 1b Substances react chemically in characteristic ways with other substances to form new substances (compounds) with different characteristic properties. In chemical reactions, the total mass is conserved. Substances often are placed in categories or groups if they react in similar ways; metals is an example of such a group.

Word Help: chemical
of or having to do with properties or actions of substances

Word Help: reaction
a response or change

6. Describe Rainwater with a pH below 4.5 would be classified as what kind of rain?

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What Are Salts?

When you hear the word *salt*, you probably think of the table salt you use on your food. However, the sodium chloride in your saltshaker is only one kind of salt. It is one of a large group of compounds called salts.

When an acid neutralizes a base, a salt and water form. A **salt** is an ionic compound. A salt forms when a positive ion from a base combines with a negative ion from an acid. As shown below, sodium hydroxide (NaOH) and hydrochloric acid (HCl) make water (H_2O) and sodium chloride (NaCl). ☑

Sodium hydroxide + Hydrochloric acid → Water + Sodium chloride

$NaOH + HCl \longrightarrow H_2O + NaCl$

READING CHECK

7. Describe How is a salt formed?

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Salts have many uses. The sodium chloride in food is also used to melt the snow and ice on roads and sidewalks. We use it to make other compounds, including lye and baking soda. The salt calcium sulfate is used to make wallboard for buildings. ☑

READING CHECK

8. Name What are two uses of sodium chloride?

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Name ______________________ Class ______________ Date ______________

Section 3 Review

NSES PS 1b

SECTION VOCABULARY

neutralization reaction the reaction of an acid and a base to form a neutral solution of water and a salt **pH** a value that is used to express the acidity or basicity (alkalinity) of a system	**salt** an ionic compound that forms when a metal atom replaces the hydrogen of an acid

1. **Compare** What makes an acid a strong acid? What makes a base a weak base?

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2. **Describe** What happens when an acid and a base combine?

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3. **Complete** Fill in the equations below to show the reaction of sodium hydroxide and hydrochloric acid.

Sodium hydroxide	+ Hydrochloric acid	______________	+ Sodium chloride
NaOH	+ HCl	______________	+ ______________

4. **Identify** What are two ways to measure the pH of a solution?

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5. **Apply Concepts** Soap is made from a strong base and oil. Do you think the pH of soap is 4 or 9? Explain why.

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6. **Explain** A lake has a pH of 3.5. Is it acidic or basic? Would fish be healthy in this lake?

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Name ______________________ Class ______________ Date ____________

CHAPTER 15 Chemical Compounds

SECTION 4

Organic Compounds

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- Why are there so many organic compounds?
- What are the names and the properties of organic compounds?
- What organic compounds are found in living things?

National Science Education Standards

PS 1a, 1b, 1c

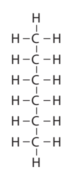
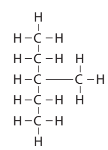
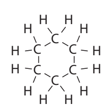
How Does Carbon Form Compounds?

Most of the chemical compounds that exist contain carbon. These compounds are called organic compounds. **Organic compounds** are compounds made of molecules in which carbon atoms are covalently bonded to other atoms.

Every organic compound contains carbon. Carbon atoms have four outer electrons. This means that each carbon atom can make four covalent bonds with other atoms. Most organic molecules have two or more carbon atoms linked to one another. ☑

The illustrations in the figure below are models of organic molecules. These models are called *structural formulas*. They show the order in which atoms in a molecule are connected to one another. A line between two element symbols represents a covalent bond, or one pair of shared electrons.

Models of Organic Molecules

		
Straight chain Carbon atoms are connected one after another.	**Branched chain** The chain of carbon atoms branches when a carbon atom bonds to more than two other carbon atoms.	**Ring** The chain of carbon atoms forms a ring.

Notice that these molecules have chains of carbon atoms linked to one another. Some organic molecules have hundreds or thousands of carbon atoms linked together to form a backbone of the molecule.

STUDY TIP

Brainstorm With a partner, write down the names of several of your favorite foods. After you have read about the carbohydrates, lipids, and proteins, identify which of these groups are in the foods.

READING CHECK

1. Identify What do most organic molecules have in them?

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TAKE A LOOK

2. Identify What are three ways carbon atoms link together in organic molecules?

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What Are Some Kinds of Organic Compounds?

Many organic compounds contain atoms of several elements. The simplest organic compounds only contain two elements—carbon and hydrogen. Organic compounds that contain only carbon and hydrogen are called **hydrocarbons**. Hydrocarbons are grouped based on the covalent bonds between the carbon atoms, as shown in the figure below. ☑

READING CHECK

3. Describe What are hydrocarbons?

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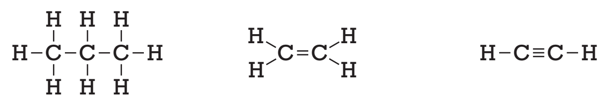
Three Types of Bonds Between Carbon Atoms

Single Bond | **Double Bond** | **Triple Bond**



The **propane** in a camping stove contains only single bonds.

Fruits make **ethene,** which is a compound that helps ripen the fruit.

Ethyne is better known as *acetylene.* It is burned in miners' lamps and in welding torches.

TAKE A LOOK

4. Identify What are three types of hydrocarbons?

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In some hydrocarbon molecules, each carbon atom shares one pair of electrons with each of four other atoms. This type of chemical bond is called a single bond. A hydrocarbon that has only single bonds is called a saturated hydrocarbon. It is also called an alkane.

In an unsaturated hydrocarbon, at least one pair of carbon atoms shares more than one pair of electrons. A double bond is a covalent bond with two pairs of shared electrons. A triple bond has three pairs of shared electrons. When unsaturated organic molecules react, part of the double or triple bond can be broken. Other atoms can then be added to the molecule. ☑

READING CHECK

5. Describe How do saturated and unsaturated hydrocarbons differ?

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Hydrocarbons that contain a double bond are called alkenes. Hydrocarbons that contain triple bonds are called alkynes. Alkenes and alkynes are unsaturated hydrocarbons.

Benzene is a compound that has six carbon atoms in a ring shape. It is found in most of the compounds that are called *aromatic* compounds.

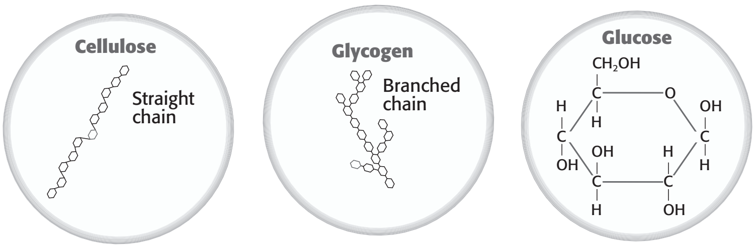
In addition to hydrocarbons, there are many other kinds of organic compounds. These compounds are made by adding atoms of other elements to hydrocarbons. The other elements include the halogens, oxygen, sulfur, and nitrogen.

What Organic Chemicals Are Important to Life?

Organic chemicals that are made by living things are called *biochemicals*. There are four important groups of biochemicals: carbohydrates, lipids, proteins, and nucleic acids.

CARBOHYDRATES

Carbohydrates are biochemicals that are made of one or more simple sugar molecules. Living things use carbohydrates as an energy source. There are two types: simple carbohydrates and complex carbohydrates. The figure below shows how atoms and molecules form carbohydrates. ☑



Glucose is a simple carbohydrate. Cellulose and glycogen are complex carbohydrates made up of chains of glucose. Each hexagon in the diagram represents one glucose unit.

The simple carbohydrates, including glucose, are made of carbon, hydrogen, and oxygen. The carbon atoms form a ring. Complex carbohydrates can have hundreds or thousands of sugar molecules held together by chemical bonds. Cellulose is part of the rigid structure of the cell walls of plants. Animals use glycogen to supply energy to muscles.

LIPIDS

Lipids are biochemicals that do not dissolve in water. Fats, oils, and waxes are examples of lipids. One of the functions of lipids in living things is to store energy. It can be unhealthy to eat too many lipids, but some fats and oils are part of a healthy diet. ☑

Lipids store extra energy in the body. This energy can be used later when the lipids take part in chemical reactions. As the lipid molecules break down, they release the stored chemical energy. In general, animals use fats for this purpose and plants use oils. When the organism has used up its carbohydrates, it can obtain energy from its lipids.

STANDARDS CHECK

PS 1c Chemical elements do not break down during normal laboratory reactions involving such treatments as heating, exposure to electric current, or reactions with acids. There are more than 100 known elements that combine in a multitude of ways to produce compounds, which account for the living and nonliving substances that we encounter.

Word Help: chemical
of or having to do with the properties or actions of substances

Word Help: involve
to have as a part of

6. Compare What are four groups of biochemicals important for living things?

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READING CHECK

7. Describe What are carbohydrates

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READING CHECK

8. Describe What are lipids?

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Vegetable oil, meat, cheese, eggs, and milk are sources of lipids in your diet.

READING CHECK

9. Describe What are proteins?

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Say It

Research Find out how hemoglobin can pick up and carry oxygen to the cells of the body. Report your finding to the class.

PROTEINS

Most of the biochemicals found in living things are proteins. **Proteins** are biochemicals that are made of chains of building blocks called amino acids. Amino acids are small molecules made of carbon, hydrogen, oxygen and nitrogen. Some amino acid molecules also have sulfur atoms. ☑

Protein molecules are made of hundreds or thousands of amino acid molecules. Chemical bonds hold them together in long chains or complex webs. The function of a protein molecule depends on its shape. The shape of the protein molecule is determined by the exact order of amino acids in its structure.

Proteins have many functions in living organisms. Enzymes are proteins that increase the rate of chemical reactions in a cell. Hemoglobin is a protein in red blood cells that carries oxygen to the cells of the body. Proteins help carry materials through cell membranes

Some proteins provide structure and strength. Your hair and fingernails are made of protein molecules. The muscles that control the movement of your body are made primarily of protein molecules. Spiders use long chains of protein molecules to build light, but strong, silk webs.

Spider webs are made up of proteins that are shaped like long fibers.

NUCLEIC ACIDS

The largest molecules made by living things are nucleic acids. **Nucleic acids** are biochemicals made up of nucleotides. Nucleotides are molecules made of carbon, hydrogen, oxygen, nitrogen and phosphorus atoms. ☑

There are only five different types of nucleotides. They are combined in chains of up to millions of units in nucleic acids. The order of the nucleotides determines the nucleic acid, just as the order of letters in a word determines the word.

One of the functions of nucleic acids is to store genetic information. They are sometimes called the blueprints of life because they contain all of the information a cell needs to work. The patterns of the nucleotides are used by a cell when it builds proteins and other nucleic acids.

READING CHECK

10. Describe What are nucleic acids?

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DNA AND RNA

There are two kinds of nucleic acids: DNA and RNA. DNA molecules contain the genetic material of a cell. The DNA molecules in a single human cell contain millions of nucleotides and are about 2 meters long. This size allows the DNA molecules to store all of the information that a body's cells need to function. ☑

DNA molecules are shaped as a double spiral, as shown in the figure below. Each nucleotide in one spiral matches a specific nucleotide in the other spiral.

When a cell needs to make a particular protein, information is copied from part of the DNA molecule. A second kind of nucleic acid, called RNA, is built using this information. The RNA molecule contains the information that the cell needs to build the protein molecules. RNA is involved in the actual building of proteins. ☑

READING CHECK

11. Describe What is stored in a DNA molecule?

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READING CHECK

12. Describe What information does an RNA molecule contain?

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Two strands of DNA are twisted in a spiral shape. Four different nucleotides make up the rungs of the DNA ladder.

Section 4 Review

NSES **PS 1a, 1b, 1c**

SECTION VOCABULARY

carbohydrate a class of energy-giving nutrients that includes sugars, starches, and fiber; contains carbon, hydrogen, and oxygen

hydrocarbon an organic compound composed only of carbon and hydrogen

lipid a type of biochemical that does not dissolve in water; fats and steroids are lipids

nucleic acid a molecule made up of subunits called nucleotides

organic compound a covalently bonded compound that contains carbon

protein a molecule that is made up of amino acids and that is needed to build and repair body structures and to regulate processes in the body

1. Identify Complete the following table.

Type of carbon backbone	Description
	The chain of carbon atoms forms a ring.
	All carbon atoms are connected in a straight line.
	The chain of carbon atoms separates into different directions.

2. Explain What group of hydrocarbons contains saturated compounds? What groups of hydrocarbons contain unsaturated compounds?

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3. Identify Complete the following table.

Type of biochemical	Description
	made of hundreds or thousands of amino acid molecules
	one of the functions is to store genetic information
	made of one or more simple sugar molecules
	one of the functions in living things is to store energy

4. Identify and Describe What are two kinds of nucleic acids? What does each one do in living things?

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Name ______________________ Class ____________ Date __________

CHAPTER 16 Atomic Energy

SECTION 1

Radioactivity

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What are three types of radioactive decay?
- How does radiation affect living and non-living things?
- How do people use radioactive materials?

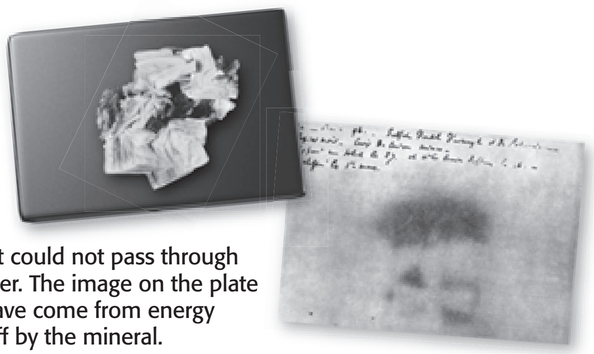
National Science Education Standards

PS 3a, 3e

How Was Radiation Discovered?

In 1896, a French scientist named Henri Becquerel performed an experiment to test a hypothesis. He thought that certain materials made X rays when light shone on them.

To test his idea, he wrapped a photographic plate in black paper to protect it from sunlight. Then he placed a mineral that glows when it is exposed to light on top of the paper. Becquerel placed the photographic plate and the mineral in the sun. When he developed the plate, he saw an image of the mineral as shown below.



Sunlight could not pass through the paper. The image on the plate must have come from energy given off by the mineral.

STUDY TIP

Compare In a table, list the types of radioactive decay, the particle given off, how penetrating it is, and how it is useful.

When Becquerel tried to do the experiment again, the weather was cloudy, so he put his materials away in a drawer. He decided to develop the plate anyway and found a surprising result. Even without sunlight, an image of the mineral formed on the photographic plate. He repeated the test with the same result. He concluded that some kind of energy came from uranium, an element in the mineral. ☑

The energy was *nuclear radiation*, high-energy particles that come from the nuclei of some atoms. A scientist who worked with Becquerel, Marie Curie, named the process that causes nuclear radiation. That process is called **radioactivity**. It is also known as *radioactive decay*. ☑

READING CHECK

1. Identify What caused the image of the mineral in Becquerel's experiment to form on the photographic plate?

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2. Identify What is another name for radioactivity?

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What Are the Types of Radioactivity?

The nuclei of some atoms are not stable. During radioactive decay, an unstable nucleus changes and gives off particles and energy. There are three types of radioactive decay, called alpha, beta, and gamma.

ALPHA DECAY

An *alpha particle* is made of two protons and two neutrons. The **mass number** of a nuclear particle or a nucleus is the sum of the numbers of protons and neutrons. The mass number of an alpha particle is 4 and its charge is 2+. An alpha particle is also labeled helium-4, because a helium-4 nucleus has two protons and two neutrons. ☑

READING CHECK

3. Describe What is an alpha particle made of? What is mass number?

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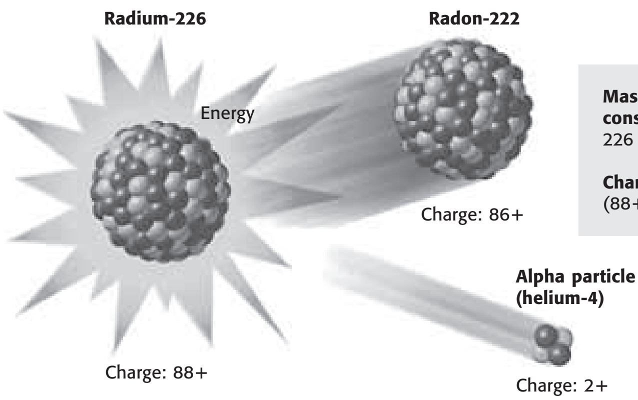
The release of an alpha particle from a nucleus is called *alpha decay*. When an alpha particle is released from a nucleus, it changes into the nucleus of another element. See the figure below.

Alpha Decay of Radium-226



Mass number is conserved.
226 = 222 + 4

Charge is conserved.
(88+) = (86+) + (2+)

Math Focus

4. Determine If the mass number of radium were 228, what would be the mass number of the radon formed?

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Many large radioactive nuclei break apart by releasing an alpha particle. When a nucleus emits an alpha particle, it becomes the nucleus of a different element because the new nucleus has a different number of protons. Radium-226 becomes radon-222.

The model of alpha decay in the figure shows two important facts about radioactive decay. The first is that mass is conserved. Radium-226 has the same mass as radon-222 plus helium-4.

The second fact is that charge is conserved. A radium nucleus has a charge of 88+. If you add the charge of radon, 86+, and an alpha particle, 2+, you get 88+. ☑

READING CHECK

5. Identify What is conserved by the radioactive decay process?

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BETA DECAY

A *beta particle* is an electron or positron that is released from an atomic nucleus. An electron has a charge of 1−. A positron has a charge of 1+. Both particles have a mass that is very close to zero compared to the mass of a nucleus. That means the mass of a nucleus does not change when it emits a beta particle. ☑

READING CHECK

6. Describe What happens to the mass of the nucleus that emits a beta particle?

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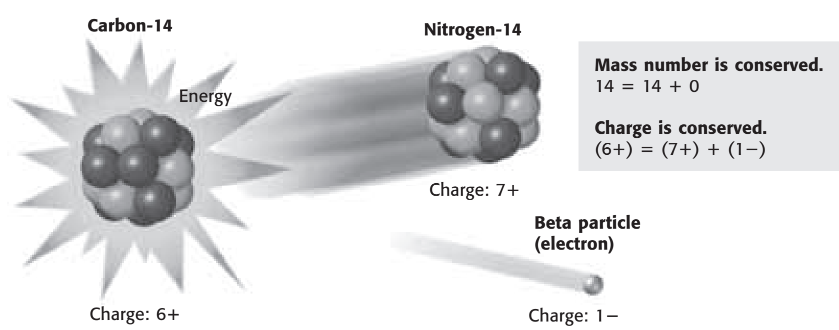
The beta decay shown in the figure below is the loss of an electron from a carbon-14 nucleus. During this kind of decay, one of the neutrons becomes a proton and an electron leaves the nucleus. Mass and charge are conserved. The number of protons changes so the nucleus becomes a different element.

Beta Decay of Carbon-14



Critical Thinking

7. Infer What would have been the charge of the new nucleus formed if the beta particle had been a positron?

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Isotopes are atoms that have the same number of protons but different number of neutrons. Different isotopes of an element can decay in different ways. A carbon-11 nucleus decays by emitting a positron. Again, the overall mass and charge do not change. The decay of carbon-11 creates a nucleus of boron-11, which has 5 protons and 6 neutrons. ☑

READING CHECK

8. Describe What are isotopes?

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GAMMA DECAY

Some changes to a nucleus also emit energy in the form of high-energy waves. These waves are called *gamma rays*. During *gamma decay*, particles in the nucleus move and change position, but there is no change of mass or charge. That means one element does not change into another. Gamma decay often occurs at the same time as alpha or beta decay. ☑

READING CHECK

9. Describe What are gamma rays?

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How Does Radiation Affect Matter?

Because the particles and rays of nuclear radiation have a lot of energy, they can move through matter. As shown in the figure below, each type of radiation has a different ability to penetrate, or go through, matter. This penetration depends on charge and on mass.

Alpha particles have the most mass and charge so they tend to interact with atoms more easily. Alpha particles are stopped by a piece of paper or clothing. A beta particle has almost no mass and a single charge. Clothing does not stop beta particles but about 3 mm of a metal such as aluminum can. ☑

Gamma rays have no charge or mass. They pass through metals such as aluminum. Only very dense, thick materials can stop gamma rays. They can be blocked by a few centimeters of lead or a few meters of concrete.

READING CHECK

10. Explain Why are alpha particles less penetrating than beta particles?

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STANDARDS CHECK

PS 3e In most chemical and nuclear reactions, energy is transferred into or out of a system. Heat, light, mechanical motion, or electricity might all be involved in such transfers.

11. Describe How can gamma rays cause changes deep inside matter?

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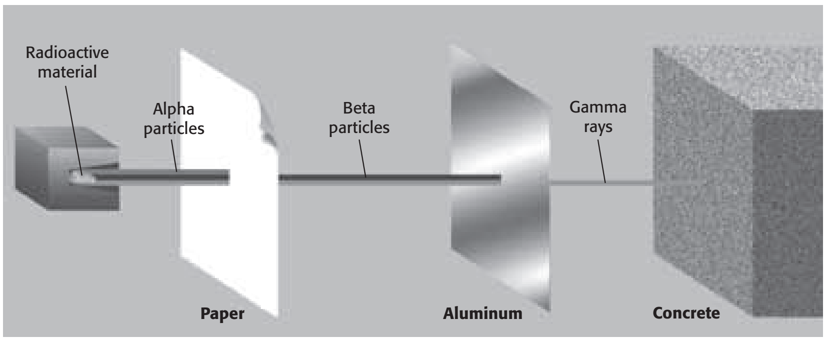
The Penetrating Abilities of Nuclear Radiation



▲ **Alpha particles** have a greater charge and mass than beta particles and gamma rays do. Alpha particles travel about 7 cm through air and are stopped by paper or clothing.

▲ **Beta particles** have a 1− or 1+ charge and almost no mass. They are more penetrating than alpha particles. Beta particles travel about 1 m through air but are stopped by 3 mm of aluminum.

▲ **Gamma rays** have no charge or mass and are the most penetrating. They are blocked by very dense, thick materials, such as a few centimeters of lead or a few meters of concrete.

When nuclear radiation hits atoms, atoms can lose electrons. Radiation can also break bonds between atoms. These changes can cause damage to matter. The amount and location of the changes depends on the type of radiation.

Gamma rays can cause changes deep inside matter because they penetrate deeply. Beta radiation does not penetrate as far, so it causes damage closer to the surface. Alpha particles are much larger and have more charge than beta particles. Although they are easier to stop, alpha particles cause the most damage when they get inside matter.

Say It

Describe Research the effects of alpha, beta, and gamma radiation on a living cell. Describe to the class what each type can do to a cell.

DAMAGE TO LIVING MATTER

Radiation can harm the cells of a living organism. The damage is often similar to a burn caused by touching something hot. A large exposure to radiation causes radiation sickness. The symptoms of this sickness include fatigue, loss of appetite, and hair loss. When blood cells are destroyed, radiation sickness can cause death.

Repeated exposure to radiation can damage many cells in the body. One of the effects of this damage can be cancer. Many people who work near radiation wear badges that can warn them when radiation levels are too high. ☑

READING CHECK

12. Explain Why do people exposed to radiation regularly need to wear radiation badges?

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DAMAGE TO NONLIVING MATTER

Radiation can also damage nonliving matter. For example, when electrons are knocked away from metal atoms, the metal becomes weaker. The metal structures in nuclear power plants must be tested often. Too much exposure to radiation can make them unsafe. Parts in spacecraft can be changed by radiation from the sun.

How Do People Use Radioactivity?

Radiation can be harmful but it can also be useful in industry, in medicine, and even in your home. Some smoke detectors use a tiny amount of radioactive material. It ionizes atoms in smoke and the ions turn on the alarm.

Radioactive materials can also be used as tracers. *Tracers* are radioactive elements whose paths can be followed through a process such as a chemical reaction. ☑

READING CHECK

13. Describe What do tracers allow people to do?

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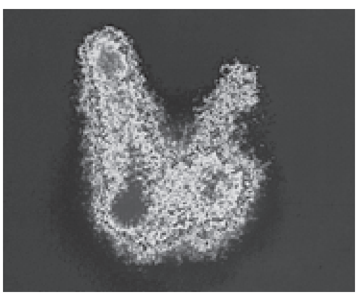
RADIOACTIVITY IN HEALTH CARE

Doctors use tracers to help find patient's medical problems. The figure below shows an image of a thyroid gland. The image shows parts of the gland are not working correctly. Radioactive materials are also used to treat diseases, including cancer.



Radioactive iodine -131 was used to make this scan of a thyroid gland. The dark area shows the location of a tumor.

TAKE A LOOK

14. Identify Circle the dark area in the thyroid shown in the figure.

RADIOACTIVITY IN INDUSTRY

Radioactive isotopes are also used as tracers in industry. The figure below shows a worker looking for leaks in pipes by tracing radioactive material in the pipe. Notice that he is wearing protective clothing so his cells are not exposed to radiation. Another way to use radiation is to look for flaws in metal objects. This is similar to the way a doctor uses an X-ray image to look at your bones. ☑

READING CHECK

15. Identify What are two uses for tracers in industry?

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Tracers are used to find weak spots in materials and leaks in pipes. A Geiger counter is often used to detect the tracer.

Some space probes use radioactive isotopes for power. The energy given off as nuclei decay is converted to electrical power.

How Can Radiation Tell Us About the Past?

In 1991, hikers in the Alps found a frozen body high in mountains. Scientists used radioactivity to figure out that the Iceman, shown below, lived about 5,300 years ago.

The Iceman is a 5,300-year-old mummy. His are the best-preserved remains of a human from that time.

Every living thing has many carbon atoms. A small percentage of these atoms is radioactive carbon-14. This percentage does not change in a living organism because carbon atoms are constantly being replaced. When the organism dies, though, it no longer replaces atoms. As the radioactive isotope decays, the percentage of carbon-14 decreases. Scientists can figure out when the organism was alive by measuring how much carbon-14 remains. ☑

READING CHECK

16. Identify What radioactive isotope of carbon is not replaced after an organism dies?

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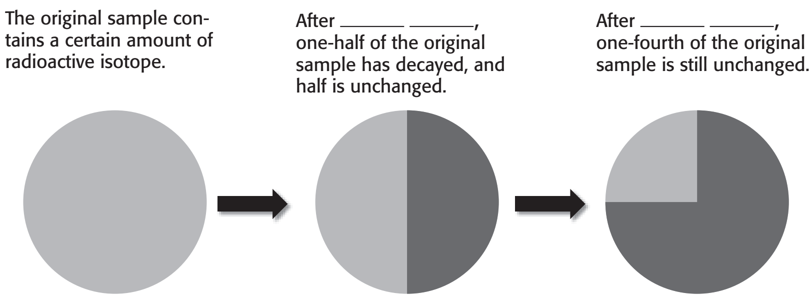
Radioactive Decay and Half-Life



Math Focus

17. Identify Fill in the blanks to identify which half-life (one, two, three, etc.) the sample has decayed through.

A STEADY DECAY

Every radioactive isotope decays at a particular rate, called its half-life. As shown in the figure above, a **half-life** is the amount of time that it takes for one-half the nuclei of a radioactive isotope to decay.

The half-life is the same for every sample of a particular isotope. It is not affected by any conditions such as temperature and pressure. As shown in the table, half-lives range from part of a second to billions of years.

Examples of Half-lives

Isotope	Half-life		Isotope	Half-life
Uranium-238	4.5 billion years		Polonium-210	138 days
Oxygen-21	3.4s		Nitrogen-13	10 min
Hydrogen-3	12.3 years		Calcium-36	0.1s

FINDING AGE

The half-life of carbon-14 is 5,730 years. This rate is constant. Scientists know what percentage of the carbon in the Iceman's body was carbon-14 when he was alive. They measured the number of decays per minute in a sample from his body. This showed what the percentage of carbon-14 is now.

A little less than half of the carbon-14 had decayed after his death. That means that not quite one half-life has passed since the Iceman walked in the mountains. ☑

Carbon-14 can be used to find the age of objects up to 50,000 years old. After that, there is not enough carbon-14 left to make good measurements. To find the age of older things, scientists use isotopes with longer half-lives. For example, the half-life of potassium-40 is about 1.3 billion years. It is used to find the age of dinosaur fossils. Isotopes with very long half-lives, such as uranium-238, are used to measure the age of Earth's oldest rocks.

READING CHECK

18. Describe Why do scientists think that the Iceman is less than 5,730 years old?

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Name ______________________ Class ______________ Date ______________

Section 1 Review

NSES PS 3a, 3e

SECTION VOCABULARY

half-life the time required for half of a sample of a radioactive isotope to break down by radioactive decay to form a daughter isotope

isotope an atom that has the same number of protons (or the same atomic number) as other atoms of the same element but has a different number of neutrons (and thus a different atomic mass)

mass number the sum of the numbers of protons and neutrons in the nucleus of an atom.

radioactivity the process by which an unstable nucleus gives off nuclear radiation

1. **Compare** Most atoms of uranium, which has 92 protons, are either uranium-235 or uranium-238. Compare the mass numbers and atomic numbers of these two isotopes of uranium. Recall, atomic number is the number of protons in the nuclei of elements.

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2. **Compare** Use the information in this section to fill in the blank spaces in the comparison table below.

Types of Radiation				
Name	**Form**	**Mass**	**Charge**	**Penetrating power**
	particle (helium nucleus)		2+	
Beta		0		medium
	particle (positron)	0	1+	medium
	energy			

3. **Make Inferences** Nuclear radiation can be used to look for flaws in metal parts of bridges. The process is similar to using X rays to look at human bones. What type of radioactive decay would work best for this test? Explain your answer.

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4. **Evaluate Results** A rock contains one-fourth of its original potassium-40. The half-life of potassium 40 is 1.3 billion years. What is the rock's age?

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Name ______________________ Class ______________ Date ____________

CHAPTER 16 Atomic Energy

SECTION 2

Energy from the Nucleus

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is nuclear fission?
- What is nuclear fusion?
- What are the advantages and disadvantages of nuclear fission and nuclear fusion?

National Science Education Standards

PS 3a, 3e

How Are Atoms Broken Apart?

Changes to atomic nuclei can release tremendous amounts of energy. This energy can be useful but there are risks that come with the energy. Understanding the advantages and the disadvantages of nuclear energy helps people make good decisions about its use.

The nuclei of some atoms decay by breaking apart. They then form two smaller nuclei that are more stable. During **nuclear fission**, a large nucleus splits into two smaller nuclei, releasing energy at the same time. ☑

Some large atoms, including some isotopes of uranium, break apart naturally by nuclear fission. These kinds of large atoms can also be forced to undergo fission. This is done by hitting the nucleus of an atom with a neutron, as shown in the figure below.

STUDY TIP

Describe Make a list of the advantages and disadvantages of using each type of nuclear energy.

READING CHECK

1. Describe What happens during nuclear fission?

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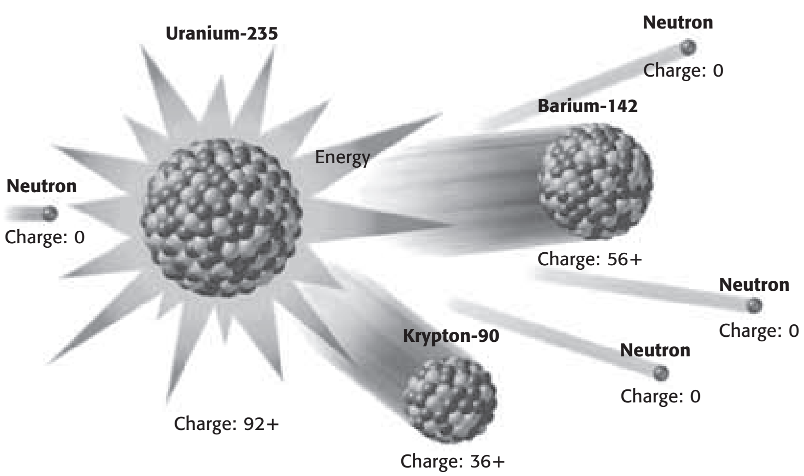
Fission of a Uranium-235 Nucleus



Math Focus

2. Determine What is the difference in mass between uranium-235 and the sum of the masses of barium-142 and krypton-90? Why are they different?

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STANDARDS CHECK

PS 3a Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.

3. Describe What happens during nuclear fission that gives off energy?

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ENERGY FROM MATTER

The process of nuclear fission releases a lot of energy. Where does it come from? If you could carefully measure the mass of all the particles before and after fission, you would find an interesting change. The total mass of the products is slightly less than the total mass of the original nucleus and the neutron. The masses are different because some of the mass was changed into energy.

The amount of energy given off by a single uranium nucleus is very small. There are a large number of uranium atoms in a small sample, though. The fission of the uranium nuclei in a pellet that is smaller than a penny can release as much energy as burning 1,000 kg of coal.

NUCLEAR CHAIN REACTIONS

What happens to the three neutrons shown as products of the fission of uranium-235? If they each hit another uranium-235 nucleus and those nuclei split, the fission would produce nine more neutrons. If the neutrons continue to cause fission, the result is a *nuclear chain reaction.*

In a **nuclear chain reaction**, a continuous series of nuclear fission reactions occurs. A model of the beginning of a nuclear chain reaction is shown in the figure below. ☑

READING CHECK

4. Describe What is a nuclear chain reaction?

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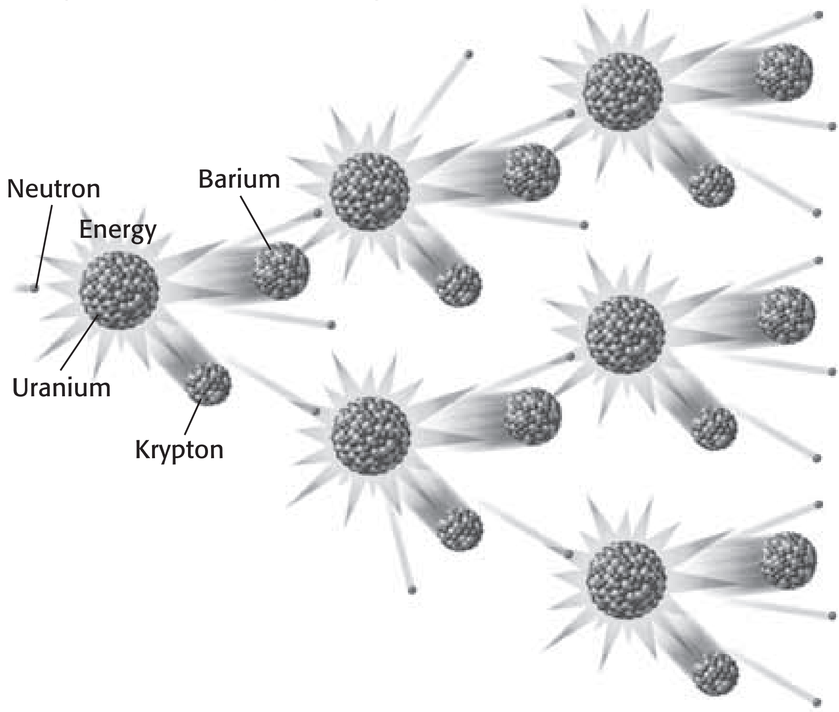
An Uncontrolled Nuclear Chain Reaction



ENERGY FROM A CHAIN REACTION

In an uncontrolled chain reaction, huge amounts of energy are released very quickly. An exploding atomic bomb is an example. Keeping some of the neutrons from hitting uranium nuclei can control the nuclear chain reaction. Then energy is released but not fast enough to cause an explosion. ☑

Nuclear power plants use controlled chain reactions. They change the energy from the fission of uranium fuel into electrical energy. The figure below shows how a nuclear power plant works. Control rods are made of materials that absorb neutrons without releasing energy.

In a power plant, the energy from fission is absorbed as heat. The heat turns water into steam. Then a turbine changes the kinetic energy of the moving water atoms in steam into mechanical energy. A generator converts mechanical energy into electrical energy. ☑

READING CHECK

5. Describe How is a nuclear chain reaction controlled?

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READING CHECK

6. Identify What are two energy changes that take place after heat is changed to steam in a power plant?

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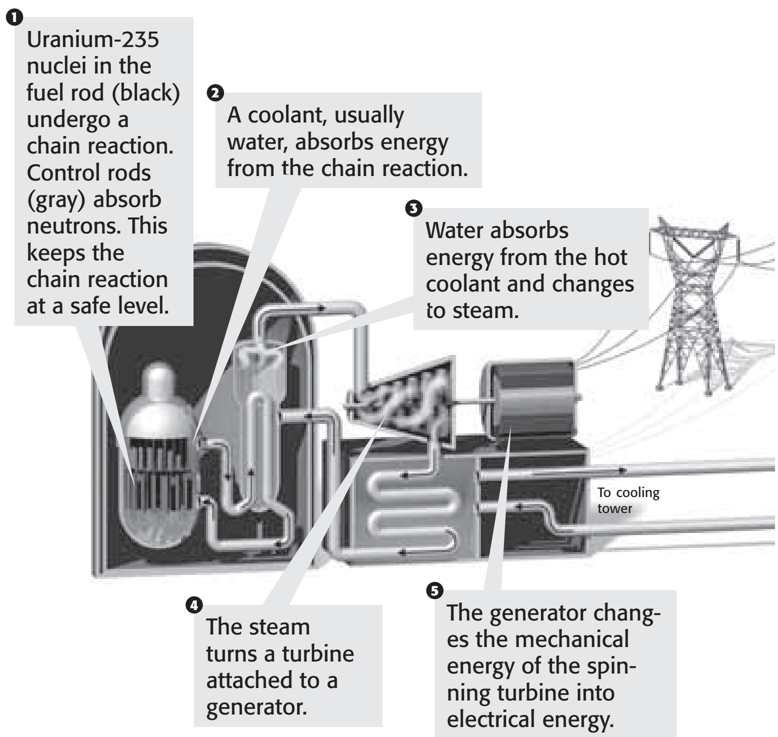
How a Nuclear Power Plant Works



How Is Fission Harmful or Helpful?

Every kind of energy has advantages and disadvantages. To make decisions about using nuclear power, people need to know both.

ACCIDENTS

One of the concerns about nuclear power is shown in the figure below. In 1986 an accident occurred at a nuclear power plant at Chernobyl, Ukraine. An explosion blew a large amount of radioactive fuel and waste into the atmosphere. The cloud spread over much of Europe and Asia, and some material even reached North America. ☑

READING CHECK

7. Describe What can happen during a nuclear accident?

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During a test at the Chernobyl nuclear power plant, the emergency protection system was turned off. The reactor overheated, causing an explosion.

RADIOACTIVE WASTE

Another reason people are concerned about nuclear power is radioactive waste. The waste includes used fuel rods, chemicals used to process uranium, and even the workers' protective clothing. Some of this waste will have dangerous levels of radioactivity for thousands of years. That means it must be stored for a very long time before it is safe. ☑

READING CHECK

8. Describe Why must some radioactive waste be stored for thousands of years?

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NUCLEAR VERSUS FOSSIL FUELS

Even though there are concerns about nuclear power, there are also advantages. Nuclear power plants use a lot less fuel than plants that burn fossil fuels. They can be much less expensive to operate.

Nuclear power plants do not release gases, such as carbon dioxide given off by burning fossil fuels, into the atmosphere. That means they do not contribute to climate change and other pollution problems. Using nuclear power allows the supply of fossil fuels to last longer. However, the supply of uranium fuel is also limited. ☑

READING CHECK

9. Identify What gas, produced by burning fossil fuels, is not released into the atmosphere by nuclear power plants?

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How Are Atoms Put Together?

Fusion is another nuclear reaction in which matter is converted to energy. In **nuclear fusion**, two or more nuclei that have small masses combine to form a larger nucleus. ☑

Two positively charged nuclei repel one another. In order for fusion to occur, they must be forced very close together. Fusion requires very high temperatures—more than 100,000,000°C! At this temperature, the electrons are removed from atoms, forming a state of matter called *plasma*.

In plasma, the positive nuclei and electrons are separated. This happens in the core of the sun and other stars. Hydrogen nuclei in stars fuse to form helium nuclei as shown in the figure below. ☑

READING CHECK

10. Describe What happens during nuclear fusion?

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READING CHECK

11. Identify Where, in the sun, is plasma found?

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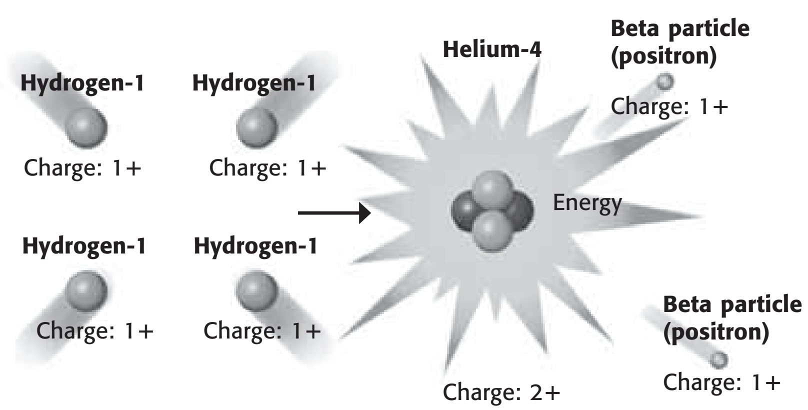
Nuclear Fusion of Hydrogen



ADVANTAGES AND DISADVANTAGES OF FUSION

Nuclear fusion is not used yet to make energy electricity for your home. Scientists cannot yet control the high temperatures well enough use fusion. Also, it takes more energy to hold the plasma together than we can get from the fusion. Fusion power plants may exist once these problems are solved. ☑

If a fusion power plant were to have an accident, it would not release large amounts of radioactive material. The process does not release any pollutants, so fusion energy would be a clean energy source.

Another advantage is that there is enough fuel in Earth's water to provide energy for millions of years. Many scientists think that producing energy from fusion will be possible in the future. However, this will require a large amount of money to pay for research.

READING CHECK

12. Describe Why can't we use nuclear fusion to make electricity for homes today?

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Name ______________________ Class ______________ Date ____________

Section 2 Review

NSES PS 3a, 3e

SECTION VOCABULARY

nuclear chain reaction a continuous series of nuclear fission reactions **nuclear fission** the process by which the nucleus of a heavy atom splits into two or more fragments; the process releases neutrons and energy	**nuclear fusion** the process by which nuclei of small atoms combine to form a new, more massive nucleus; the process releases energy

1. **Describe** Where do the neutrons for nuclear fission come from in a nuclear chain reaction? What do they do after they are set free by fission?

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2. **Make inferences** What could happen in a nuclear fission power plant if the control rods could not be put into place?

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3. **Analyze Processes** In a nuclear power plant, the energy is converted into different forms several times. Describe two of these changes and explain why they are necessary.

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4. **Make Judgments** In terms of radioactive wastes, why would fusion be a better source for making electricity than a fission power plant?

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5. **Determine** During the nuclear fission of plutonium-244, barium-144 is produced, along with an unknown nucleus and three neutrons. What must be the mass of the unknown nucleus? Show your work.

SECTION 1 Electric Charge and Static Electricity

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is an electric charge?
- How can an object become charged?
- How are conductors different from insulators?
- What are static electricity and electric discharge?

National Science Education Standards
PS 3a

What Is an Electric Charge?

Almost everywhere you go, you see electricity at work. Electricity starts our cars and lights our houses. It makes refrigerators and toasters run. Lightning flashes in the sky because of electricity. It can even make your hair stand on end.

To understand this amazing kind of energy, you need to learn about atoms and charge. All matter is made up of very small particles called atoms. Atoms are made of even smaller particles. The center, or *nucleus*, of every atom contains protons and neutrons. Protons have a positive charge and neutrons have no charge. Particles called electrons move around the nucleus. They have a negative charge. ☑

STUDY TIP

Reading Organizer As you read this section, write an outline about electric charge. Use the vocabulary and italicized words in the outline.

READING CHECK

1. Name What are the two kinds of charged particles in atoms?

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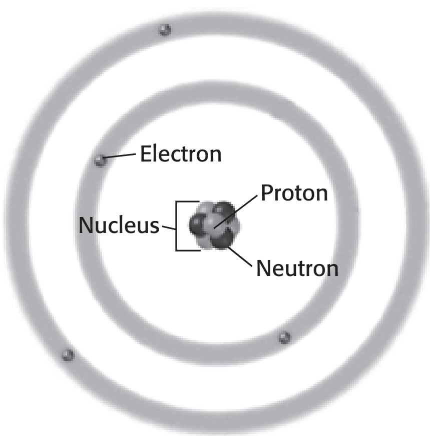

Protons and neutrons make up the center of the atom, the nucleus. Electrons are found outside the nucleus.

TAKE A LOOK

2. Identify What kind of particle has a positive charge? What kind has a negative charge? In the figure, put a plus sign (+) next to the particle with a positive charge. Put a minus sign (−) next to the particle with a negative charge.

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CHARGES EXERT FORCES

Charge is a physical property. An object can have a positive charge, a negative charge, or no charge at all. Charged objects exert a *force*—a push or a pull—on other charged objects.

LAW OF ELECTRIC CHARGES

The **law of electric charges** says that objects with the same charge *repel*. That means they push away from each other. Opposite charges *attract*, or pull together. The ping-pong balls in the figure below show the law of electric charges. ☑

READING CHECK

3. Explain What does the law of electric charges say about two objects that each have a positive charge?

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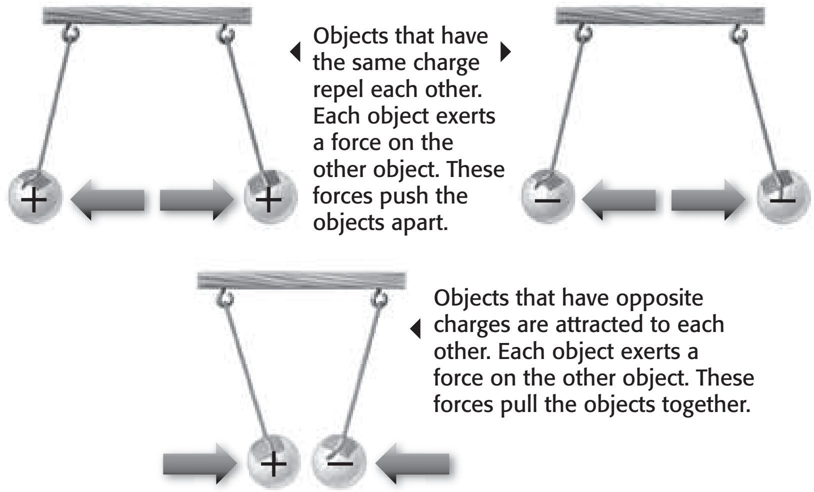
The Law of Electric Charges



TAKE A LOOK

4. Explain Why do the two balls in the bottom figure attract each other?

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Critical Thinking

5. Infer What would happen if the balls in the figures had no charge?

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THE FORCE BETWEEN PROTONS AND ELECTRONS

Protons have a positive charge. Electrons have a negative charge. Because protons and electrons have opposite charges, they are attracted to each other. This attraction holds electrons in atoms.

THE ELECTRIC FORCE AND THE ELECTRIC FIELD

The force between charged objects is an **electric force**. The size of the force depends on two things. The first thing is the amount of charge on each object. The greater the charge is, the greater the electric force is. The other thing that determines the size of the electric force is the distance between the charges. The closer together the charges are, the greater the electric force is. ☑

READING CHECK

6. Name What are the two things that make an electric force stronger?

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Charged objects have an electric field around them. An **electric field** is the region around a charged object in which an electric force is exerted on another charged object. The electric field of a charged object pushes or pulls another charged object. They don't need to be touching each other. ☑

READING CHECK

7. Identify What is the name of the region that is around all charged objects?

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How Do Objects Become Charged?

Objects become positively charged when they lose electrons. They become negatively charged if they gain electrons. Important—protons do not move! There are three ways to charge an object: friction, conduction, and induction. ☑

READING CHECK

8. Name What are three ways to charge an object?

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FRICTION

Charging by *friction* happens when electrons are "wiped" from one object onto another. If you rub a plastic ruler with a cloth, electrons move from the cloth to the ruler. The ruler gains electrons and becomes negatively charged. At the same time, the cloth loses electrons. It becomes positively charged.

CONDUCTION

Charging by *conduction* happens when electrons move from one object to another by direct contact or a spark. What happens if you touch an uncharged piece of metal with a positively charged glass rod? Electrons from the metal will move to the glass rod. The metal loses electrons and becomes positively charged.

STANDARDS CHECK

PS 3a Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.

9. Compare What is the difference between charging by conduction and by induction?

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INDUCTION

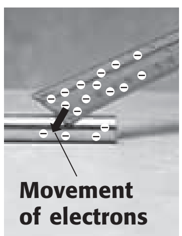
Charging by *induction* happens when charges in an uncharged metal object change without direct contact with a charged object. Suppose you held a negatively charged balloon near a metal beam. Electrons in the metal are repelled away by the negatively charged balloon. This movement causes (or *induces*) an area of positive charge on the surface of the metal near the balloon. See the figure below.

Three Ways to Charge an Object

Friction

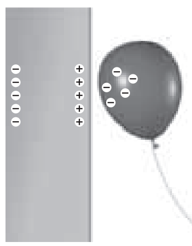
The friction of rubbing a balloon on your hair causes electrons to move from your hair to the balloon. Your hair and the balloon become oppositely charged and attract each other.

Conduction



When a negatively charged plastic ruler touches an uncharged metal rod, the electrons in the ruler travel to the rod. The rod becomes negatively charged by conduction.

Induction



A negatively charged balloon makes a small section of a metal beam have a positive charge through induction. Electrons in the metal are repelled by and move away from the balloon.

CONSERVATION OF CHARGE

When you charge something, no charges are created or destroyed. So, we say the charge is *conserved*. That means that the numbers of electrons and protons stay the same when a object is charged. Electrons simply move from one atom to another. ☑

READING CHECK

10. Explain What is conservation of charge?

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DETECTING CHARGE

You can use a device called an *electroscope* to see if something is charged. An electroscope is a glass flask that has a metal rod inside. Two metal leaves are attached to the bottom of the rod. When the electroscope is not charged, the leaves hang straight down. When the electroscope is charged, the leaves repel each other, or spread apart. ☑

READING CHECK

11. Explain What can you do with an electroscope?

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When an electroscope is charged, the metal leaves have the same charge and repel each other.

TAKE A LOOK

12. Identify Label the two leaves with the charge sign that shows they have a negative charge.

The photo above shows a negatively charged ruler touching the top of an electroscope. Electrons move from the ruler to the electroscope. The leaves become negatively charged and repel each other.

If the ruler were positively charged, electrons would move from the electroscope into the ruler. The leaves become positively charged and repel each other.

An electroscope whose leaves are spread apart tells you the object that touched it was charged. However, you do not know if the charge is positive or negative.

HOW DO CHARGES MOVE?

Have you ever noticed that electrical cords are made from metal and plastic? We make electrical cords from different materials because each part of the cord has a different purpose. Cords use metal wire inside to carry electric charges. Plastic on the outside keeps the electricity away from your hands. ☑

READING CHECK

13. Describe Why do we cover electrical cords with plastic?

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CONDUCTORS

Most materials are either conductors or insulators based on how easily charges move through them. An **electrical conductor** is a material in which charges can move easily. Most metals are good conductors because they have electrons that are free to move. We use conductors to make wires. For example, a lamp cord has metal wire and metal prongs. Copper, aluminum, and mercury are good conductors.

Critical Thinking

14. Explain What is the difference between insulators and conductors?

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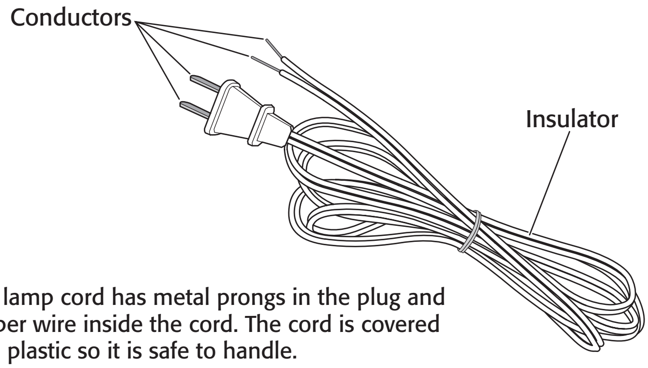

This lamp cord has metal prongs in the plug and copper wire inside the cord. The cord is covered with plastic so it is safe to handle.

INSULATORS

An **electrical insulator** is a material in which charges cannot move easily. Insulators do not conduct charges very well. The atoms of an insulator hold onto their electrons. So, the electrons do not flow freely. The insulating material in a lamp cord stops charges from leaving the wire. It protects you from an electric shock. Plastic, rubber, glass, wood, and air are good insulators. ☑

READING CHECK

15. Name Which of the following is an insulator: copper, rubber, aluminum, or iron?

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What is Static Electricity?

On dry days, you might get a shock when you open a door, put on a sweater, or touch another person. This is static electricity at work.

Static electricity is the electric charge at rest on an object. When something is *static*, it does not move. The charges of static electricity stay on the object. Sometimes charges build up. When this happens, the charges may move suddenly to another object, causing a spark.

Friction and induction create static electricity. For example, your clothes sometimes stick together when you take them out of the dryer. That's because as your clothes tumble against each other in the dryer, negative charges move from some clothes to others. When the dryer stops, the transfer of charges also stops.

Critical Thinking

16. Infer Is static electricity on clothes in a dryer caused by friction or induction?

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ELECTRIC DISCHARGE

Charges that build up as static electricity eventually leave the charged object. The loss of static electricity as charges move off an object is called **electric discharge**. Sometimes, electric discharge happens slowly. Clothes stuck together with static electricity eventually separate. Their electric charges move to water molecules in the air. ☑

READING CHECK

17. Define What is electric discharge?

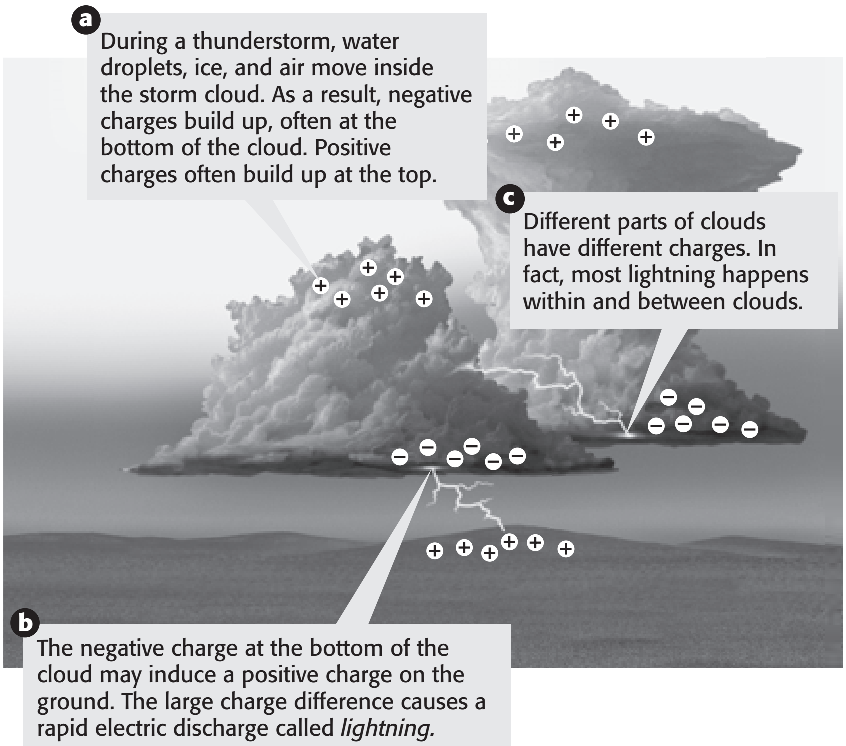
Other times, electric discharge happens quickly. For example, when you wear rubber-soled shoes and walk on carpet, negative charges build up on your body. When you touch a metal doorknob, the negative charges on your body suddenly jump to the doorknob. You feel a small shock and may see a spark.

Lightning is a giant spark of static electricity. The picture below shows how charges build up in clouds during a storm.

TAKE A LOOK

18. Explain How does static electricity build up in clouds?

How Lightning Forms



LIGHTNING DANGERS

Lightning usually strikes the highest point in a charged area. That point provides the shortest path for the charges to reach the ground. Anything that sticks up or out in an area can provide a path for lightning. Trees and people in open areas risk being struck by lightning. ☑

So, it is very dangerous to be at the beach or on a golf course during a lightning storm. Even standing under a tree during a storm is dangerous. The charges from lightning striking a tree can jump to your body.

READING CHECK

19. Describe Why is it dangerous to be standing outside in an open area during a storm?

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Lightning strikes the lightning rod rather than the building, because the lightning rod is the tallest point on the building.

LIGHTNING RODS

In a storm, a tall building may be struck by lightning because it is the highest point in the area. So, most tall buildings have a *lightning rod* on the roof. A lightning rod is a pointed metal rod connected to the ground by a wire. We say that objects that are connected to the ground by a conductor, such as a wire, are *grounded*. Any object that is grounded provides a path for electric charges to move to the ground.

When lightning strikes a lightning rod, the electric charges move safely to the ground through the rod's wire. By moving the electric charges to the ground, lightning rods prevent lightning from damaging buildings.

READING CHECK

20. Describe What happens when lightning strikes a lightning rod?

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Name ______________________ Class ______________ Date ______________

Section 1 Review

NSES PS 3A

SECTION VOCABULARY

electric discharge the release of electricity stored in a source **electric field** the space around a charged object in which another charged object experiences an electric force **electric force** the force of attraction or repulsion on a charged particle that is due to an electric field **electrical conductor** a material in which charges can move freely	**electrical insulator** a material in which charges cannot move freely **law of electric charges** the law that states that like charges repel and opposite charges attract **static electricity** electric charge at rest; generally produced by friction or induction

1. **Identify** What are the two causes of static electricity?

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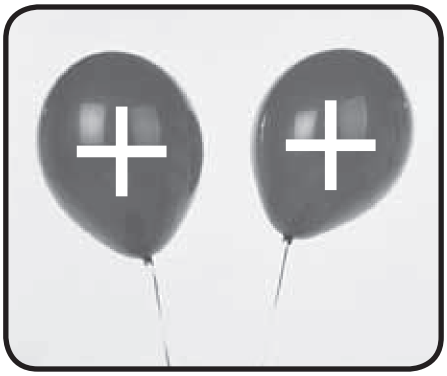
2. **Use Graphics** These balloons have positive charges. How would the balloons look if both balloons were given negative charges? What law explains what the balloons are doing?



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3. **List** What are two examples of electric discharge?

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4. **Analyze Processes** You touch the top of an electroscope with an object and the metal leaves spread apart. Can you tell if the charge is positive or negative? Why?

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5. **Apply Concepts** Why must you touch a charged object to the metal rod of an electroscope and not the rubber stopper?

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SECTION 2

Electric Current and Electrical Energy

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is electric current?
- What is voltage?
- What is resistance?
- How does a cell produce electrical energy?
- What are thermocouples and photocells?

National Science Education Standards

PS 3a

What Is Electric Current?

We use electricity every day to watch TV, use a computer, or turn on a light. Electricity makes all of these things work.

Electrical energy is the energy of electric charges. In most of the things that use electrical energy, the charges (electrons) flow through wires.

The drawing below shows electrons moving through a wire when it is connected to a battery. This movement is called an *electric current*. Electric currents provide the energy to things that use electrical energy. ☑

STUDY TIP

Reading Organizer As you read this section, make a table. The table should describe what electric current, voltage, and resistance are and how one property affects another property.

READING CHECK

1. Describe What movement causes an electric current in a wire?

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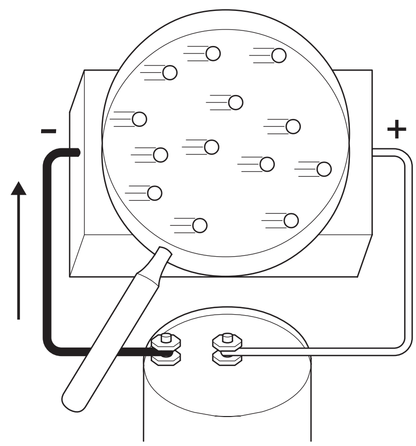
When a wire is connected to a battery, electrons will move through the wire. Electrons moving through a wire make up current. This provides energy to the things that you use every day.



An **electric current** is the rate at which charges pass a given point. Electric current is like the current of a river or a stream. When the current is high, more charges pass the point each second, like a fast-flowing river. We talk about electric current in units called *amperes*, or *amps*. The symbol for ampere is A. In equations, the symbol for current is the letter *I*. ☑

READING CHECK

2. Name What unit is used to measure electric current? What is its symbol?

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STANDARDS CHECK

PS 3a Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.

3. Explain What makes electrons move when you turn on a lamp?

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MAKING CHARGES MOVE

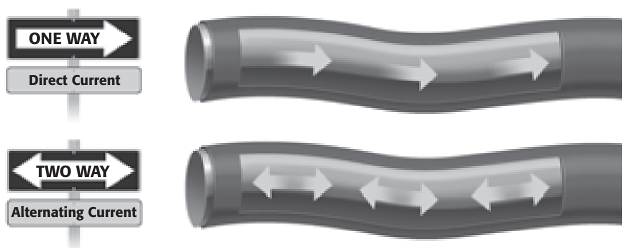
When you flip the switch on a flashlight, the light comes on quickly. But do charges in the battery instantly reach the bulb? No, they don't. When you flip the switch, it sets up an electric field in the wire at the speed of light. The electric field makes the free electrons in the wire move. The energy of each electron is transferred instantly to the next electron.

COMMANDING ELECTRONS TO MOVE

When you flip a switch, the electric field is created very quickly. All of the electrons start moving through the wire at the same time. Think of the electric field as a command to the electrons to move ahead. The light comes on right away because all of the electrons obey the command at the same time. So, the current that lights the bulb starts very quickly even though each electron moves slowly. A single electron may take more than an hour to travel through one meter of wire.

AC AND DC

There are two kinds of electric current—*direct current* (DC) and *alternating current* (AC). In the drawing below you can see that in direct current, the charges always flow in the same direction. In alternating current, the direction of the charges continually changes. It moves in one direction, then in the opposite direction.



Charges move in one direction in DC, but charges continually change direction in AC.

The electric current from the batteries in a camera or a flashlight is DC. The current from outlets in your home is AC. In the United States, the alternating current changes directions 120 times each second. That means it has 60 cycles each second. ☑

Both kinds of current give you electrical energy. For example, if you connect a flashlight bulb to a battery, the bulb will light. And, you can light a household bulb by putting it in a lamp and turning it on.

Critical Thinking

4. Describe What kind of current makes a refrigerator run and in what direction do the charges move?

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What Is Voltage?

If you are on a bike at the top of a hill, you can roll down to the bottom. This happens because of the difference in height between the two points. The "hill" that causes charges in a circuit to move is voltage. This process can occur in an electric circuit.

Voltage is the potential difference between two points in a circuit. We use volts, V, as to measure voltage. We write voltage in equations with the letter *V*.

VOLTAGE AND ENERGY

Voltage is a measure of how much work is needed to move a charge between two points. Voltage is like the water pressure in your plumbing system. More volts means more energy pushing electrons through the wire.

VOLTAGE AND ELECTRIC CURRENT

The voltage between two points on a wire causes charges to flow through the wire. The size of the current depends on the voltage. If the voltage between two points on a wire is increased, more current will flow in the wire. ☑

READING CHECK

5. Describe What happens to the electric current in a wire when voltage is increased?

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DIFFERENT KINDS OF VOLTAGE

Different devices need different amounts of current to run. So, batteries are made with many different voltages. For example, it takes a large current to start a car. So, the battery in a car has a high voltage, 12 V. Things that run on batteries often need a low voltage. For example, a portable radio might need only 3 V. If you have a device that uses direct current, you would probably use one of the batteries in the photo below.

Batteries are made with various voltages for use in many different devices.

Critical Thinking

6. Analyze Why do batteries come in different sizes and voltages?

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Most devices in your home use alternating current from an outlet. In the United States, outlets usually have AC at 120 V. So, things like TVs, toasters, and clocks run on 120 V.

What Is Resistance?

Have you ever tried to run in a swimming pool? The water makes it hard for you to move ahead. That's a type of resistance.

With electricity, resistance is a factor that determines the amount of current in a wire. **Resistance** is the *opposition* to the flow of electric charge. Opposition means "to work against." So, a material that is resistant lowers the flow of current. We use *ohms* (Ω) as a measure of resistance. In equations, the symbol for resistance is the letter *R*. ☑

You can think of resistance as "electrical friction." The higher the resistance of a material, the lower the current flowing through it. So, if the voltage does not change, as resistance goes up, the current goes down.

Resistance depends on four things: an object's thickness, length, the material it is made of, and temperature. ☑

READING CHECK

7. Describe What is resistance and how does it affect the flow of current?

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READING CHECK

8. List What are the four factors that affect resistance?

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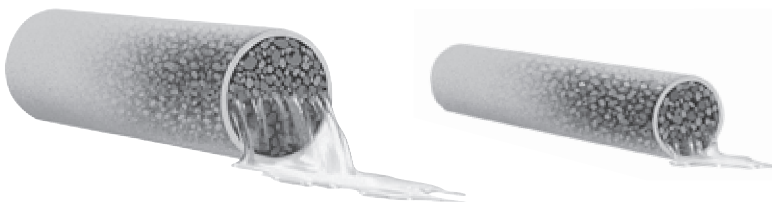
RESISTANCE, THICKNESS, AND LENGTH

The figure below shows how the thickness and length of a wire affect the wire's resistance. This figure compares the flow of electricity through a wire to water that flows through a pipe. The pipe filled with gravel is like a wire. The water is like the flow of electric charges.



A thick pipe has far less resistance than a thin pipe does. This is because there are more spaces between pieces of gravel in a thick pipe for water to flow around.

A short pipe has less resistance than a long pipe does. This is because the water in a short pipe does not have to move around as many pieces of gravel.

RESISTANCE AND MATERIAL

Materials with different amounts of resistance can do different jobs. Good conductors, such as copper, have low resistance. Electricity flows easily through them. That's why we use good conductors to make electrical wire.

Poor conductors, such as iron, have higher resistance. Materials with high resistance are useful. For example, the tiny wire in a light bulb is made of resistant material. It heats up and gives off light

Critical Thinking

9. Infer Toasters and space heaters heat up when current flows through them. Do they use material with low resistance or high resistance?

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RESISTANCE AND TEMPERATURE

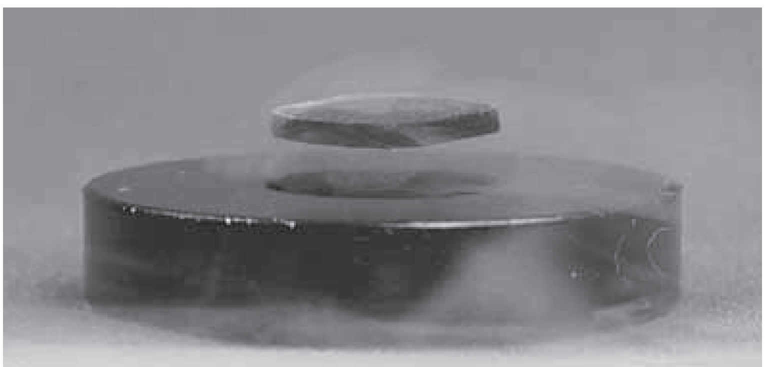
Resistance also depends on temperature. The resistance of metals usually increases as temperature rises. The atoms vibrate faster at higher temperatures. They get in the way of the flowing electric charges.

If you cool certain materials to a very low temperature, resistance will drop to 0 Ω. Materials in this state are *superconductors*. Very little energy is wasted when electric charges move in a superconductor. However, it takes a large amount of energy to cool them.

Scientists are studying how to use superconductors to store and transmit energy. One possible application of superconductors is *maglev trains*. These are trains that use magnets made by an electric current in coils of wire. The magnetic field produced raises the train above the track and pulls it along. If the coils could be made from a superconducting material, operating the train would cost much less than it does today.

Say It

Investigate Research how superconductors work and their potential uses and report to the class.

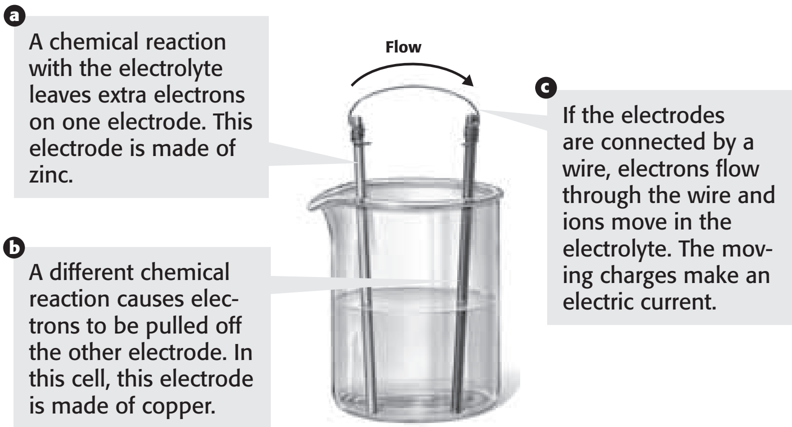


One interesting property of superconductors is that they repel magnets. The superconductor in this photograph is repelling the magnet so strongly that the magnet is floating.

How Do We Generate Electrical Energy?

Recall that energy cannot be created or destroyed. It can only be changed into other kinds of energy. Many things change energy into electrical energy. For example, generators convert mechanical energy (the energy of motion) into electrical energy. **Cells** convert chemical energy or radiant energy from the sun into electrical energy. Batteries are made of one or more cells.

How a Cell Works



TAKE A LOOK

10. Identify What are the parts of a cell?

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PARTS OF A CELL

A cell, such as the one in the picture above, contains a mixture of chemicals called an *electrolyte*. Electrolytes allow charges to flow. Every cell also has a pair of electrodes made from conducting materials. Charges enter or exit electrodes through wires. Chemical changes between the electrolyte and the electrodes convert chemical energy into electrical energy.

KINDS OF CELLS

Two kinds of cells are wet cells and dry cells. Wet cells, such as the one above, have liquid electrolytes. A car battery is made of several wet cells that use sulfuric acid as the electrolyte. You can make your own wet cell by poking strips of zinc and copper into a lemon. When the metal strips are connected, the cell generates enough electrical energy to run a small clock or light a small light. ☑

Dry cells work in a similar way. But the electrolytes in dry cells are solid or like paste. Radios and flashlights use batteries with dry cells.

READING CHECK

11. Name What are two kinds of cells?

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PHOTOCELLS

If you look at a solar-powered calculator, you will see a dark strip called a *solar panel*. This panel is made of several photocells. A **photocell** converts light energy into electrical energy. How do photocells work? Most photocells contain silicon atoms. As long as light shines on the photocell, electrons gain enough energy to move between atoms. The electrons can move through a wire to provide electrical energy to power a device, such as a calculator. ☑

With larger panels, photocells can provide energy to buildings and cars. Large panels of photocells are even used on satellites. Photocells change light energy from the sun into electrical energy to power the many devices on the satellite.

READING CHECK

12. Name What device changes light energy into electrical energy?

____

THERMOCOUPLES

We can change thermal energy (heat energy) into electrical energy with a **thermocouple**. The picture below shows a simple thermocouple. You can make a thermocouple by joining wires made of two different metals into a loop. The temperature difference in the loop causes charges to flow through the loop. You must heat one part of the loop and cool the other. The greater the temperature difference, the greater the current. ☑

Thermocouples do not usually generate much energy. But, they are useful for monitoring the temperatures of car engines, furnaces, and ovens.

READING CHECK

13. Name What device changes heat energy into electrical energy?

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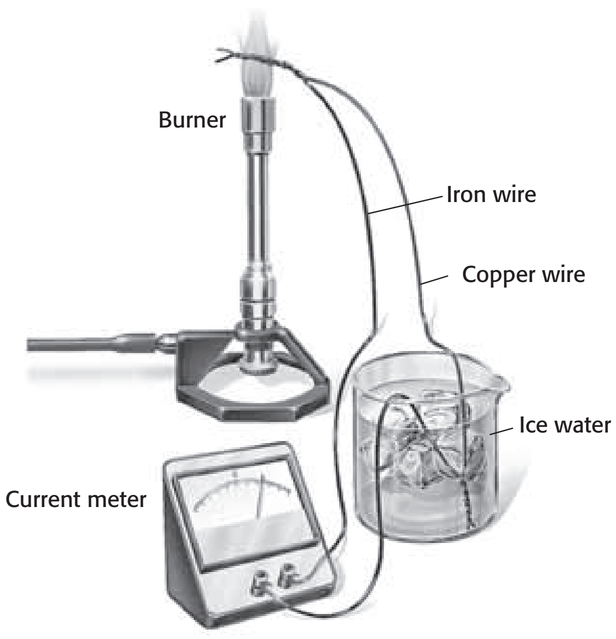


In a simple thermocouple, one section of the loop is heated and one section is cooled. The current meter shows that an electric current is produced.

Section 2 Review

NSES PS 3a

SECTION VOCABULARY

cell in electricity, a device that produces an electric current by converting chemical or radiant energy into electrical energy

electric current the rate at which charges pass through a given point; measured in amperes

photocell a device that converts light energy into electrical energy

resistance in physical science, the opposition presented to the current by a material or device

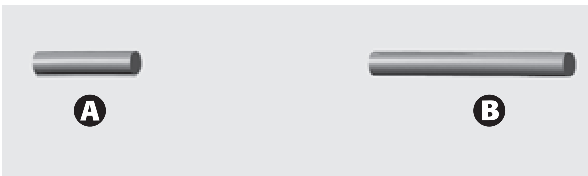
thermocouple a device that converts thermal energy into electrical energy

voltage the potential difference between two points; measured in volts

1. **Explain** Cells can convert what types of energy to make an electrical current?

____

2. **Apply Concepts** The two wires below are made of copper. They also have the same temperature. Which wire has the lower resistance? How can you tell?



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3. **Describe** What is the difference between alternating current and direct current? What type of current runs in the wires of your house?

____

____

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4. **Describe** How does increasing resistance affect the current?

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5. **Make Inferences** How does the current from a 1.5 V flashlight battery compare to the current from a 12 V car battery? Explain.

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6. **Describe** What are the three factors that would give a piece of copper wire high resistance?

____

Name ______________________ Class ____________ Date ____________

CHAPTER 17 Introduction to Electricity

SECTION 3

Electrical Calculations

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is Ohm's Law?
- What is electric power?
- How much energy do electrical devices use?

National Science Education Standards

PS 3a

How Do Current, Voltage, and Resistance Relate?

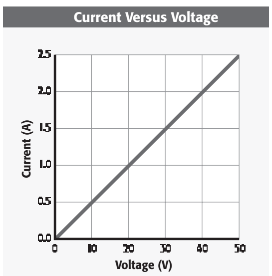
In the previous section, you learned that we use the word "ohm" to discuss resistance. The word comes from the name of a German schoolteacher named George Ohm (1789–1854). He studied the resistance of materials.

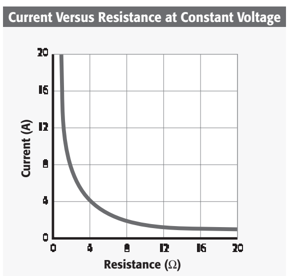
STUDY TIP

Summarize in Pairs Read this section silently. With a partner, take turns summarizing the material. Stop to talk about ideas that confuse you.

OHM'S LAW

Ohm measured the current produced when different voltages were applied to a piece of metal wire. In another experiment, he applied one voltage to wires of different resistances and measured the current. The graphs below are similar to the graphs of his results.





The relationship between current and voltage is a direct relationship. The relationship between current and resistance is an inverse relationship.

Math Focus

1. Identify When the voltage doubles, what happens to the current?

____

In the first graph, as voltage increases, current increases. In the second graph, as the resistance goes up, the current goes down. Notice that if you multiply the current and the resistance for any point on the second graph, you get 16. This is actually 16 volts. It is the voltage he used to make this graph.

Ohm found that the ratio of voltage (V) to current (I) is a constant for each material. This ratio is the resistance (R) of the material. When the voltage is expressed in volts (V) and the current is in amperes (A), the resistance is in ohms (Ω). The equation below is called *Ohm's law.* ☑

$$V = I \times R$$

READING CHECK

2. Identify What is the ratio of voltage to current called?

____

Math Focus

3. Calculate Use Ohm's law to find the voltage if the current is 2 A and the resistance is 12 Ω. Show your work.

USING OHM'S LAW

When using Ohm's law to solve a problem, show your work. Let's try a problem. The resistance of an oven is 20 Ω and the current is 15 A. What voltage is being used?

Step 1: Write the equation: $V = I \times R$
Step 2: Put the values in the problem into the equation:
$V = 15\ \text{A} \times 20\ \Omega = 300\ \text{V}$

Math Focus

4. Calculate How much power is supplied by a 12 V car battery starting a car using 700 A? Show your work.

What Is Electric Power?

Electric power is the rate at which electrical energy is changed into other forms of energy. The unit for power is the *watt* (W). The symbol for power is *P*. We express electric power in watts when the voltage is in volts and the current is in amperes. Use this equation to calculate electric power: *power = voltage × current*, or $P = V \times 1$.

Let's try a problem. How much power is given off by a toaster with a voltage of 120 V and a current of 8 A?

Step 1: Write the equation: $P = V \times I$
Step 2: Put the values in the problem into the equation:
$P = 120\ \text{V} \times 8\ \text{A} = 960\ \text{W}$

STANDARDS CHECK

PS 3a Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.

5. Explain Why does a 60 W light bulb give off a brighter light than a 40 W bulb?

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WATT: THE UNIT OF POWER

If you have ever changed a light bulb, you probably know about watts. Light bulbs, like the ones in this photo, have labels such as "60 W," "75 W," or "100 W." That tells you how quickly the bulb uses energy. A 100 W bulb glows brighter than a 60 W bulb because it uses energy more quickly.

These light bulbs have different wattages, so they use different amounts of electric power.

READING CHECK

6. Identify What are two common units for electric power?

____

Another common unit of power is the *kilowatt* (kW). One kilowatt is equal to 1,000 W. We use kilowatts to express high values of power, such as the power needed to heat a house. ☑

How Do We Measure Electrical Energy?

Electrical energy is determined by how much power is used and for how long. For example, the amount of electricity used in your home depends on the appliances used and the time of use. The equation for electrical energy is:

$$\textit{electrical energy} = \textit{power} \times \textit{time}, \text{ or } E = P \times t$$

Let's try a problem. How much energy is used to heat a frozen dinner in a 1500 W oven for 360 s?

Step 1: Write the equation: $E = P \times t$
Step 2: Put the values in the problem into the equation:
$E = 1500 \text{ W} \times 360 \text{ s} = 540{,}000 \text{ J}$

Math Focus

7. Calculate How much energy is given off by a 30 W fluorescent light in 3600 s (1 hour)? Show your work.

MEASURING HOUSEHOLD ENERGY USE

Electric power companies sell electricity to homes and businesses. We use different amounts of electrical energy each day in our homes. Electric companies usually calculate electrical energy by multiplying the power in kilowatts by the time in hours (kWh). If 2,000 W (2 kW) of power are used for 3 h, then 6 kWh (kilowatt-hours) of energy were used.

Electric power companies use meters, such as the one below, to determine how many kilowatt-hours of energy a household uses.

Math Focus

8. Calculate How many kilowatt-hours of electricity are used by a 5,000 W air conditioner used for 8 hours? Show your work.

The electric company reads the dials on an electric meter at two times about one month apart. The difference between the two readings is how much electric energy was used, in kWh.

HOW TO SAVE ENERGY

Every appliance uses energy, but some use much more than others. A fan, for example, could help you save energy. If you use a fan, you can run an air conditioner less often.

You can also replace items that use a lot of power with things that use less. For example, a new furnace will usually use less power than an old one. You can save energy by turning off unnecessary lights or by turning down the heat in your home. ☑

READING CHECK

9. List What are three ways to save energy at home?

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Name ________________ Class ________________ Date ________________

Section 3 Review

NSES PS 3a

SECTION VOCABULARY

electric power the rate at which electrical energy is converted into other forms of energy	

1. Identify Circuit A has twice the resistance of circuit B. The voltage is the same in each circuit. Which circuit has the higher current?

____

2. Apply Concepts As you turn on appliances in your home, you use more electrical energy. The voltage stays the same. Complete the following to show what is happening when you turn on an appliance.

		Current	→	
Electrical circuit	Hairdryer turned on →	Voltage	→	
		Resistance	→	Decreases
		Energy use	→	

3. Calculate Use Ohm's law to find the voltage needed to make a current of 3 A in a resistance of 9 Ω. Show your work.

4. Calculate How much electrical energy, in kilowatt-hours, does a 200 W light bulb use if it is left on for 12 h? Show your work.

5. Apply Concepts Why does increasing the voltage of a wire have the same effect on the current that decreasing the resistance has?

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SECTION 4

Electric Circuits

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What are the three main parts of a circuit?
- What is the difference between series circuits and parallel circuits?
- How do fuses and circuit breakers protect your home?

National Science Education Standards

PS 3d

What Are the Parts of an Electric Circuit?

Think about a roller coaster. The roller coaster starts out slow and easy. Then, it roars around the track. A few minutes later, the ride ends right where it started. The ride starts and ends in the same place. This kind of closed path is called a *circuit*.

It's the same with an electrical circuit. It always forms a loop. Notice that the word "circuit" is a little like the word "circle." Because a circuit forms a loop, a circuit is a closed path. So, an *electric circuit* is a complete, closed path with electric charges flowing through it.

All circuits need three basic parts: an energy source such as a battery, wires, and a *load*. Loads—such as a light bulb or oven—connect to the energy source by wires.

Loads change electrical energy into other forms of energy. These other forms might include heat, light, or mechanical energy. Loads change electrical energy into other forms because of their resistance to electric currents. The picture below shows the parts of a simple circuit. ☑

STUDY TIP

Compare Make a Venn Diagram comparing series and parallel circuits.

READING CHECK

1. Identify What are the three parts of an electric circuit?

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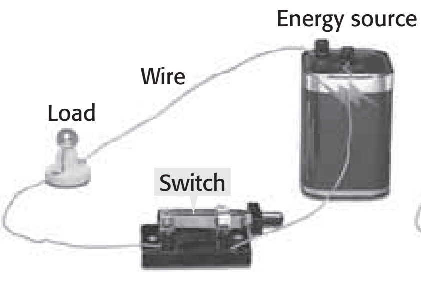
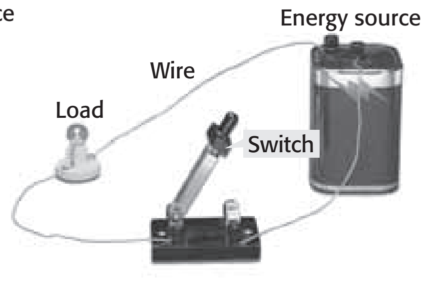
When the *switch is closed*, the metal blades and contacts on the switch touch. This allows the electric charges to flow through the circuit.



When the *switch is open*, the metal blades and contacts on the switch no longer touch. This stops the electric charges from flowing through the circuit.



TAKE A LOOK

2. Identify Below each switch, label the circuit as a closed circuit or an open circuit.

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STANDARDS CHECK

PS 3d Electrical circuits provide a means of transferring electrical energy when heat, light, sound, and chemical changes are produced.

3. Describe What do loads do?

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A SWITCH TO CONTROL A CIRCUIT

Most circuits have one or more switches. As you have seen, a switch opens and closes a circuit. It is usually made of two pieces of conducting material. One of the pieces moves.

For charges to flow through a circuit, the switch must be closed, or "turned on." If the switch is open, or "off," the loop of the circuit is broken. Charges cannot flow through a broken circuit. Light switches, power buttons on radios, and even the keys on a computer keyboard open and close circuits.

What Are the Types of Circuits?

Look around the room. Count the number of objects that use electricity. You may find lights, a clock, a computer, or other appliances. All of the things you count are loads in a large circuit.

The loads in a circuit can be connected in different ways. As a result, circuits come in two types: *series circuits* and *parallel circuits*. One of the main differences in these circuits is the way that the loads are connected to each other. As you read about each type of circuit, look at how the loads connect. ☑

READING CHECK

4. Identify What are two kinds of circuits?

____

SERIES CIRCUITS

In a **series circuit**, all the parts connect in a single loop. There is only one path for charges to follow. So the charges moving through a series circuit must flow through each part of the circuit. ☑

READING CHECK

5. Describe How are loads connected in a series circuit?

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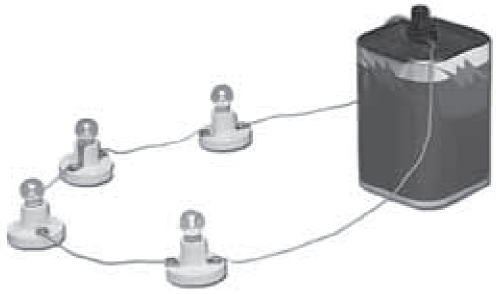
All of the loads in a series circuit share the same current. The four identical light bulbs in the figure below join in a series. Because the current in each bulb is the same, the lights glow with the same brightness. However, if you add more light bulbs, the resistance of the whole circuit goes up. This causes the current in the circuit to drop, so all of the bulbs will dim.



In a series circuit, the same current flows through each light bulb (load) and back to the battery.

USES FOR SERIES CIRCUITS

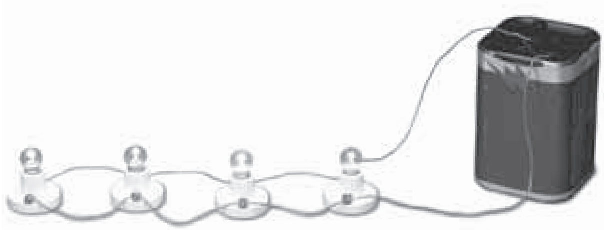
Series circuits have only one path for moving charges. So, if there is any break in the circuit, the current stops. For example, if one light bulb in a series circuit burns out, the circuit breaks. None of the light bulbs in the circuit will light. ☑

Using series circuits would not be a very good way to wire your home. Imagine if your refrigerator and a lamp were in a circuit together. Your refrigerator would run only when the lamp was on. And, if the bulb burned out, the refrigerator would stop working!

However, series circuits are useful in some ways. For example, we use series circuits to wire burglar alarms. If any part of the circuit in a burglar alarm fails, the current stops. The lack of current signals that a problem exists, and the alarm will sound.

PARALLEL CIRCUITS

Instead of being wired in a series, circuits in buildings and houses are wired in parallel. A **parallel circuit** is a circuit in which loads are connected side by side. Current in a parallel circuit flows through more than one path. ☑



In a parallel circuit, current flows from the battery and travels a path through each bulb. The current then flows back to the battery. If one bulb is unscrewed, the other three continue to glow at full brightness.

Unlike the loads in a series circuit, the loads in a parallel circuit do not have the same current. Instead, each load in a parallel circuit uses the same voltage. For example, each bulb in the figure above uses the full voltage of the battery. As a result, each light bulb glows at full brightness. If more bulbs are connected in parallel, all will glow at full brightness.

You can connect loads that need different currents to the same parallel circuit. For example, a hair dryer, needing high current, can be connected to a circuit with a lamp, needing less current.

READING CHECK

6. Explain What causes all of the lights in a series circuit to go out, if one burns out?

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Critical Thinking

7. Explain Why are series circuits not a good way to wire your home?

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READING CHECK

8. Describe How does the current in a parallel circuit flow?

____

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Critical Thinking

9. Explain Why do we use parallel circuits in household wiring?

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USES FOR PARALLEL CIRCUITS

In a parallel circuit, each path of the circuit can work by itself. If one load is broken or missing, the charges will still run through the other paths. So, the loads on those paths will keep working.

In your home, each electrical outlet is usually on its own path and has its own switch. With a parallel circuit, you can use a light or appliance, even if another stops working.

How Do We Make Circuits Safe?

In every home, several circuits connect all of the lights, appliances, and outlets. The circuits come from a *breaker box* or a *fuse box* that acts as the "electrical center" for the building. Each part of the circuit is called a *branch*. In the United States, most branches are 120 V. ☑

READING CHECK

10. Identify What is the name given to each part of a circuit coming from a beaker box or fuse box?

____

CIRCUIT FAILURE

Broken wires or water can cause a *short circuit*. In a short circuit, charges do not go through one or more loads in the circuit. The resistance decreases, so the current increases. The wires can heat up, and the circuit could fail. The wires might even get hot enough to start a fire.

Circuits also may fail if they are overloaded. When too many loads are in a circuit, the current increases, and a fire might start. Safety features, such as fuses and circuit breakers, help prevent electrical fires. ☑

READING CHECK

11. Identify What are two safety devices used in circuits?

____

The blown fuse on the left must be replaced with a new fuse, such as the one on the right.

FUSES

A fuse has a thin strip of metal. It is placed in the wiring at the beginning of a circuit. The electrons in the circuit flow through this strip. If the current is too high, the metal strip melts. As a result, the circuit breaks and charges stop flowing. To make the current flow again, you must find out what made the current too high. Sometimes too many appliances are running at the same time. Then, you must put in a new fuse.

CIRCUIT BREAKERS

Circuit breakers, like fuses, stop the current if it is too high. A circuit breaker is a switch that automatically opens if the current is too high. A strip of metal in the breaker warms up, bends, and opens the switch, which opens the circuit. Charges stop flowing. You can close an open circuit breaker by flipping its switch after the problem has been fixed. ☑

A *ground fault circuit interrupter* (GFCI), shown in the figure below, acts as a small circuit breaker. The GFCI opens the circuit if the currents on both sides of the circuit are different. To close the circuit, you must push the reset button found in the middle of the GFCI switch.

READING CHECK

12. Describe How can a circuit breaker be made to work after it has opened?

____

GFCIs are often found on outlets in bathrooms and kitchens to protect you from electric shock.

ELECTRICAL SAFETY TIPS

You use electrical devices every day. So it is important to remember that using electricity can be hazardous. Warning signs, such as the ones below, can help you avoid electrical dangers. To stay safe when you use electricity, follow these tips:

- Make sure the insulation on cords is not worn.
- Do not overload circuits by plugging in too many appliances.
- Do not use electrical devices while your hands are wet or while you are standing in water.
- Never put objects other than a plug into an electrical outlet.

Say It

Identify Discuss some of the electrical problems you have experienced with a partner. Could any of the safety tips have helped avoid the problems?

Obeying signs that warn of high voltage can keep you safe from electrical dangers.

Name ________________ Class ________________ Date ________________

Section 4 Review

NSES **PS 3d**

SECTION VOCABULARY

parallel circuit a circuit in which the parts are joined in branches such that the potential difference across each part is the same	**series circuit** a circuit in which the parts are joined one after another such that the current in each part is the same

1. **Describe** What three parts must be present in a circuit for it to work correctly?

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____

2. **Interpret Graphics** Look at the circuits below. Label each circuit as a series circuit or a parallel circuit. Label the following parts on Circuit A: energy source, load, and wires.

________________________ ________________________

3. **Explain** How do fuses and circuit breakers protect your home against electrical fires?

____

4. **Infer** Suppose that you turn on the heater in your room and all of the lights in your room go out. Why would the lights go out?

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5. **Identify** Which part of a circuit changes electrical energy into another form of energy?

____

6. **Identify** Which safety tip should you use if you have a overloaded circuit?

____

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Name ______________________ Class ______________ Date ____________

CHAPTER 18 Electromagnetism

SECTION 1

Magnets and Magnetism

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What are the properties of magnets?
- Why are only some materials magnetic?
- What are four kinds of magnets?
- What are two examples of the effect of the Earth's magnetic field?

National Science Education Standards

PS 3a

What Are the Properties of Magnets?

Have you ever experimented with magnets? If so, you know that they can stick to each other and to some kinds of metal. You also know that magnets can stick to things without touching them directly. For example, a magnet sticks to a refrigerator door even with a piece of paper in between. They are not really sticky, so what makes things cling to them?

More than 2,000 years ago, the Greeks discovered a mineral that attracted things made of iron. They found it in a part of Turkey called Magnesia, so the Greeks called it *magnetite*. Today, we call any material that attracts iron or things made of iron a **magnet**. All magnets have certain properties. For example, all magnets have two poles. Magnets exert forces on each other. Last, all magnets are surrounded by magnetic fields. ☑

STUDY TIP

Predict Before reading this section, predict whether each of the following statements is true or false:

- Every magnet has a north pole and a south pole.
- The magnetic pole near the Earth's South Pole is a north pole.

READING CHECK

1. List What are three properties of a magnet?

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MAGNETIC POLES

More paper clips stick to the ends, or magnetic poles, of the magnet because the magnetic forces are strongest there.

Magnetic effects are not the same throughout the magnet. What happens when you put a bar magnet into a box of paper clips? Most of the clips stick to the ends of the magnet. The strongest magnetic forces occur near the ends of the bar magnet. Each end of the magnet is a magnetic pole. **Magnetic poles** are points on a magnet that have opposite magnetic qualities. ☑

READING CHECK

2. Describe What are magnetic poles?

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NORTH AND SOUTH

Suppose you hang a magnet by a string so that the magnet can rotate. You will see that one end of the magnet always points toward north. A compass is a suspended magnet. The pole of the magnet that points toward north is called the magnet's *north pole*. The opposite end of the magnet points toward south. It is called the magnet's *south pole*. Magnetic poles are always in pairs. You will never find a magnet that has only one pole. ☑

READING CHECK

3. Identify What is the name of a magnet's pole that points north?

____

The needle in a compass is a magnet that is free to rotate.

TAKE A LOOK

4. Describe What is a compass?

____

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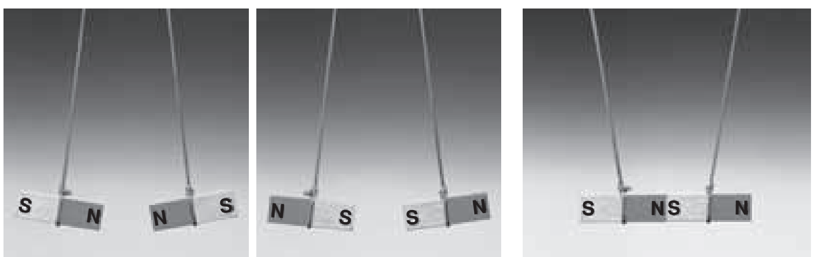
MAGNETIC FORCES

When you bring two magnets close together, the magnets exert a magnetic force on each other. **Magnetic force** can either push the magnets apart or pull them together. This force comes from spinning electric charges in the magnets. The force is a *universal* force. That means it is always present when magnetic poles come near each other. ☑



▲ If you hold the north poles of two magnets close together, the magnetic force will push the magnets apart. The same is true if you hold two south poles close together.

▲ When the north pole of one magnet is close to the south pole of another, magnetic force pulls the magnets together.

TAKE A LOOK

5. Describe What are two ways two magnets can be placed to show them repelling each other?

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The magnetic force between magnets depends on how the poles of the magnets line up. Poles that are the same repel. So if you put two south poles together, they push apart. Opposite poles attract, as you can see in the pictures above.

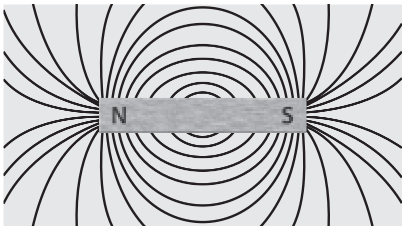
MAGNETIC FIELDS

A magnetic field exists in the region around a magnet in which magnetic forces can act. We can show the shape of a magnetic field with lines drawn from the north pole of a magnet to the south pole. ☑

READING CHECK

6. Describe Magnetic field lines point in what direction?

____



Magnetic field lines show the shape of the magnetic field around a magnet.

These lines map out the magnetic field and are called *magnetic field lines*. The closer together the field lines are, the stronger the magnetic field is. The lines around a magnet are closest together at the poles. That's where the magnetic force on an object is strongest. ☑

READING CHECK

7. Describe When looking at magnetic field lines, how can you tell where the field is strongest?

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What Causes Magnetism?

Some materials are magnetic. Some are not. For example, a magnet can pick up paper clips and iron nails. But it cannot pick up paper, plastic, pennies, or aluminum foil. Whether a material is magnetic depends on the material's atoms.

ATOMS AND DOMAINS

All matter is made of atoms. Electrons are negatively charged particles of atoms. As an electron moves around, it creates a magnetic field. The atom has a north and south pole. In materials that are not magnetic, magnetic fields of the atoms cancel each other out.

But in materials such as iron, nickel, and cobalt, groups of atoms are in tiny areas called *domains*. The north and south poles of the atoms in a domain line up and make a strong magnetic field. Domains are like tiny magnets of different sizes within an object. Most of the domains must line up for the object to be magnetic. ☑

READING CHECK

8. Explain Why is iron magnetic, but copper and aluminum are not?

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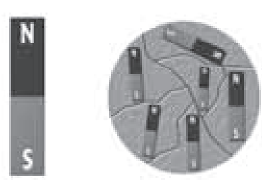
If the domains in an object are not aligned, the magnetic fields cancel. The object is not magnetic.



If the domains in an object are aligned, the magnetic fields combine. The object is magnetic.

LOSING ALIGNMENT

The figure on the previous page shows how domains work. If the domains line up, the object has a magnetic field. But the domains of a magnet may not always stay lined up. When domains move, the magnet is *demagnetized*. It loses its magnetic properties.

A magnet can lose its magnetic properties if you:

- drop or hit the magnet
- put the magnet in a strong magnetic field that is opposite to its own
- heat up the magnet (which makes the atoms vibrate faster).

Any one of the above actions can change the domains so they are no longer in line. ☑

READING CHECK

9. Describe What are two ways a magnet can lose its magnetic properties?

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MAKING MAGNETS

You can make a magnet out of, or *magnetize*, iron, cobalt, or nickel. You just need to line up the domains in it. For example, you can magnetize an iron nail if you rub it in one direction with one pole of a magnet. The domains in the nail line up with the magnetic field of the magnet. So the domains in the nail get in line. As more domains line up, the magnetic field of the nail grows stronger.

The process of making a magnet also explains how a magnet can pick up an object that is not magnetic. Bring a magnet close to a paper clip. Some domains in the paper clip line up with the field of the magnet. So the paper clip becomes a temporary magnet.

The north pole of the paper clip points toward the south pole of the magnet. The paper clip is attracted to the magnet. When the magnet is removed, the domains of the paper clip will become scrambled again.

Critical Thinking

10. Explain How is magnetizing an object the opposite of demagnetizing a magnet?

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This nail was magnetized by dragging a magnet down it many times.

TAKE A LOOK

11. Identify If the tip of the nail is a north pole, what is the pole on the end of the attached paper clip?

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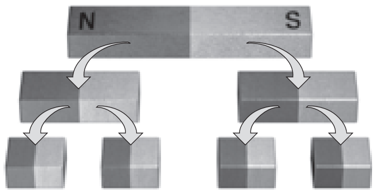
CUTTING A MAGNET

What do you think would happen if you cut a magnet in half? You might think that you would end up with one north-pole piece and one south-pole piece. But that's not what happens. Instead, when you cut a magnet in half, you get two magnets. Each piece has its own north and south pole. The picture below shows what happens when a magnet is cut.



If you cut a magnet in pieces, each piece will still be a magnet with two opposite poles.

A magnet has poles because its domains are lined up. Each domain within a magnet is like a tiny magnet with a north pole and a south pole. So even the smallest pieces of a magnet have two poles. ☑

READING CHECK

12. Explain Why do even the smallest magnets have two poles?

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What Kinds of Magnets Are There?

There are different ways to describe magnets. Some magnets are made of iron, nickel, cobalt, or mixtures of those metals. Magnets made with these metals have strong magnetic properties and are called *ferromagnets*. The mineral magnetite (which has iron in it) is an example of a natural ferromagnet. ☑

Another kind of magnet is the *electromagnet*. This is a magnet made by an electric current through a coil of wire. An electromagnet usually has an iron core.

READING CHECK

13. Define What is a ferromagnet?

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TEMPORARY AND PERMANENT MAGNETS

We also describe magnets as temporary or permanent. *Temporary magnets* are made from materials that are easy to magnetize. Something that is *temporary* does not last as long time. Temporary magnets lose their magnetization easily. Soft iron makes a good temporary magnet.

Permanent magnets are difficult to magnetize. However they keep their magnetic properties longer than temporary magnets. *Permanent* means something lasts or stays the same. Some permanent magnets are made with alnico, an alloy of aluminum, nickel, cobalt, and iron.

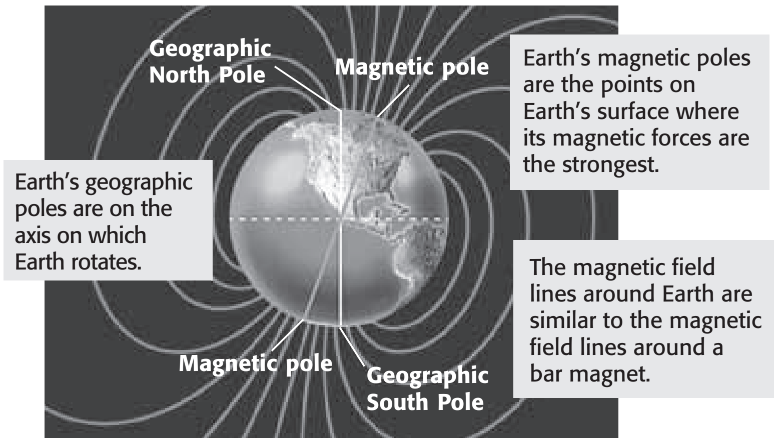
How Does the Earth Work as a Magnet?

Tie a string around a magnet so when the end of the string is held, the magnet is free to rotate. One end of the magnet will point north. For more than 2,000 years, travelers have used this property to find their way. You use it when you use a compass because a compass has magnet that is free to rotate.

ONE GIANT MAGNET

In 1600, an English doctor named William Gilbert suggested that magnets point to the north because Earth is one giant magnet. Earth really does act as if it has a bar magnet running through its center. The poles of this imaginary magnet are located near Earth's *geographic* poles. Geographic poles are the poles you see on maps.

Earth's Geographic and Magnetic Poles



TAKE A LOOK

14. Identify What are the magnetic field lines around Earth similar to?

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POLES OF A COMPASS NEEDLE

If you put a compass near a bar magnet, the marked end of the needle points to the south pole of the magnet. Does that surprise you? Remember that opposite poles of magnets attract each other. A compass needle is really a small magnet. The tip that points to the north is the needle's north pole. Therefore, the point of a compass needle moves toward the south pole of the magnet.

SOUTH MAGNETIC POLE NEAR NORTH GEOGRAPHIC POLE

A compass needle points north. This is because the magnetic pole of Earth that is closest to geographic north is a magnetic south pole. A compass needle points north because its north pole is attracted to the Earth's very large magnetic south pole. ☑

READING CHECK

15. Identify Is Earth's north pole a magnetic north pole or a magnetic south pole?

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THE CORE OF THE MATTER

Earth may act as if it has a giant bar magnet through its center, but there isn't really a magnet there. The temperature of Earth's core (or center) is very high. That makes the atoms in it move too violently to stay lined up in domains.

Scientists think that the movement of electric charges in the Earth's core creates Earth's magnetic field. The Earth's core is made mostly of iron and nickel. Great pressure makes Earth's inner core solid. The outer core is liquid because the pressure is not as high. As Earth rotates, the liquid in the core flows. That makes electric charges move, which makes a magnetic field. ☑

READING CHECK

16. Explain What do scientists think causes Earth's magnetic field?

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A MAGNETIC LIGHT SHOW

The beautiful curtain of light in the picture below is called an *aurora*. Earth's magnetic field plays a part in making auroras. An aurora forms when charged particles from the sun hit oxygen and nitrogen atoms in the air. The atoms become excited and then give off light of many colors.

Earth's magnetic field blocks most of the charged particles from the sun. However, the field bends inward at the magnetic poles. This causes the charged particles from the sun to enter the atmosphere at and near the poles. We see auroras near Earth's North Pole. They are called the northern lights, or *aurora borealis*. Auroras near the South Pole are called the southern lights, or *aurora australis*. ☑

READING CHECK

17. Identify What causes charged particles from the sun to bend inwards after entering the atmosphere?

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An aurora is an amazing light show in the sky.

Name ______________________ Class ______________ Date ____________

Section 1 Review

NSES NSES PS 3a

SECTION VOCABULARY

magnet any material that attracts iron or materials containing iron **magnetic force** the force of attraction or repulsion generated by moving or spinning electric charges	**magnetic pole** one of two points, such as the ends of a magnet, that have opposing magnetic qualities

1. **Describe** How do you make a metal object such as a nail into a magnet? What happens to make it magnetic?

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2. **Interpret Graphics** Which magnetic pole is closest to the geographic North Pole?

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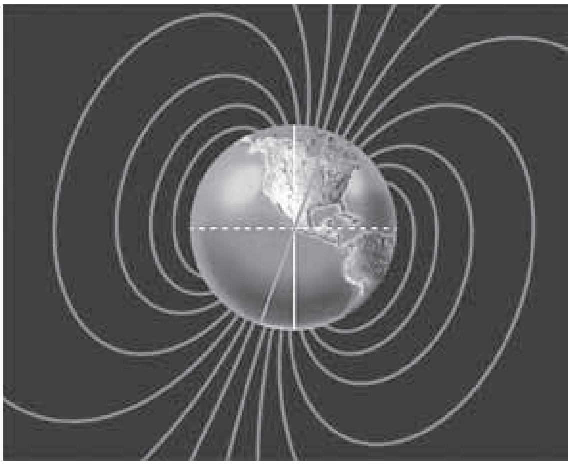

3. **Explain** Is the magnetic field of Earth stronger near the equator or near the South Pole? Why?

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4. **Explain** Why are some objects magnetic and others are not?

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5. **Identify** If a material is difficult to magnetize but stays magnetized, what kind of magnet is it?

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6. **Infer** Why would heating a magnetic demagnetize it?

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SECTION 2

Magnetism from Electricity

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- How are an electric current and a magnetic field related?
- What are solenoids and electromagnets?
- How does electromagnetism run doorbells, electric motors, and galvanometers?

National Science Education Standards
PS 3a

How Was Electromagnetism Discovered?

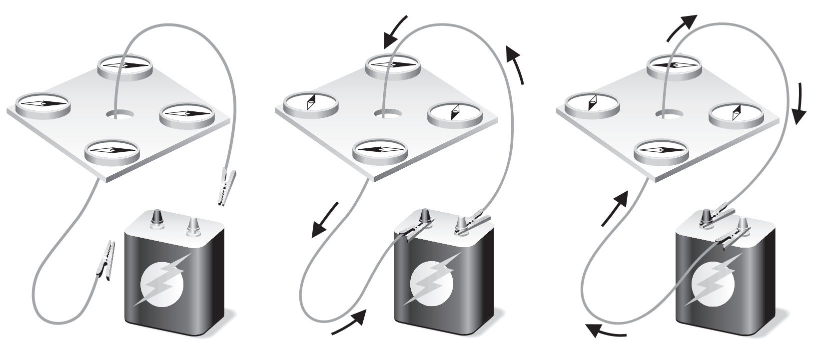
Many things around you—doorbells and motors, for example—use electricity to make magnetism. In this section, you will learn how electricity and magnetism are related and how we make electromagnets.

Danish physicist Hans Christian Oersted discovered how electricity and magnetism are related in 1820. While teaching a class, he held a compass near a wire carrying an electric current. When the compass was brought close to the wire, the compass needle moved. It no longer pointed to the north. He had accidentally discovered that electricity and magnetism are related.

A compass needle is a magnet. It moves from its north-south position only when it is in a magnetic field different from Earth's. Oersted tried a few experiments with the compass and the wire. He learned that electric current produces a magnetic field. That made the needle of the compass line up with the direction of the magnetic field. The picture below shows how his experiments worked.

STUDY TIP

Compare As you read this section, make a table to compare solenoids and electromagnets.



a If no electric current is in the wire, the compass needles point in the same direction.

b Electric current in one direction causes two compass needles to deflect in a clockwise direction.

c Electric current in the opposite direction causes the two compass needles to deflect in a counter-clockwise direction.

TAKE A LOOK

1. Describe Why does a compass needle move when it is near a wire with an electric current running though it?

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MORE RESEARCH

Oersted also found that the direction of the magnetic field depends on the direction of the current. The French scientist André-Marie Ampère heard about Oersted's findings. Ampère did more research with electricity and magnetism. Their work was the first research into electromagnetism. **Electromagnetism** is the interaction between electricity and magnetism. ☑

READING CHECK

2. Define What is electromagnetism?

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How Do We Use Electromagetism?

The magnetic field produced by an electric current in a wire can move a compass needle. But the magnetic field is not strong enough to be very useful. However, two devices, the solenoid and the electromagnet, make the magnetic field stronger. They make electromagnetism more useful.

SOLENOIDS

A single loop of wire that carries a current does not have a very strong magnetic field. But if you form many loops into a coil, it makes the magnetic field stronger. The magnetic fields of the loops work together.

The picture below shows a solenoid. A **solenoid** is a coil of wire that produces a magnetic field when an electric current runs through it. The magnetic field around a solenoid is very similar to the magnetic field of a bar magnet. The magnetic field of a solenoid gets stronger if it has more loops. The magnetic field also becomes stronger as the current in the wire increases. ☑

READING CHECK

3. Identify What are two things you can do to make the magnetic field of a solenoid stronger?

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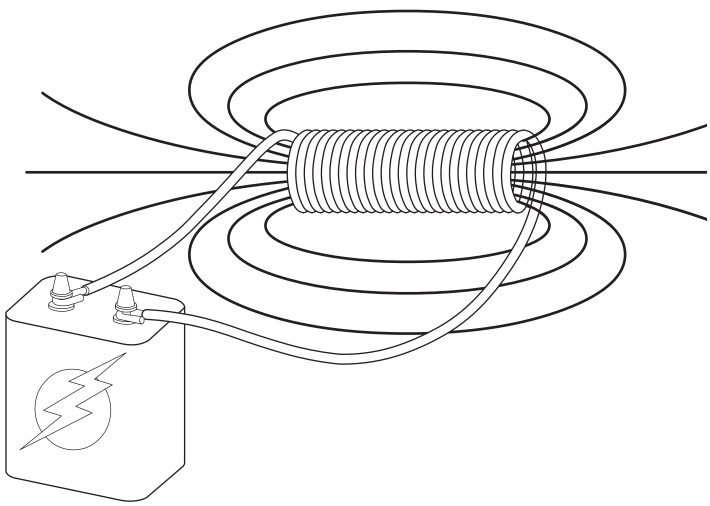

The ends of the solenoid are like the poles of a bar magnetic.

ELECTROMAGNETS

We can make magnets with an even stronger magnetic field than one made by a solenoid. Electromagnets can make a train float! An **electromagnet** is made up of a solenoid wrapped around an iron core. It acts as a magnet when an electric current runs through the coil. The magnetic field of the solenoid makes the domains inside the iron core line up.

The magnetic field of the electromagnet is the field of the solenoid plus the field of the magnetized core. As a result, the magnetic field of an electromagnet may be hundreds of times stronger than the magnetic field of just the solenoid. You can make an electromagnet stronger by increasing the number of loops per meter in the solenoid. You can also increase the electric current in the wire. ☑

Engineers have developed trains called *maglev* trains that use electromagnetism. Maglev is a short name for *magnetic levitation*. Instead of rolling on wheels over the tracks, these trains *levitate*, or float, above the track. How? Remember what happens when you bring two magnets close together—the magnets exert a magnetic force on each other. In maglev trains, powerful electromagnets in the rails repel strong magnets on the train cars.

READING CHECK

4. Explain Why is the magnetic field of an electromagnet stronger than a solenoid?

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Electromagnets used in salvage yards are turned on to pick up iron objects and turned off to put them down.

TURNING ELECTROMAGNETS ON AND OFF

Electromagnets are very useful because we can turn them on and off. The solenoid has a field only when electric current runs through it. So electromagnets attract things only when a current exists in the wire. When no current runs through the wire, the electromagnet turns off.

Critical Thinking

5. Infer Why could an electromagnet be more useful than a permanent magnet?

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Applications of Electromagnetism

You may not ride on a maglev train, but you use electromagnetism in simple ways every day. For example, you use a solenoid when you ring a doorbell. Electromagnetism makes vending machines give you the right change. It's what makes metal detectors and motors work. An electromagnet makes the fuel gauge in a car work. ☑

READING CHECK

6. Name What are two things that operate using electromagnetism?

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DOORBELLS

Have you ever noticed a doorbell button that has a light inside? When you pushed the button, did the light go out? Two solenoids in the doorbell allow the doorbell to work.

When you push the button, it opens the circuit of the first solenoid. The current stops. That makes the magnetic field drop and the light go out. The change in the field causes a current in the second solenoid. This current induces a magnetic field that pushes an iron rod and that makes the bell ring.

MAGNETIC FORCE AND ELECTRIC CURRENT

An electric current in a wire can cause a compass needle to move. The needle is a small magnet. The needle moves because the electric current in a wire creates a magnetic field that exerts a force on the needle. ☑

READING CHECK

7. Explain Why does a wire having an electric current running through it cause a compass needle to move?

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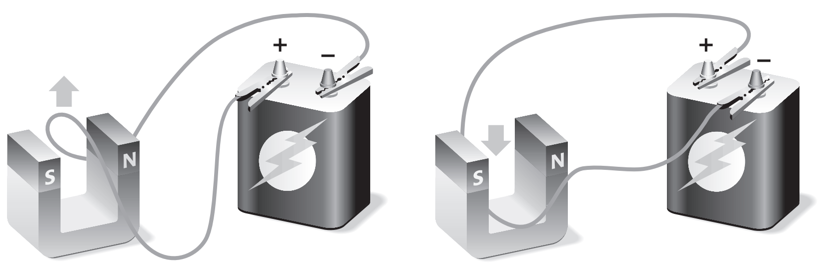
Can a magnet cause a wire that has an electric current running through it to move? The picture below shows that the answer is yes. The wire is pushed up or down depending on the direction of the current in the wire. This force makes electric motors work.



a A wire is connected to a battery as shown above. When the wire is placed between two poles of a strong magnet, the wire will move up.

b Switching the wires at the battery reverses the direction of the electric current. Now the wire will be pushed down.

ELECTRIC MOTORS

An **electric motor** is a device that changes electrical energy into mechanical energy. All electric motors have an *armature*—a loop or coil of wire that can rotate. The armature is mounted between the poles of a permanent magnet or electromagnet.

An electric motor that uses direct current, like the one below, contains a device called a commutator. It is attached to the armature to reverse the direction of the electric current in the wire.

A *commutator* is a ring that is split in half and connected to the ends of the armature. Electric current enters the armature through brushes that touch the commutator. Every time the armature and the commutator make a half turn, the direction of the current in the armature reverses.

STANDARDS CHECK

PS 3a Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.

8. Identify An electric motor changes electrical energy into what kind of energy?

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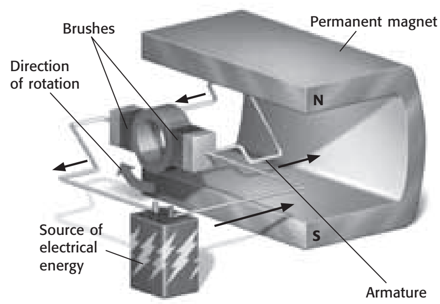
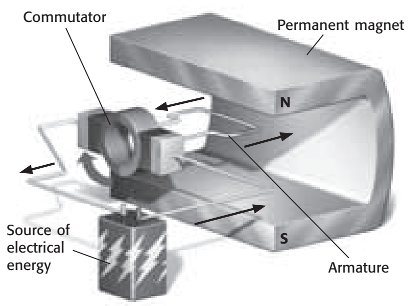
Getting Started The electric current in the armature causes the magnet to push on the armature. The current is moving in a different direction in either side of the armature. So one side is pushed up and the other side down. This causes the armature to rotate.





Running the Motor The commutator causes the electric current in the rotating armature to change directions. This causes the side that was pushed down to be pushed up and the other side to be pulled down. So the armature keeps rotating in the same direction.

GALVANOMETERS

A *galvanometer* measures current or voltage. Electricians use galvanometers when they use ammeters and voltmeters. ☑

A galvanometer has an electromagnet placed between the poles of a permanent magnet. The electromagnet is free to rotate and is attached to a pointer. A current in the galvanometer causes the permanent magnet to push the electromagnet, rotating the pointer. The pointer moves along a scale that shows the size and direction of the current, or the voltage.

READING CHECK

9. Identify What does a galvanometer measure?

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Name ______________________ Class ______________ Date ______________

Section 2 Review

NSES PS 3a

SECTION VOCABULARY

electric motor a device that converts electrical energy into mechanical energy **electromagnet** a coil that has a soft iron core and that acts as a magnet when an electric current is in the coil	**electromagnetism** the interaction between electricity and magnetism **solenoid** a coil of wire with an electric current in it

1. Describe What does an electric current through a wire produce? What affects the strength of what is produced?

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2. Interpret Graphics Which of the magnets below is a solenoid? Which one is an electromagnet? Label each one. If the current and the number of coils are the same, which of the magnets has a stronger magnetic field?

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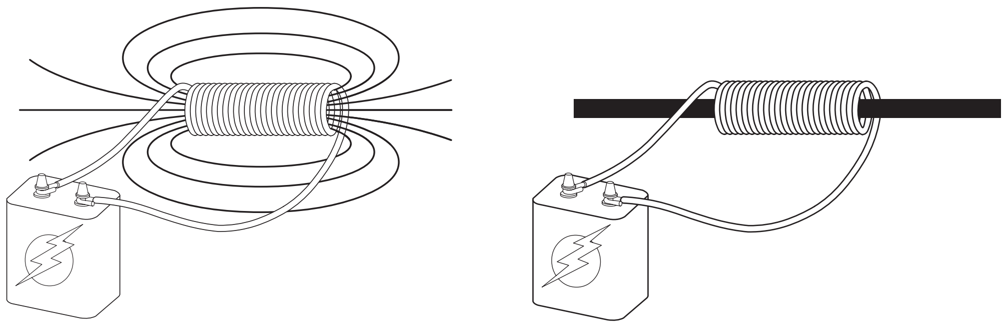

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3. Explain Why does a current in a galvanometer move a pointer?

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4. Name What are four devices that use electromagnetism?

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5. Explain What makes the armature in an electric motor rotate?

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Name ______________________ Class ______________ Date ____________

CHAPTER 18 Electromagnetism

SECTION 3

Electricity from Magnetism

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- How can a magnetic field make an electric current?
- How does a generator use electromagnetic induction?
- What are step-up and step-down transformers?

National Science Education Standards

PS 3a

How Does a Changing Magnetic Field Make an Electric Current?

Hans Christian Oersted discovered that an electric current could make a magnetic field. Soon after, scientists wondered if a magnetic field could make an electric current. In 1831, two scientists solved this problem. Joseph Henry, of the United States, made the discovery first. However, Michael Faraday, from Great Britain, published his results first. Faraday also reported them in great detail, so we know more about his results.

STUDY TIP

Summarize Read this section silently. In pairs, take turn summarizing the material. Stop to discuss ideas that seem confusing.

FARADAY'S EXPERIMENT

Faraday used a setup like the one in the picture below. The ring is an electromagnet. He hoped that the magnetic field of the electromagnet would make, or induce, an electric current in the second wire. But no matter how strong the electromagnet was, he could not make an electric current in the second wire. ☑

READING CHECK

1. Explain What was Faraday trying to do in his experiment?

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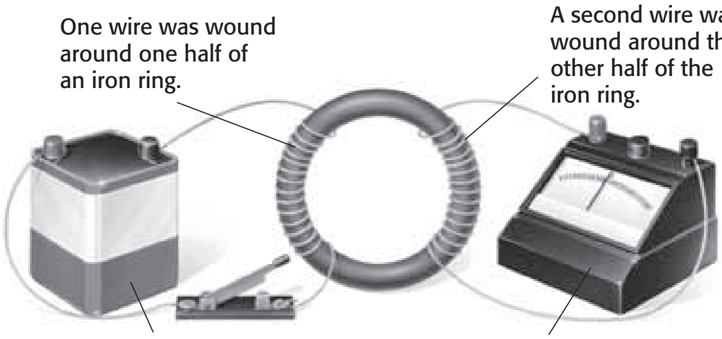
Faraday's Experiment with Magnets and Induction



SUCCESS FOR AN INSTANT

As Faraday experimented with the electromagnetic ring, he noticed something interesting. At the instant he connected the wires to the battery, the galvanometer pointer moved. This movement showed that an electric current was present. The pointer moved again at the instant he disconnected the battery. However, he did not see an electric current when the battery was fully connected.

Faraday saw that electric current in the second wire happened only when the magnetic field changed. It changed as the battery was connected and disconnected. The process of creating a current in a circuit by a changing a magnetic field is called **electromagnetic induction**. Faraday did many more experiments in this area. Some of his results are shown in the figure below. ☑

READING CHECK

2. Describe What is electromagnetic induction?

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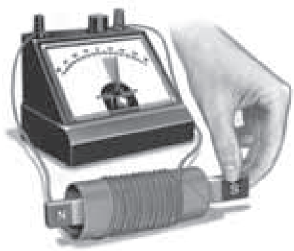
Factors that Affect an Induced Current



ⓐ An electric current is induced when you move a magnet through a coil of wire.

ⓑ A greater electric current is induced if you move the magnet faster through the coil because the magnetic field is changing faster.

TAKE A LOOK

3. Identify What are two factors that determine the size of the electric current induced?

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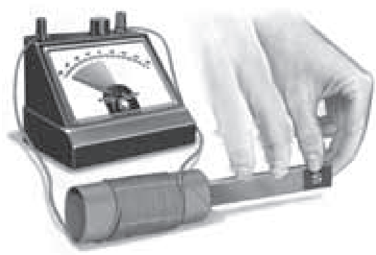
ⓒ A greater electric current is induced if you add more loops of wire. This magnet is moving at the same speed as the magnet in b.



ⓓ The induced electric current reverses direction if the magnet is pulled out rather than pushed in.

INDUCING ELECTRIC CURRENT

Faraday's experiments also showed that moving either the magnet or the wire changes the magnetic field around the wire. An electric current is made when a magnet moves in a coil of wire. An electric current is also made when a wire moves between the poles of a magnet.

As the wire moves between the poles of the magnet, it cuts through magnetic field lines. This induces an electric current.

TAKE A LOOK

4. Predict If the wire in the picture does not move, will there be an electric current? Explain your answer.

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In the figure above, an electric current is induced only by moving the wire across the magnetic field lines. Moving the wire induces the current because the force at each magnetic field line makes electric charges move. The charges only move in a wire when the wire moves through the magnetic field.

How Do Electric Generators Work?

Every day, you use electricity made by machines called *generators*. The figure below shows the parts of a simple generator.

Electric motors turn electrical energy into mechanical energy (movement). An **electric generator** uses electromagnetic induction to change mechanical energy into electrical energy. ☑

READING CHECK

5. Describe What does an electric generator do?

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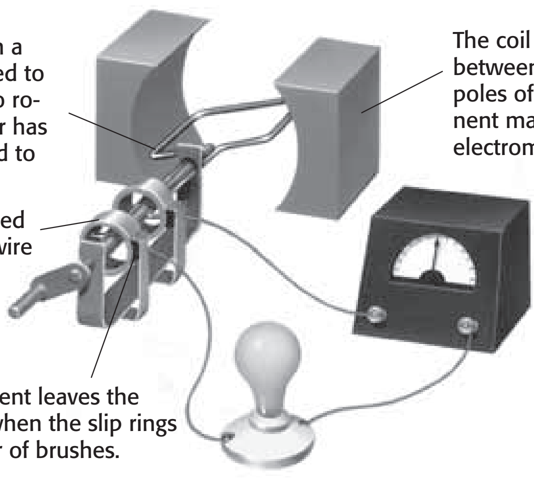
Parts of a Simple Generator



TAKE A LOOK

6. Identify What is the source of mechanical energy for this electric generator?

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ALTERNATING CURRENT

The electric current that the generator produces changes direction each time the coil makes a half-turn. Because the electric current changes direction, it is an alternating current. Generators in power plants make alternating current.

Generators in power plants are very large. They have many coils of wire instead of just one. In most large generators, the magnet turns instead of the coils.

STANDARDS CHECK

PS 3a Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.

7. Identify What are three sources of energy that generators turn into electrical energy?

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GENERATING ELECTRICAL ENERGY

The energy that generators convert into electrical energy comes from different sources. The source in nuclear power plants is thermal energy from a nuclear reaction. The energy boils water into steam. The steam turns a turbine. The turbine turns the magnet of the generator, which induces electric current and generates electrical energy. Other kinds of power plants burn fuel such as coal or gas to release thermal energy.

We can use energy from wind to turn turbines. We also convert the power of rushing water into electrical energy in a hydroelectric power plant.

What Are Transformers?

Another device that relies on induction is a transformer. A **transformer** increases or decreases the voltage of alternating current. A simple transformer is made up of two coils of wire wrapped around an iron ring. The *primary* (or first) coil gets alternating current from an electrical energy source. The current makes an iron ring an electromagnet. The changing magnetic field in the iron ring induces a current in the *secondary* (or second) coil. ☑

READING CHECK

8. Describe What does a transformer do?

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The number of loops in the primary and secondary coils determines if the voltage increases or decreases. The table below shows how voltage is affected by the number of loops.

Number of loops in primary coil	Number of loops in secondary coil	Voltage in primary coil	Voltage in secondary coil
10	20	100 V	200 V
40	20	100 V	50 V

Math Focus

9. Compare Suppose the secondary coil has 100 loops and the primary coil has 200. What is the secondary coil voltage compared to the primary coil voltage?

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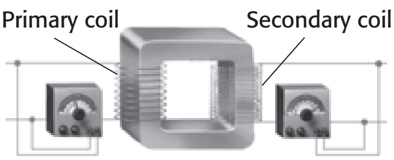
STEP-UP, STEP-DOWN

The figure below shows two types of transformers. The type of transformer is determined by the number of loops in the primary and secondary coils.

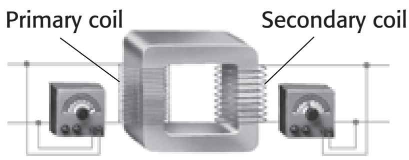
A *step-up transformer* has more loops of wire in the secondary coil, so it increases voltage and decreases current. A *step-down transformer* has fewer loops of wire in the secondary coil, so it decreases voltage and increases current. However, the amount of energy going into and out of the transformer does not change.

How Transformers Change Voltage

Step-up Transformer The primary coil has fewer loops than the secondary coil. So, the voltage in the secondary coil is higher than the voltage in the primary coil. The voltage is increased.



Step-down Transformer The primary coil has more loops than the secondary coil. So, the voltage in the secondary coil is lower than the voltage in the primary coil. The voltage is decreased.



Math Focus

10. Determine A transformer has 300 loops in the primary coil and 100 loops in the secondary coil. The primary coil voltage is 90 V. What would be the voltage in the secondary coil? What kind of transformer is this?

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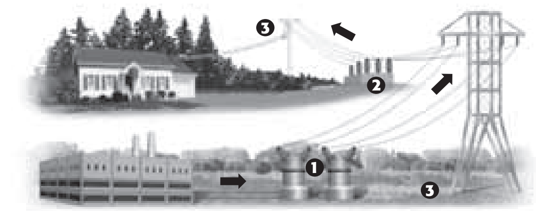
ELECTRICAL ENERGY FOR YOUR HOME

Electric power companies supply energy for most homes. Electricity travels over long distances. As it travels, it loses power in the form of heat because of the resistance in the cables. Much less power is wasted if the current is low and voltage high. So power companies transmit electricity at high voltage and low current.

However, high voltage in your home is dangerous. So, the voltage must be decreased again before the current goes to your home. Two step-down transformers decrease the voltage before the current enters your home. ☑

Getting Energy to Your Home



1. The voltage is stepped up thousands of times at the power plant.
2. The voltage is stepped down at a local power distribution center.
3. The voltage is stepped down again at a transformer near your house.

READING CHECK

11. Describe Why are step-down transformers needed before the electricity from the power company enters your home?

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Name ______________________ Class ______________ Date ______________

Section 3 Review

NSES PS 3a

SECTION VOCABULARY

electric generator a device that converts mechanical energy into electrical energy **electromagnetic induction** the process of creating a current in a circuit by changing a magnetic field	**transformer** a device that increases or decreases the voltage of alternating current

1. **Compare** How are an electric generator and an electric transformer different?

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2. **Interpret Graphics** What kind of transformer is the transformer below? How does the voltage change with this kind of transformer?

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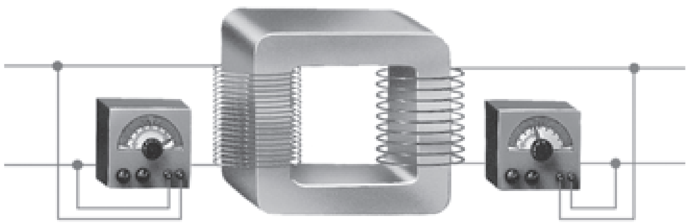

3. **Determine** A transformer has 500 loops in its primary coil and 5,000 loops in its secondary coil. What is the voltage in the secondary coil if the voltage in the primary coil is 2,000 V? What type of transformer is this?

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4. **Explain** How does a generator produce an electric current?

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5. **Explain** Why does an electric power plant increase the voltage of electricity as it leaves the power plant on its way to your home?

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CHAPTER 19 Electronic Technology

SECTION 1

Electronic Devices

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is the role of a circuit board in an electronic device?
- What is a semiconductor?
- What are transistors and diodes, and how do we use them in circuits?
- How have integrated circuits influenced electronic technology?

National Science Education Standards

PS 3a

What Is Inside an Electronic Device?

Electronic devices such as calculators and televisions use electricity. They don't use it in the same way that lamps do, though. The *components*, or parts, inside electronic devices use electrical energy to send and receive information.

STUDY TIP

Organize Use the vocabulary words in this section to make a Concept Map.

SENDING INFORMATION TO YOUR TELEVISION

Consider a remote control that sends information to a television. The picture below shows the inside of a remote control. What you see is called a circuit board. A **circuit board** is a collection of many electrical circuit components on a sheet of insulating material. The circuit board uses electric current to send signals to the electronic components of the TV.

To change the channel, you push a button on the remote control. Pushing the button sends a signal to the circuit board, which sends a signal to the TV. The electronic components of the TV get the signal and change the channel.

STANDARDS CHECK

PS 3a Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.

1. Compare What is the difference between the way machines use electrical energy and the way electronic devices use electrical energy?

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What Are Semiconductors?

Many electronic devices use materials called semiconductors. A **semiconductor** is a substance that conducts an electric current better than an insulator, but not as well as a conductor. We use semiconductors to control current in electronic equipment. They have allowed people to make many advances in electronic technology. ☑

READING CHECK

2. Identify What are semiconductors used for in electronic equipment?

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HOW SEMICONDUCTORS WORK

Scientists group semiconductors based on how the electrons in the semiconductor are arranged. Most semiconductors are made of silicon (Si). Silicon atoms have four valence electrons. When silicon atoms bond, they share all of their valence electrons. There are no electrons free to move and make electric current, so the silicon acts as an insulator. However, people can change the conductivity of silicon to make it into a semiconductor. ☑

READING CHECK

3. Explain Why doesn't silicon conduct electricity well?

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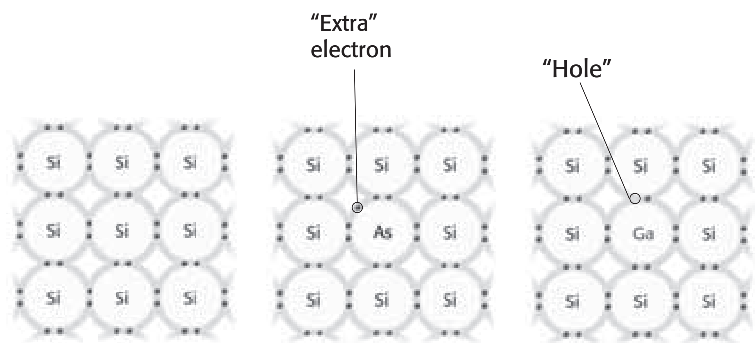
Scientists change the conductivity of a semiconductor by doping it. **Doping** means adding another element to the semiconductor. The extra element makes it *impure*, or not all the same.

Doping changes the arrangement of electrons in the semiconductor. A few atoms of the semiconductor are replaced with a few atoms of another element, such as arsenic. The other element has a different number of electrons than silicon. Doping provides electrons that are free to carry current. It makes the silicon a better conductor.



Each silicon atom shares its four valence electrons with other silicon atoms.

N-Type Semiconductor An atom of arsenic, As, has five electrons in its outermost energy level. Replacing a silicon atom with an arsenic atom results in an "extra" electron.

P-Type Semiconductor An atom of gallium, Ga, has three electrons in its outermost energy level. Replacing a silicon atom with a gallium atom results in a "hole" where an electron could be.

TAKE A LOOK

4. Infer Silicon is doped with phosphorus, which has five valence electrons. Which kind of semiconductor is formed?

____

DIODES

When scientists put an n-type semiconductor and p-type semiconductor together, they form a diode. A **diode** is an electronic component that allows electric charges to move mainly in one direction. It acts like a one-way gate. ☑

READING CHECK

5. Identify What does a diode do to a current?

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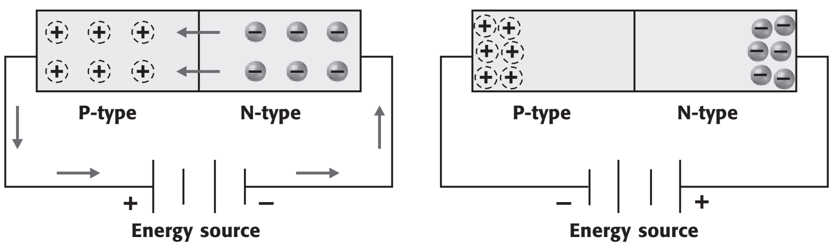
THE FLOW OF ELECTRONS IN DIODES

In a diode, layers of semiconductors are put together like sandwiches. Where the layers meet, some electrons move from one layer to the other. Electrons from the n-type layer move to fill some "holes" in the p-type layer. This gives the n-type layer a positive charge and the p-type layer a negative charge.

If the p-type layer of a diode is connected to the positive terminal of a battery, there will be a current. If the p-type layer is connected to the negative terminal, no electrons will flow. The picture below shows how a diode works.



a Electrons move from the negatively charged p-type layer toward the positive terminal. As a result, electrons from the n-type layer can move to fill the newly created "holes" in the p-type layer, and a current is made.

b When the battery is turned around, electrons in the negatively charged p-type layer are repelled by the negative terminal. No new "holes" are made, so no electrons move from the n-type layer to the p-type layer. Therefore, there is no current.

TAKE A LOOK

6. Explain What happens when the p-type layer of a diode is next to the negative pole of an energy source? Why?

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USING DIODES TO CHANGE AC TO DC

Alternating current (AC) switches direction many times each second. Power plants send electrical energy to homes as alternating current. However, many things in homes use direct current (DC). *Direct current* always flows in the same direction. AC can be changed to DC with the help of diodes. The diodes in an AC adapter block the current in one direction. ☑

READING CHECK

7. Explain How can a diode change AC to DC?

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READING CHECK

8. Define What does a transistor do?

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READING CHECK

9. Identify What are two kinds of transistors made from semiconductors?

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What Are Transistors?

When three layers of semiconductors are sandwiched together, they make a transistor. A **transistor** is an electronic component that amplifies current. When you *amplify* something, you make it bigger. ☑

There are two types of transistors: NPN and PNP. An NPN transistor has a p-type layer between two n-type layers. A PNP transistor has an n-type layer between two p-type layers. We use transistors in sound amplifiers and in switches. ☑

TRANSISTORS AS AMPLIFIERS

When you speak or sing into a microphone, the sound waves you make enter the microphone. The sound waves create a small electric current. This current is too small to run a loudspeaker. However, this problem is solved by a transistor in the circuit. The small current triggers the transistor to allow a larger current into the loudspeaker.

The electric current can be larger in the loudspeaker side of the circuit because it is connected to a large source of electrical energy.

TAKE A LOOK

10. Predict What would happen if the boy spoke into the microphone without plugging the circuit into the electrical outlet? Explain why.

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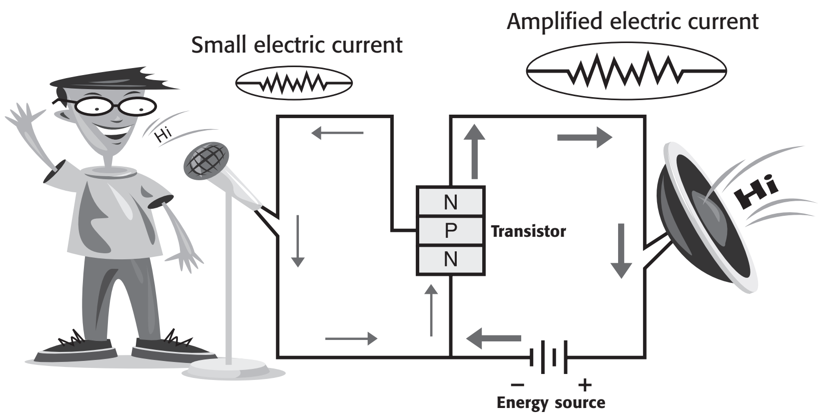


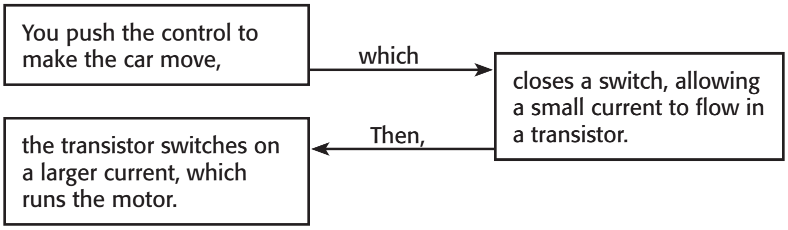
❶ Sound waves from your voice enter the microphone. As a result, a small electric current is made in the microphone side of the circuit.

❷ A transistor allows the small electric current to control a larger electric current that operates the loudspeaker.

❸ The current in the loudspeaker is larger than the current produced by the microphone. Otherwise, the two currents are identical.

TRANSISTORS IN SWITCHES

A remote-controlled toy car uses a transistor as a switch. The flowchart shows how this works. Computers also rely on transistors in switches.



What Is an Integrated Circuit?

An **integrated circuit** is an entire circuit that has many components on a single semiconductor. The parts of the circuit are made by carefully doping certain spots. Fifty years ago, all the components would have taken up a lot of space. Integrated circuits, however, are very small—about 1 cm by 3 cm. That's smaller than a piece of gum.

Integrated circuits and circuit boards have helped shrink electronic devices. Many complete circuits can fit into one integrated circuit. Therefore, complicated electronic systems can be made very small. Because the circuits are so small, the electric charges moving through them do not have to travel very far. Therefore, devices that use integrated circuits can run at very high speeds. ☑

SMALLER AND SMARTER DEVICES

Before transistors and semiconductor diodes were made, vacuum tubes were used. *Vacuum tubes* can amplify electric current and change AC to DC. However, they are much larger than semiconductor components. They also can get very hot, and they don't last very long. Early radios and televisions had to be large. They needed to have space inside to hold the vacuum tubes and to keep them from overheating.

Today's radios are very small. A modern TV can have a big screen but be very thin. That's because they use transistors and integrated circuits instead of vacuum tubes.

Integrated circuits have done more than let us make smaller TVs and radios. Computers have gone from the size of a room to the size of a notebook. Integrated circuits have changed the world by making smaller, faster computers possible.

Critical Thinking

11. Infer What do you think is the reason that devices such as hand-held games and computers are called "electronic devices"?

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READING CHECK

12. Describe What are two benefits of using integrated circuits in electronic devices?

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Name ______________________ Class ______________ Date ____________

Section 1 Review

NSES PS 3a

SECTION VOCABULARY

circuit board a sheet of insulating material that carries circuit elements and that is inserted in an electronic device	**integrated circuit** a circuit whose components are formed on a single semiconductor
diode an electronic device that allows electric charge to move more easily in one direction than in the other	**semiconductor** an element or compound that conducts electric current better than an insulator does but not as well as a conductor does
doping the addition of an impurity element to a semiconductor	**transistor** a semiconductor device that can amplify current and that is used in amplifiers, oscillators, and switches

1. **Identify** List three elements that are used in semiconductors.

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2. **Identify** What are two things that transistors are used for?

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3. **Apply Concepts** You buy a radio that runs on direct current. In order to plug it into the alternating current from your wall outlet, you need to use an adaptor. What kind of device is probably found inside the adaptor? Explain your answer.

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4. **Calculate** An integrated circuit made in 1974 contained 6,000 transistors. An integrated circuit made in the year 2000 contained 42,000,000 transistors. How do the numbers of transistors compare?

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5. **Compare** How would a TV that uses vacuum tubes be different from one that uses integrated circuits? Explain your answer.

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6. **Identify** What do circuit boards and integrated circuits use electricity to do?

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Name ______________________ Class ______________ Date ______________

CHAPTER 19 Electronic Technology

SECTION 2 Communication Technology

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- How do signals transmit information?
- How are analog signals used in telephones and records?
- How are digital signals used in compact discs?
- How is information transmitted and received in radios and televisions?

How Do We Communicate with Signals?

What electronic devices do you use to send and receive information? You may have answered telephones and radios. What you may not know is that electronic communication started even before telephones and radios were invented.

One of the first electronic communication devices was the telegraph. The telegraph was invented in the 1830s. It used an electric current to send messages between places joined by wires.

People used *Morse code*, a code of signals that stood for letters and numbers, to send messages through the telegraph. They tapped a *telegraph key*, shown in the picture. Each tap on the key closed a circuit. This was heard as a click at the other end of the telegraph line. ☑

The chart below shows Morse code. Many people still use Morse code to communicate today.

STUDY TIP

Discuss Questions Read this section silently. Write down questions that you have. Discuss your questions in a small group.

READING CHECK

1. Identify How did people send messages through a telegraph?

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Table 1 International Morse Code

A	•–	G	––•	Q	––•–	1	•––––
B	–•••	H	••••	R	•–•	2	••–––
C	–•–•	I	••	S	•••	3	•••––
D	–••	J	•–––	T	–	4	••••–
E	•	K	–•–	U	••–	5	•••••
F	••–•	L	•–••	V	•••–	6	–••••
		M	––	W	•––	7	––•••
		N	–•	X	–••–	8	–––••
		O	–––	Y	–•––	9	––––•
		P	•––•	Z	––••	0	–––––

By tapping this telegraph key in the right combinations of taps, people could send messages over long distances. A short tap was code for a dot. A long tap was code for a dash.

TAKE A LOOK

2. Apply Ideas Translate the following Morse code message:
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READING CHECK

3. Identify What is a carrier signal?

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SIGNALS AND CARRIERS

The telegraph and other communication devices send information by using signals. A *signal* is anything used to send information. A thumb pointed up, a radio transmission, and Roman numerals are all signals. Often, as in the case of the radio wave, one signal is used to send another signal. In this case, the first signal is called a *carrier*. ☑

Electric current is the carrier of the signals made by tapping a telegraph key. All electronic communication devices use electric current as the carrier. There are two kinds of carrier signals: analog signals and digital signals.

What Are Analog Signals?

An **analog signal** is a signal whose properties change continuously. *Continuous* means "never stopping." Think of a volume knob on a radio. You can make the volume softer or louder smoothly, rather than in steps. That is, the volume doesn't change in distinct steps.

Say It

Describe Have you ever used a dimmer switch on a light? Describe how it works to a small group. If you haven't used one, describe something else that changes smoothly.

An analog signal for a sound changes continuously. It is based on changes in the original sound. Remember that the carrier signal in an electronic device is electric current. As a sound changes, it makes changes in an electric current, which is carried by the electronic device. The current can be shown as a wave, as below. The wave is an analog signal. ☑

READING CHECK

4. Describe What is the carrier signal in an electronic device?

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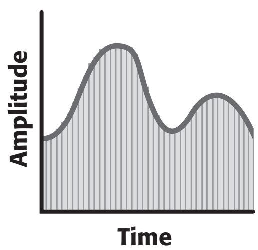
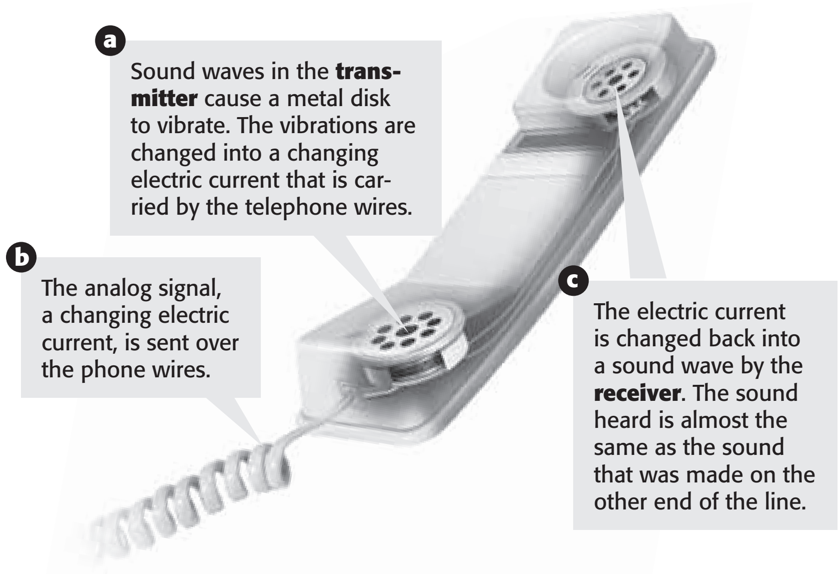


An analog signal looks like a wave.

TALKING ON THE PHONE

When you use a telephone, you talk into the *transmitter*. You listen to the *receiver*. When you speak, the transmitter changes the sound waves of your voice into an analog signal. This signal moves through the phone wires to the receiver in another phone. The receiver changes the analog signal back into the sound of your voice.

In some cases, the analog signals are changed to digital signals and back again before they reach the other phone.



TAKE A LOOK

5. Identify What are the four steps involved in sending an analog signal over the phone? Begin at the transmitter and end at the receiver.

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ANALOG RECORDING

If you want to save a sound, you can store an analog signal of the sound wave. In vinyl records, the signal is made into grooves on a plastic disk. The number and depth of the grooves in the disk represent the sound. ☑

READING CHECK

6. Describe How are analog signals stored in vinyl records?

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PLAYING A RECORD

When you play a record, the needle of the record player rides in the grooves of the record as it turns. The needle makes an electromagnet vibrate. The vibration produces an electric current, which carries the signal. Analog signals produce sound that is very like the real thing.

Even though they sound good, vinyl records aren't used very much anymore. One problem with them is that the needle touches the record to play it, and the record wears out. So, the sound changes over time.

What Are Digital Signals?

A **digital signal** does not change continuously. In that way, it is like a telegraph signal. A telegraph signal was a series of long and short taps. A digital signal is a series of electric current or no current, instead of different taps.

Each pulse of current is translated into the number 1. Each non-pulse is translated into the number 0. The numbers 1 and 0 are the only numbers in the *binary system*. Each number is a *digit*. Then, *binary digit* is shortened to *bit*. You could use the code of 0 and 1 bits to understand a signal. Computers do it much faster.

Critical Thinking

7. Compare What is the main difference between digital and analog signals?

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DIGITAL STORAGE ON A CD

You've probably heard digital sound from a compact disc, or CD. Sound is recorded onto a CD by changing it into digital signals. A CD stores the signals in a thin layer of aluminum. Look at the figure below. To understand how the *pits* and *lands* are named, keep in mind that the CD is read from the bottom.

TAKE A LOOK

8. Compare How are the lands and pits on a CD like the bits understood by a computer?

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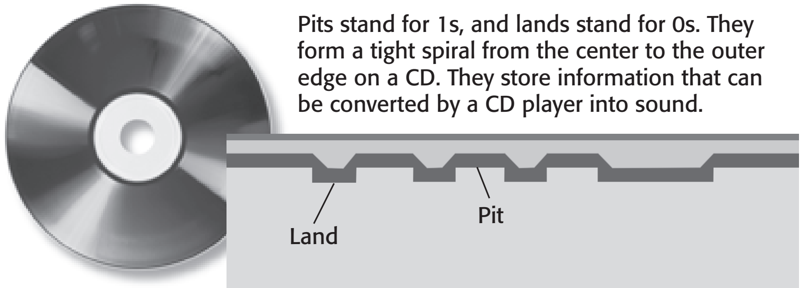

Pits stand for 1s, and lands stand for 0s. They form a tight spiral from the center to the outer edge on a CD. They store information that can be converted by a CD player into sound.

DIGITAL RECORDING

In a digital recording, the sound wave is measured many times each second. The picture below shows how these sample values represent the original sound. These numbers are then changed into binary values using 1s and 0s. You can't see them, but the 1s and 0s are stored as pits and lands on a CD.

In a digital recording, the sample values don't exactly match the original sound wave. As a result, the number of samples taken each second is important. Taking more sample values each second makes a digital sound that is closer to the original sound. ☑

READING CHECK

9. Explain How can a digital recording be made better?

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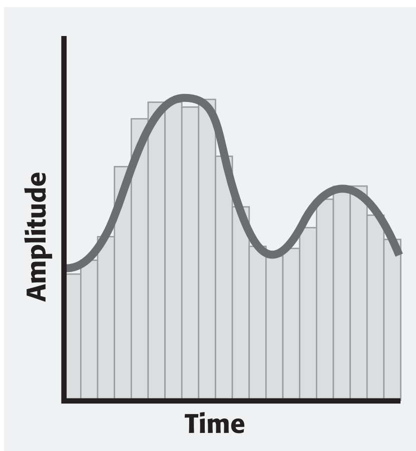


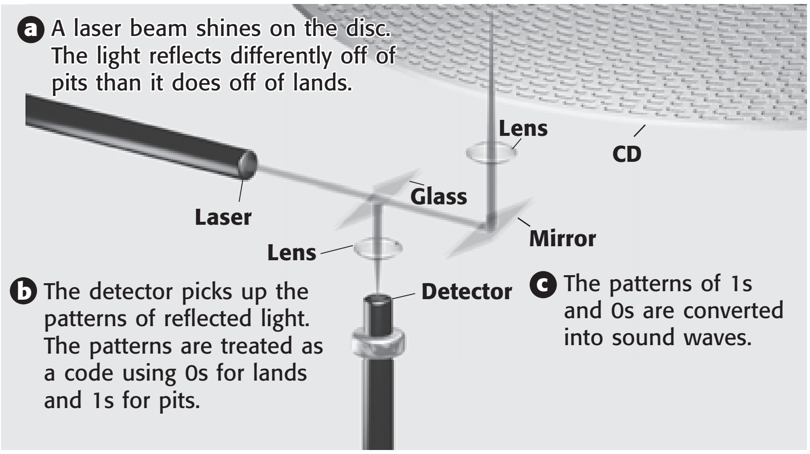
Each of the bars represent a digital sample of the sound wave.

PLAYING A CD

In a CD player, the CD spins around while a laser shines on the CD from below. As shown in the picture below, light reflected from the CD enters a detector. The detector changes the pattern of light and dark into a digital signal. The digital signal is changed into an analog signal, which is used to make a sound wave. Because only light touches the CD, the CD doesn't wear out. However, errors can happen from playing a dirty or scratched CD.

Say It

Compare What do you think is better about records than CDs? What is better about CDs? In a small group, talk about your opinions.



Different sequences and sizes of pits and lands will register different patterns of numbers that are converted into different sounds.

TAKE A LOOK

10. Identify What does a CD player use to read the information on a CD?

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How Do Radio and Television Work?

You get shows on your radio or television that are broadcast by radio or TV stations. The stations may be far away. So, how do the signals get to your radio or TV? The stations send signals that use *electromagnetic* (EM) *waves* as the carriers. ☑

Remember that electromagnetic waves are made up of changing electric and magnetic fields. They travel invisibly through the air and through walls. EM waves can be either analog or digital.

READING CHECK

11. Identify What do radio and television stations use as carriers of their signals?

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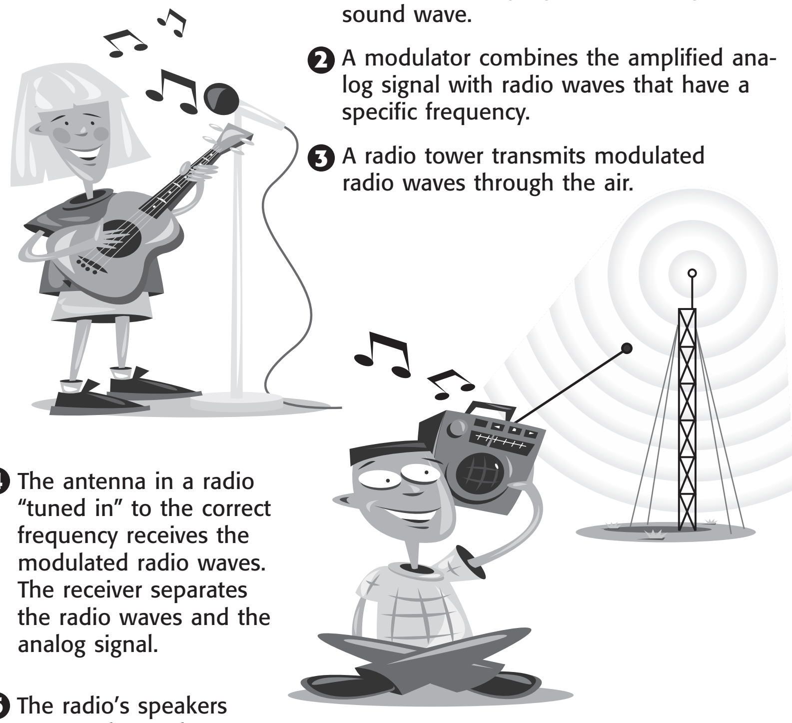
RADIO

Radio waves are one of many kinds of EM wave. Radio stations use radio waves to carry signals that represent sound. A radio tower transmits radio waves. They travel to a radio antenna.



TAKE A LOOK

12. Explain Does the boy in the picture hear EM waves? Explain your answer.

TELEVISION

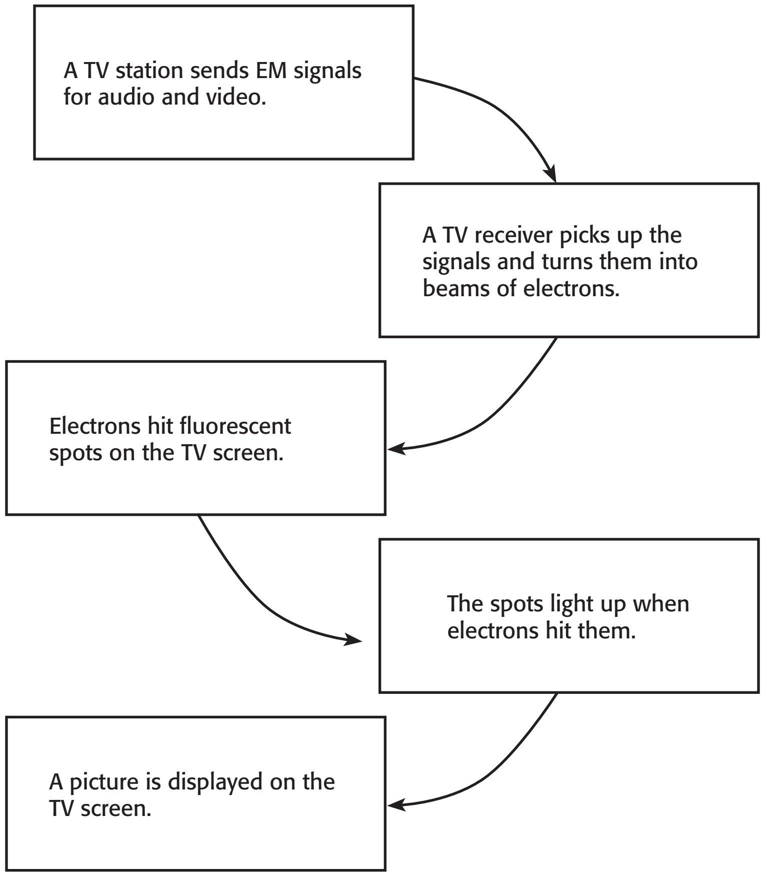
The pictures on your television's screen come from beams of electrons hitting the screen. A signal from a TV station produces a beam of electrons inside a tube in the television. The screen contains tiny dots of fluorescent material. The dots light up when the electron beams hit them. This produces the image on the screen.

Like radio stations, TV stations send out EM waves carrying analog or digital signals. Your TV receives both video (picture) and audio (sound) signals. The signals may get to your TV from an antenna or through cables. They may even beam down from satellites in space.

More and more TV programs are filmed with digital cameras. TV stations send them out as digital signals. The pictures made with digital cameras are much clearer than the pictures made for analog TVs. You can use an analog TV to watch digital shows, but they are much clearer on a digital TV.

Critical Thinking

13. Apply Concepts Why do you need electricity to watch TV? (Hint: How was electric current used by telegraphs?)



TAKE A LOOK

14. Identify What kind of signal does a television station send out?

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PLASMA DISPLAY

Standard televisions must be deep enough so that the electron beams can reach all parts of the screen. Therefore, televisions have been bulky and heavy. A newer kind of screen, called a *plasma display*, is much thinner. It can be as thin as 15 cm. That's not much thicker than a painting on the wall!

Plasma displays are thin because they do not use electron tubes. Instead, they contain thousands of tiny cells with gases in them. A computer charges the cells. That makes a current in the gases. The current generates colored lights. Each light can be red, green, blue, or a combination of these colors. As in a regular television, these three colors combine to make every picture on the screen. ☑

READING CHECK

15. Explain Why is a plasma display thinner than a regular television?

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Type of television	**How it produces an image**
Standard	Electrons hit a screen, which produces light on the screen.
Plasma	A current passes through gases in tiny cells, causing them to light up.

Name ______________________ Class ______________ Date ____________

Section 2 Review

SECTION VOCABULARY

analog signal a signal whose properties can change continuously in a given range	**digital signal** a signal that can be represented as a sequence of discrete values

1. **Apply Concepts** How is using a digital signal like turning on and off a regular light switch?

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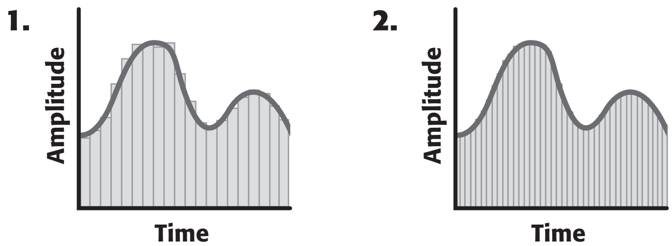
2. **Interpret Graphics** Look at the curves below. They represent a sound wave that is being changed into a digital signal. Each bar represents a digital sample of the sound wave. Which graph represents the digital signal that is most similar to the original sound wave? Explain your answer.



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3. **Identify** What is an early example of an electronic device used to send information over long distances?

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4. **Apply Concepts** Cellular phones are not connected to telephone lines. What most likely carries their signals?

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5. **Identify** Give two examples of carrier signals.

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6. **Apply Ideas** Is Morse code an analog or a digital signal? Explain your answer.

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SECTION 3

Computers

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is a computer?
- What are the main components of computer hardware?
- How can information be stored on CD-Rs and CD-RWs?
- What does computer software do?
- What is a computer network?

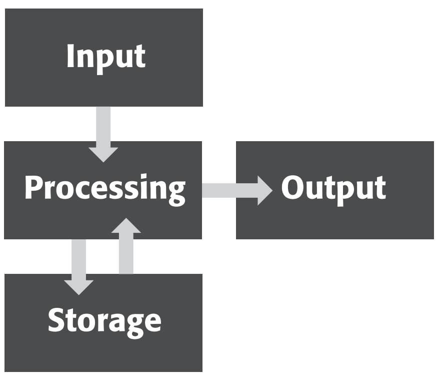
What Is a Computer?

Did you use a computer to wake up this morning? You may think of a computer as something you use to surf the Internet or to send e-mail. Computers do more than that, though. They are in automobiles, VCRs, and telephones. Even an alarm clock is an example of a simple computer.

A **computer** is an electronic device that follows instructions given to it. A computer does a task when it is given a command and the needed instructions. Computers can do tasks very quickly.

STUDY TIP

Predict Before you read this section, write its headings in your notebook. Leave space under each heading. Then, in the spaces, write what you think you will learn.



TAKE A LOOK

1. Identify What are the four basic functions of a computer?

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BASIC FUNCTIONS

The basic functions of a computer are shown above. The information you give to a computer is called *input*. The computer *processes* the input. Processing could mean adding a list of numbers, making a drawing, or even moving a piece of equipment. Input doesn't have to be processed right away. It can be stored until it is needed. The computer *stores* information in its memory. *Output* is the final result of the job done by the computer.

An Alarm Clock as a Computer

Input You set the time you need to wake up.

Storage The clock remembers your wake-up time.

Processing The clock compares wake-up time to actual time.

Output A buzzer or music sounds to wake you up.

TAKE A LOOK

2. Identify What is the output of a computerized alarm clock?

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THE FIRST COMPUTERS

Your pocket calculator is a simple computer. Computers were not always so small and easy to use. The first computers were huge. They were made up of large pieces of equipment that could fill a room!

The first general-purpose computer was the ENIAC. ENIAC stands for *E*lectronic *N*umerical *I*ntegrator *a*nd *C*omputer. The U.S. Army made it in 1946. It cost a lot to build and run. The ENIAC contained thousands of vacuum tubes and got very hot. Therefore, it had to be used in an air-conditioned room.

Critical Thinking

3. Compare What are three things about today's computers that are different from the ENIAC?

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Fast for its time, the ENIAC could add 5,000 numbers per second.

Math Focus

4. Calculate How many numbers could ENIAC add in 10 minutes?

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MODERN COMPUTERS

Computers have become much smaller because of integrated circuits. Remember that an integrated circuit is an entire circuit in the space of a few square centimeters. One type of integrated circuit is the microprocessor. It is also called a computer chip.

A **microprocessor** controls and carries out all the computer's instructions. The first widely available microprocessor had only 4,800 transistors. Since then, microprocessors have been made with more than 40 million transistors. Now, some computers are so small that we can carry them around like books. ☑

READING CHECK

5. Define What is a microprocessor?

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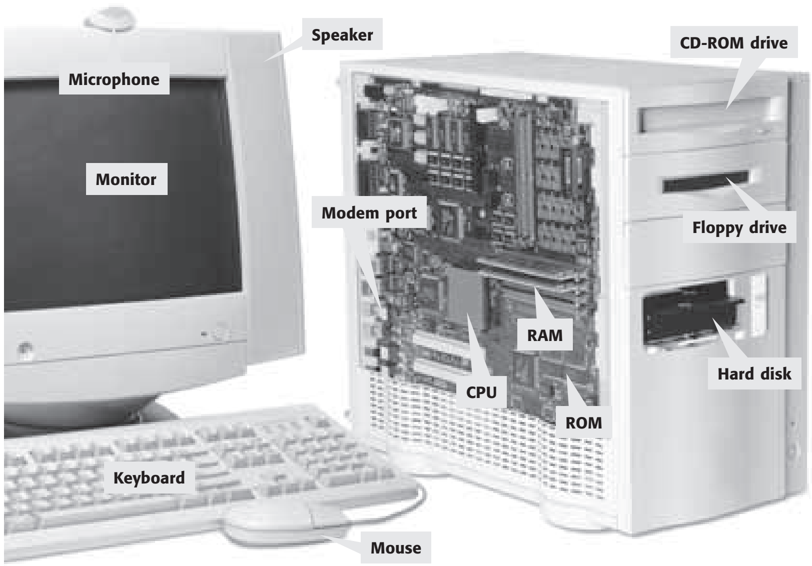
Computer Hardware



TAKE A LOOK

6. Identify Name a device for each of a computer's basic functions.

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What Does Computer Hardware Do?

Different parts of a computer do different jobs. **Hardware** is all the physical parts and pieces that make up a computer. As you read about each piece, look at the picture above or on the next page to see what it looks like.

INPUT DEVICES

An *input device* gives information, or input, to the computer. You can put information into a computer using a keyboard, a mouse, a scanner, or a digitizing pad and pen. You can even enter information with a microphone.

READING CHECK

7. Define What is a CPU?

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CENTRAL PROCESSING UNIT

A computer does tasks in its *central processing unit*, or CPU. In a home computer, the CPU is a microprocessor. Input goes to the CPU for immediate processing or for storage in memory. The CPU does calculations, solves problems, and carries out instructions given to it. ☑

MEMORY

You can store information outside the computer, on floppy disks, or CDs. However, most information is stored in the computer's memory on its hard disk. The two types of memory are *ROM* (read-only memory) and *RAM* (random-access memory).

ROM is permanent. It handles jobs such as start-up, maintenance, and hardware management. ROM normally cannot be added to or changed. It also cannot be lost when the computer is turned off.

READING CHECK

8. Identify When you save something on a computer, where does it go?

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RAM is temporary. RAM stores information only while it is being used. For this reason, RAM is sometimes called working memory. Information in RAM may disappear if the power is shut off. Therefore, it is a good habit to save your work to the hard drive or to a CD every few minutes. ☑

We measure computer memory in units called *bytes*. Many home computers have about 500 megabytes of RAM. That's about 500 million bytes. A byte is eight bits. A bit is a signal for either a pulse or no pulse of current. Therefore, a computer with 500 megabytes of RAM has space to store 4 billion signals.

Additional Computer Hardware

OUTPUT DEVICES

Once a computer does a job, you can observe the results on an *output device*. Monitors, printers, and speaker systems are all output devices.

Hardware Summary

Task	Examples of hardware for this task
Input	
Processing	CPU
Storage	
Output	

TAKE A LOOK

9. Describe Fill in the blanks in the table.

MODEMS AND INTERFACE CARDS

Computers can send information to one another if we connect them with modems or interface cards. *Modems* send information through telephone lines. They convert digital signals to analog signals, and vice versa. *Interface cards* use cables or wireless connections to connect computers. ☑

READING CHECK

10. Explain What does a modem do?

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What Are Compact Discs?

Music albums have been sold on compact discs for years. Today, you can use a CD burner on your computer to make your own CD. It can store music files, digital photos, and any other type of computer file. A CD can hold about 500 times more information than a floppy disk.

BURNING AND ERASING CDS

One kind of CD that you can store information on, or "burn," is a CD-recordable (CD-R) disc. CD-R discs use a dye to block light. When the dye is heated, light cannot pass through to reflect off the aluminum. When a CD is burned, a special laser heats some places and not others. This creates a pattern of "on" and "off" spots that store information just as the pits and lands do on a regular CD.

You can burn a CD-R only once. However, a CD-rewritable (CD-RW) disc can be used more than once. CD-RWs use a compound that can be erased, so the disc can be burned again. Not all CD players can read CD-RWs, though. CD-RWs also cost more than CD-Rs. ☑

READING CHECK

11. Compare What is the difference between a CD-R and a CD-RW?

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What Does Computer Software Do?

Computers need instructions before they can do a task. **Software** is a set of instructions or commands that tells a computer what to do. A computer program is software. ☑

READING CHECK

12. Define What is software?

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KINDS OF SOFTWARE

Software can be split into two kinds: operating-system software and application software. *Operating-system software* tells the computer how to work. It gives instructions and helps all the software communicate with the hardware, such as the mouse. It can find programming instructions on a hard disk to be loaded into memory. ☑

READING CHECK

13. Identify What are the two main kinds of software?

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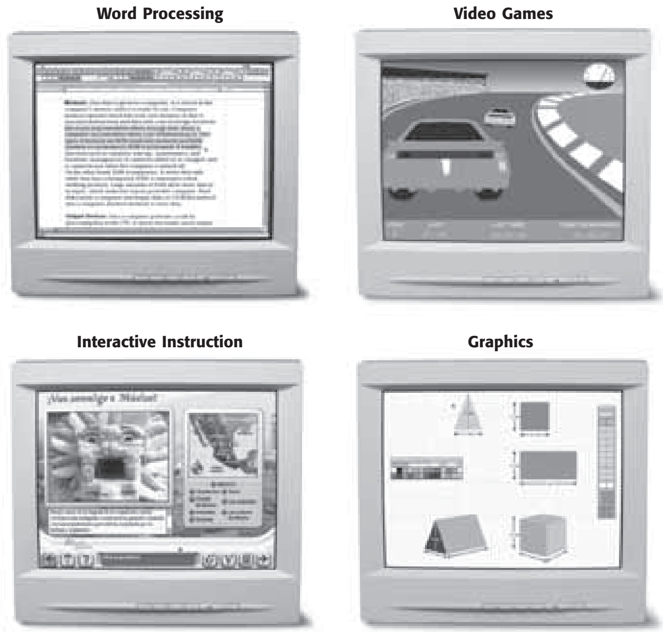
The other type, *application software*, tells the computer to run programs like the ones shown below. The pages in this book were made using many kinds of application software.

Common Types of Computer Software



TAKE A LOOK

14. Describe What are two kinds of software that you may use in school?

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What Are Computer Networks?

We can connect computers using modems and software. This allows the computers to communicate with one another. The **Internet** is a huge computer network made up of millions of computers that can share information.

THE INTERNET

The picture below shows some ways computers connect. Computers can connect on the Internet using a modem. The modem connects a computer with an *internet service provider*, or ISP. A home computer often connects to an ISP over a phone or cable line. In school, computers can be connected in a *local area network*, or LAN. These computers connect to an ISP through only one line. ISPs around the world connect using fiber optic cables. ☑

READING CHECK

15. Define What is the Internet?

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THE WORLD WIDE WEB

The part of the Internet that people know best is called the *World Wide Web*. When you use a Web browser to look at pages on the Internet, you are on the World Wide Web. Web pages share a format that is simple enough that any computer can view them.

Sets of Web pages are grouped into Web sites. Clicking on a link takes you from one page or site to another. A *search engine* can help you find Web pages on a specific topic. ☑

READING CHECK

16. Describe What is a Web site?

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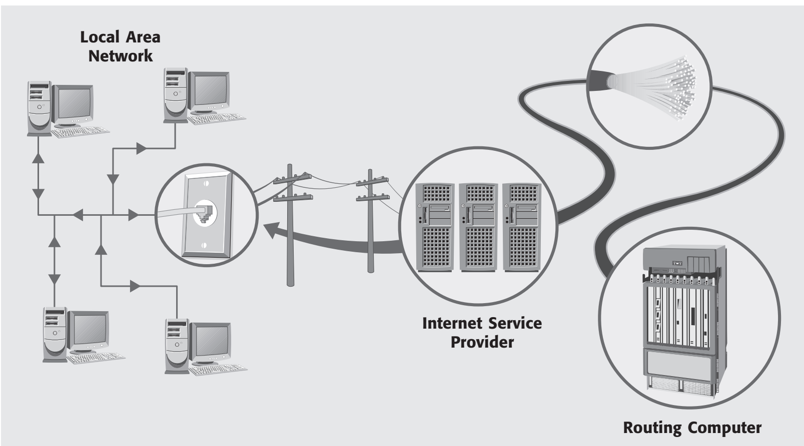

Modems, cables, phone lines, and fiber optic cables link computers around the world. Internet Service Providers allow small computers to connect to large routing computers. People can use browsers to access the World Wide Web. They can use other software to access other parts of the Internet.

TAKE A LOOK

17. Define What is the World Wide Web?

____

Name ______________________ Class ______________ Date ____________

Section 3 Review

SECTION VOCABULARY

computer an electronic device that can accept data and instructions, follow the instructions, and output the results

hardware the parts or pieces of equipment that make up a computer

Internet a large computer network that connects many local and smaller networks all over the world

microprocessor a single semiconductor chip that controls and executes a microcomputer's instructions

software a set of instructions or commands that tells a computer what to do; a computer program

1. Compare What is the difference between hardware and software?

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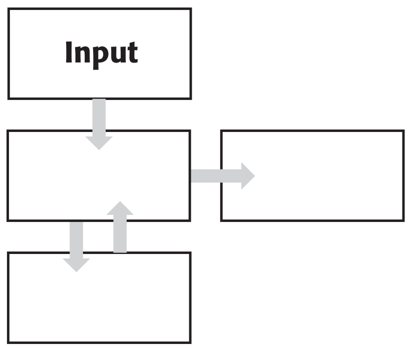
2. Identify What are the four functions of a computer? Write them in the correct boxes in the diagram here.



3. Apply Concepts Using the terms *input*, *output*, *processing*, and *store*, explain how you use a calculator to add numbers.

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4. Describe How does a CD-R work?

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5. Predict Consequences If all the phone lines in the world suddenly stopped working, would computers still be able to access the Internet? Explain your answer.

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SECTION 1

The Nature of Waves

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is a wave, and how does it transmit energy?
- How do waves move?
- What are the different types of waves?

National Science Education Standards

PS 3a

What Is Wave Energy?

A **wave** is any disturbance that transmits energy through matter or empty space. Energy can be carried away from its source by a wave. However, the material through which the wave moves is not transmitted. For example, a ripple caused by a rock thrown into a pond does not move water out of the pond.

A wave travels through a material or substance called a **medium**. A medium may be a solid, a liquid, or a gas. The plural of medium is *media*. ☑

STUDY TIP

As you read the section, make a table of the types of waves. Have columns for the type of wave, what it moves through, its direction of motion, and how it transmits energy.

READING CHECK

1. Identify What does a wave move through?

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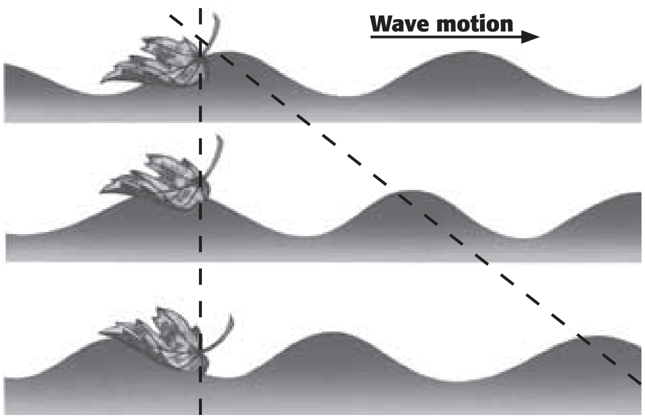

A wave travels through the medium, but the medium does not travel. In a pond, lake or ocean, the medium through which a wave travels is the water. The waves in a pond travel towards the shore. However, the water and the leaf floating on the surface only travel up and down.

How Can Waves Do Work?

As a wave travels, it does work on everything in its path. The waves traveling through a pond do work on the water. Anything floating on the surface of the water moves up and down. The fact that any object on the water moves indicates that the waves are transferring energy. Waves can transfer energy through a medium or without a medium. ☑

READING CHECK

2. Describe What indicates that a water wave transfers energy to a floating object?

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WAVES CAN TRANSFER ENERGY THROUGH A MEDIUM

When a particle *vibrates* (moves back and forth), it can pass its energy to the particle next to it. The second particle will vibrate like the first particle and may pass the energy on to another particle. In this way, energy is transmitted through a medium.

TAKE A LOOK

3. Describe How did the last ball in the figure on the right gain energy?

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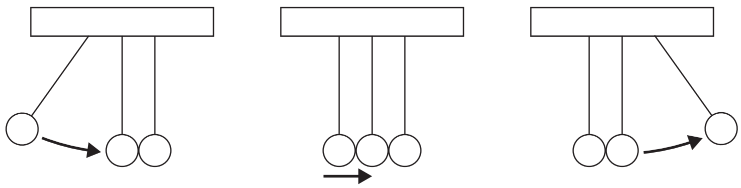

A particle can pass energy to the particle next to it. The particle receiving the energy will vibrate like the first particle. This is shown by the Newton's pendulum above. When the moving steel ball collides with another steel ball, its energy is given to that ball. Notice that the first ball stops, but its energy is passed on to a third ball.

Waves that require a medium are called *mechanical waves*. Mechanical waves include sound waves, ocean waves, and earthquake waves. For example, consider a radio inside a jar. If all of the air from inside the jar is removed to create a vacuum, the radio can not be heard.

WAVES CAN TRANSFER ENERGY WITHOUT A MEDIUM

Waves that transfer energy without a medium are called *electromagnetic waves*. Examples of electromagnetic waves include visible light, microwaves, TV and radio signals, and X-rays used by dentists and doctors.

Electromagnetic waves may also go through matter, such as air, water, or glass. Light waves travel from the sun through space toward Earth. Light waves then travel through the air in the atmosphere to reach the surface of Earth.

STANDARDS CHECK

PS 3a Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.

4. Identify What kinds of waves need a medium to transfer their energy? What kinds of waves don't need a medium to transfer their energy?

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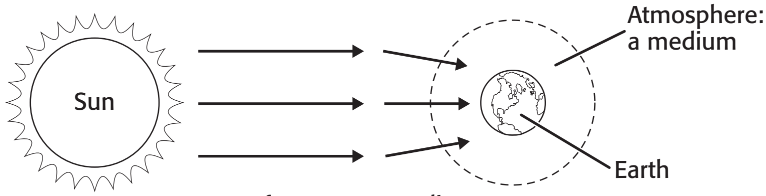

To reach the Earth, light travels from the sun, through the vacuum of space. The light then travels through the particles of the atmosphere before reaching the surface of the earth.

What Are the Different Types of Waves?

Waves transfer energy through vibrations. However, the way particles in a wave vibrate depends on the type of wave. Waves are classified based on the direction in which wave particles vibrate compared with the direction in which waves move. There are two main types of waves, *transverse waves* and *longitudinal waves*. ☑

READING CHECK

5. Identify What are the two main types of waves?

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TRANSVERSE WAVES

Waves in which the particles vibrate in an up-and-down motion are called **transverse waves**. Particles in a transverse wave move at right angles relative to the direction of the wave. See the figure below. The highest point in a transverse wave is a *crest*. The lowest point in a transverse wave is a *trough*. ☑

READING CHECK

6. Identify What is the direction of a transverse wave relative to its direction of motion?

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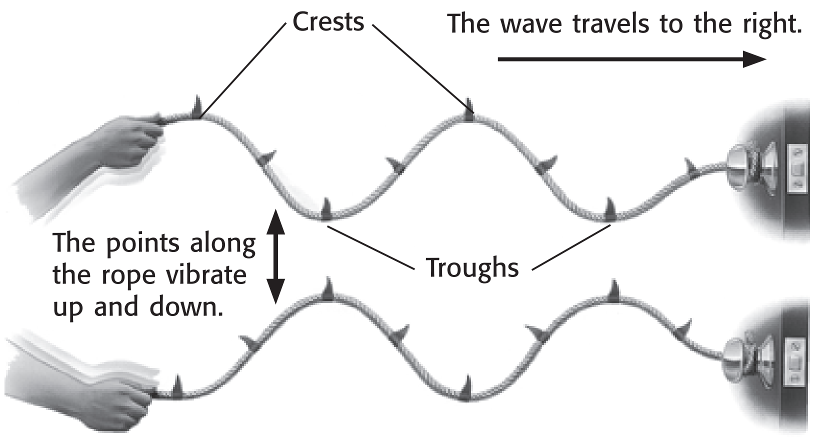
Motion of a Transverse Wave



A wave traveling down a length of rope is an example of a transverse wave. The wave travels to the right. The particles in the medium, the rope, travel up-and-down. The particles in the wave and the medium are moving at right angles to each other.

All electromagnetic waves are transverse waves. Remember, electromagnetic waves can travel through space or through a medium. Electromagnetic waves are transverse waves because the wave vibrations are at right angles to the direction the wave is traveling. ☑

READING CHECK

7. Describe Why is an electromagnetic wave identified as a transverse wave?

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LONGITUDINAL WAVES

Waves in which the particles of the medium vibrate back and forth along the path of the wave are called **longitudinal waves**. For example, pushing together two ends of a spring causes the coils to crowd together. When you let go, a longitudinal wave is created in the spring that travels along the length of the spring. ☑

READING CHECK

8. Describe How do the particles of a longitudinal wave vibrate?

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In a longitudinal wave, a *compression* is the location of the crowded particles. A *rarefaction* is where the particles are spread apart.

Compressions and rarefactions are similar to crests and troughs in a transverse wave. See the figure below.

Critical Thinking

9. Describe How could you produce a transverse wave in a spring?

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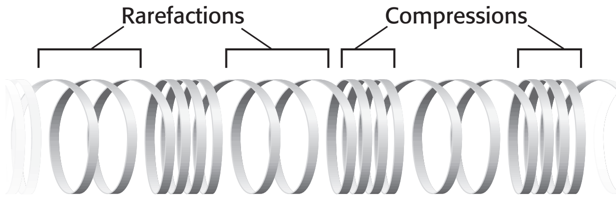
Comparing Longitudinal and Transverse Waves

Longitudinal wave

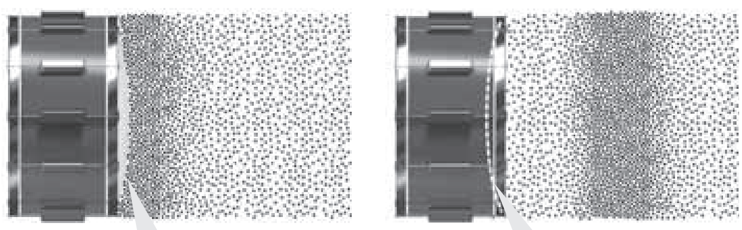


A wave traveling along the length of a spring is an example of a longitudinal wave. The wave travels to the right. The particles in the medium, the spring, move back-and-forth. The particles in wave and the medium are moving along the same direction as each other.

Transverse wave

The troughs and crests of a transverse wave represent an up-and-down motion around a central point. Similarly, the rarefactions and compressions of a longitudinal wave represent a back-and-forth motion around a central point.

A sound wave is an example of a longitudinal wave. Sound waves travel by compressions and rarefactions of air particles.



When the drumhead moves out after being hit, a compression is created in the air particles.

When the drumhead moves back in, a rarefaction is created.

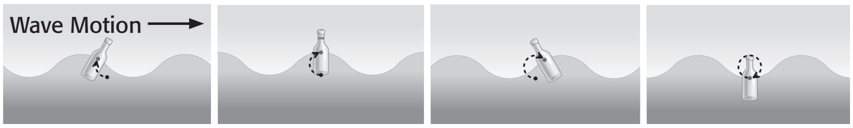
Sound energy is carried away from a drum by a longitudinal wave through the air.

TAKE A LOOK

10. Identify Circle the compression part of the wave in the second figure.

SURFACE WAVE

When waves move at or near the surface between two media a *surface wave* may form. For example, this occurs when an ocean wave comes into shallow water at the shore. Surface waves travel in both transverse and longitudinal motion. A particle in a surface wave will appear to move in a circular motion.



Ocean waves are surface waves. A floating bottle shows the circular motion of particles in a surface wave.

Critical Thinking

11. Identify An ocean wave forms a surface wave as it comes into shallow water. What are the two media involved in forming the surface wave?

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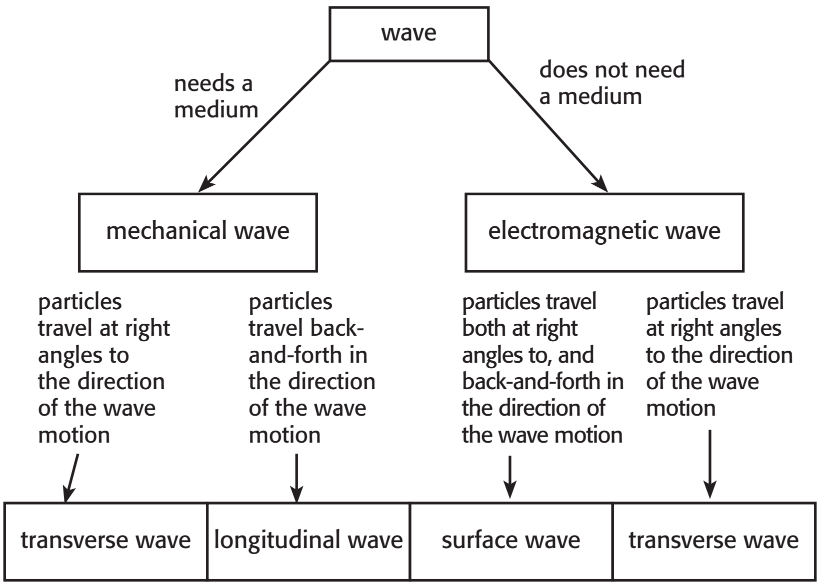
Summary of Wave Types and Their Motion Through Space



TAKE A LOOK

12. Identify Which type of wave must have a medium in order to travel?

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Section 1 Review

NSES PS 3a

SECTION VOCABULARY

medium a physical environment in which phenomena occur

longitudinal wave a wave in which the particles of the medium vibrate parallel to the direction of wave motion

transverse wave a wave in which the particles of the medium move perpendicularly to the direction the wave is traveling

wave a periodic disturbance in a solid, liquid, or gas as energy is transmitted through a medium

1. **Describe** How does energy travel through a wave in a medium?

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2. **Identify** Determine the method of energy transfer, and the wave type for each wave source.

Wave source	Wave energy transfer (electromagnetic wave or mechanical wave)	Wave type (transverse wave, longitudinal wave, or surface wave)
Light emitted from a light bulb		
Sound coming from a violin		
Rock dropped in a pond		

3. **Apply Concepts** A ribbon is tied to the first loop of a spring as a marker. The spring is pulled and then released to create a longitudinal wave. Where is the ribbon after three complete vibrations?

____

4. **Recall** Label each wave part as a crest, trough, compression, or rarefaction according to its description.

Wave Part	Description
	particles are crowded toward each other
	particles are at their highest point
	particles are at their lowest point
	particles are spread away from each other

Name ______________________ Class ______________ Date ____________

CHAPTER 20 The Energy of Waves

SECTION 2

Properties of Waves

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What are ways to describe a wave?
- What determines the energy of a wave?

National Science Education Standards

PS 3a

What Is the Amplitude of a Wave?

An earthquake in the ocean can make a transverse wave called a *tsunami*. The waves can get very tall as they reach land. The *amplitude* of a transverse wave is related to the height of the wave. **Amplitude** is the maximum distance the particles of the wave vibrate away from their rest position. The rest position, shown in the figure below, is the location of the particles of the medium before the wave gets there. ☑

STUDY TIP

With a partner, discuss the properties of a wave and how they affect the energy of a wave.

READING CHECK

1. Describe What is the amplitude of a wave?

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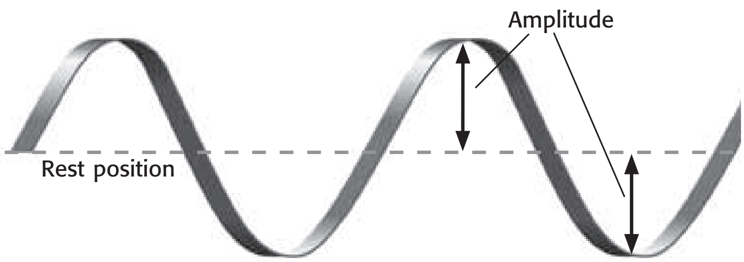

The amplitude of a transverse wave is measured from the rest position to the crest or the trough of the wave.

RELATIONSHIP BETWEEN AMPLITUDE AND ENERGY

Taller waves have larger amplitudes, and shorter waves have smaller amplitudes. It takes more energy to create a wave with a large amplitude. Therefore, it carries more energy. ☑

READING CHECK

2. Explain Why do waves of large amplitude carry more energy?

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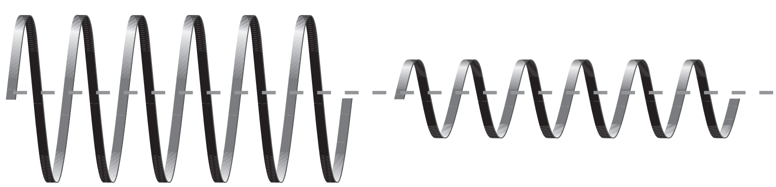


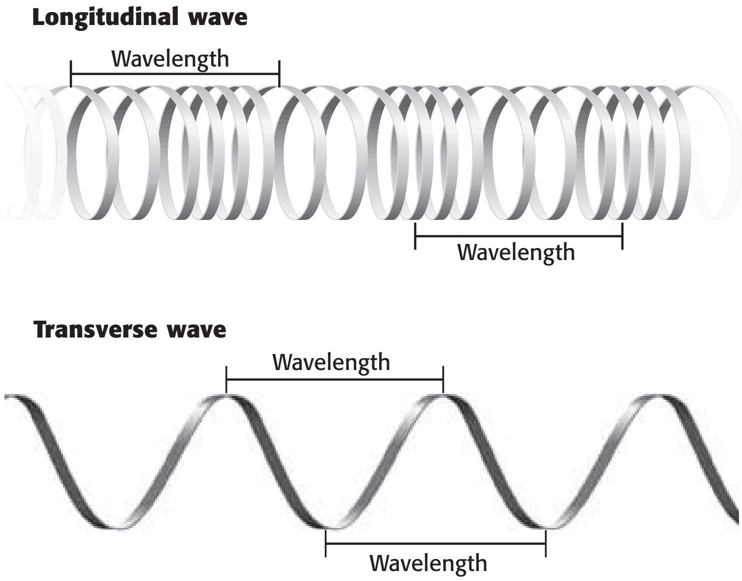
A wave with a larger amplitude carries more energy.

A wave with a smaller amplitude carries less energy.

What Is the Wavelength of a Wave?

The **wavelength** is the distance between any point on a wave and the identical point on the next wave. A wavelength is the distance between two neighboring crests or two compressions. The distance between two troughs or two rarefactions next to each other is also a wavelength. See the figure below.

Measuring Wavelengths



A wavelength can be measured between any two identical points on neighboring waves.

Math Focus

3. Infer What is the distance between a crest and a trough next to a crest? Hint: use the figure for help.

____

STANDARDS CHECK

PS 3a Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.

4. Identify There are two groups of waves with the same amplitude. One contains waves of short wavelength and the other has waves of long wavelength. Which waves have the most energy?

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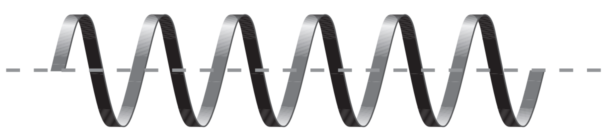
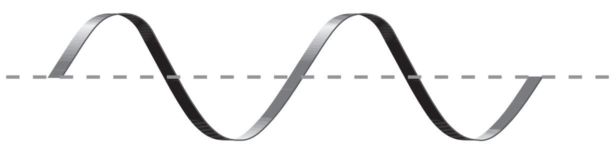
RELATIONSHIP BETWEEN WAVELENGTH AND ENERGY

Suppose you have two waves of the same amplitude. The wave with a shorter wavelength carries more energy than the wave with a longer wavelength.



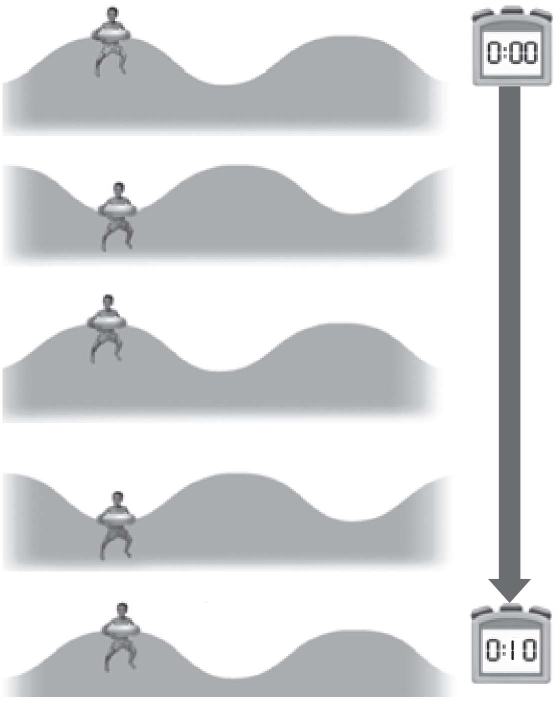
A wave with a short wavelength carries more energy.



A wave with a long wavelength carries less energy.

What Is the Frequency of a Wave?

The **frequency** of a wave is the number of waves produced in a given amount of time. Frequency is often expressed in *hertz* (Hz). One hertz equals one wave per second (1 Hz = 1/s).



Frequency is the number of waves that pass a certain point in a given amount of time. Frequency can be measured by counting the waves that pass a certain point in a certain amount of time. In the image shown here, two waves passed by in 10 s. The frequency is 2/10 s = 0.2 1/s = 0.2 Hz.

RELATIONSHIP BETWEEN FREQUENCY AND ENERGY

When the amplitudes of two waves are equal, the wave with the higher frequency has more energy. Lower-frequency waves carry less energy. ☑

What Is Wave Speed?

Wave speed is the speed at which a wave travels through a medium. Wave speed is symbolized by v. The speed of a wave is a property of the medium. Changing the medium of a wave changes its speed. For example, light travels faster in air than in water.

The equation for calculating speed is $v = \lambda \times f$. λ is the Greek letter *lambda* and means the wavelength. f is the frequency of the wave.

Let's do a problem. What is the speed of a wave whose wavelength is 5 m and frequency is 4 Hz (or 4 1/s)?

Step 1: write the equation $v = \lambda \times f$

Step 2: replace λ and f with their values

$$v = 5 \text{ m} \times 4 \text{ 1/s} = 20 \text{ m/s}$$

Math Focus

5. Determine If a source of waves produces 30 waves per second, what is the frequency in hertz?

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Critical Thinking

6. Applying Concepts What would the time of the lower clock read if the frequency of the wave were 0.1 Hz?

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READING CHECK

6. Identify When the amplitudes of waves are equal, which frequency waves have the most energy?

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Math Focus

7. Calculate What is the speed of a wave whose wavelength is 30 m and frequency is 20 Hz? Show your work.

Name ______________________ Class ______________ Date ____________

Section 2 Review

NSES PS 3a

SECTION VOCABULARY

amplitude the maximum distance that the particles of a wave's medium vibrate from their rest position **frequency** the number of waves produced in a given amount of time	**wavelength** the distance from any point on a wave to an identical point on the next wave **wave speed** the speed at which a wave travels through a medium

1. **Apply Concepts** The distance between the crest and trough of an ocean wave is 1 meter. What is the amplitude of the wave?

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2. **Identify** Indicate whether the wave description should result in higher-energy wave, or a lower-energy wave.

Wave description	Wave energy
high amplitude	
low frequency	
low wavelength	

3. **Apply Concepts** Explain how to produce a longitudinal wave on a spring that has large energy. There are two answers; one involves wavelength and the other frequency.

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4. **Math Concepts** What is the speed of a wave that has a wave length of 100 m and a frequency of 25 Hz? Show your work.

5. **Apply Concepts** A sound wave has a frequency of 125 Hz and a speed of 5000 m/s. What is the wavelength of the wave? Show your work.

SECTION 3

Wave Interactions

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- How do waves interact with objects?
- How do waves behave when they move between two media?
- How do waves interact with other waves?

National Science Education Standards

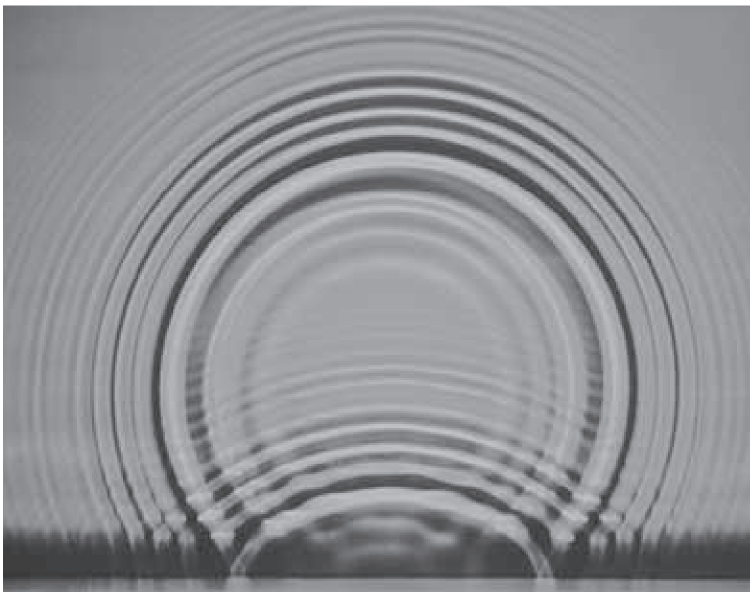
PS 3a

Why Do Waves Reflect?

A **reflection** occurs when a wave bounces back after hitting a barrier. All waves can be reflected. Light waves reflecting off an object allow you to see that object. For example, light waves from the sun reflecting off the moon allow you to see the moon. Sound wave can also reflect. Sound waves reflecting off a barrier are called an *echo*.

STUDY TIP

In your science notebook, define each new vocabulary word. Include sketches illustrating reflection, refraction, diffraction, and both kinds of interference.



The waves in this photograph were formed by drops of water that fell into a container of water. When the waves caused by the drops of water hit one side of the container, they reflect off. The shape of the reflected waves is opposite that of the waves that struck the side of the tank.

Critical Thinking

1. Infer How does your reflection in a bathroom mirror look when you raise you right arm?

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Waves are not always reflected when they hit a barrier. Sometimes they pass through a substance. When a wave passes through a substance, it is *transmitted*. Light waves transmitted through a glass window allow light to enter a room. Light waves transmitted through eyeglasses allow the wearer to see through them.

Why Do Waves Diffract?

Diffraction is the bending of waves around a barrier or through an opening. Waves usually travel in a straight line. When a wave reaches the edge of an object or an opening in a barrier, it may curve or bend. ☑

The amount of diffraction of a wave depends on its wavelength and the size of the barrier opening. Sound waves are relatively long. You can hear voices from one classroom diffract through the opening of a door into another classroom. Light waves are relatively short. You cannot see who is speaking in the other classroom.

READING CHECK

2. Describe What is diffraction?

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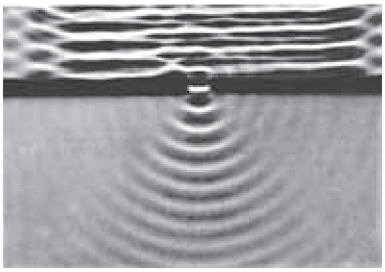
If the barrier or opening is larger than the wavelength of the wave, there is only a small amount of diffraction.



If the barrier or opening is the same size or smaller than the wavelength of an approaching wave, the amount of diffraction is large.

TAKE A LOOK

3. Describe Suppose the opening in the lower figure were made larger. What would happen to the shape of the diffracted wave?

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____

Why Do Waves Refract?

Refraction is the bending of a wave as the wave passes from one medium to another. The wave changes speed as it passes from one material to the other. The change in speed causes the wavelength to change. The resulting wave bends and travels in a new direction. ☑

READING CHECK

4. Describe What happens to a wave because of refraction?

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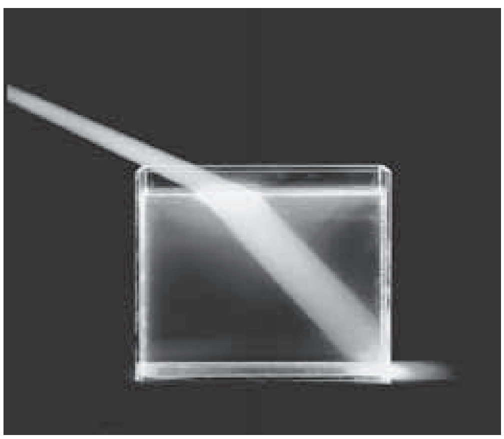
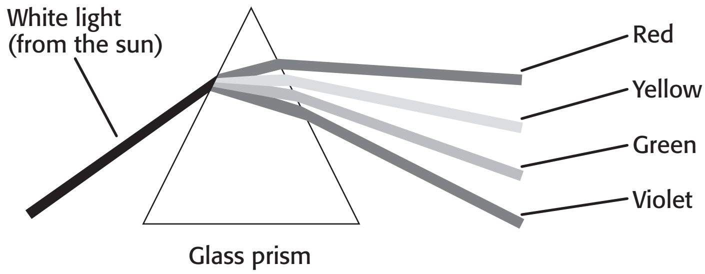


This light wave is refracted as it passes into a new medium. The light wave is passing from air into water. The wave is refracted because the speed of the wave changes.

REFRACTION OF DIFFERENT COLORS

When light waves from the sun pass through a droplet of water in the air, the light is refracted. The different colors of light travel at different speeds through the drop. Therefore, the different colors are refracted by different amounts. The light is *dispersed*, or spread out, into its separate colors. The result is a rainbow. ☑



White light is separated into its component colors when it passes through a prism. The red light is refracted the least. The violet light is refracted the most.

READING CHECK

5. Describe What does light do when it disperses?

____

TAKE A LOOK

6. Identify The order of the dispersed colors can be remembered by the mnemonic ROY G. BIV. Draw a line coming from the prism that shows the direction that orange would move in.

What Is Wave Interference?

All matter has volume. Therefore, objects cannot be in the same space at the same time. However, waves are made up of energy, not matter. So, more than one wave may be in the same space at the same time. Two waves can meet, share the same space, and pass through each other.

When two or more waves meet and share the same space, they overlap. **Interference** is the combination of two or more waves to form a single wave. ☑

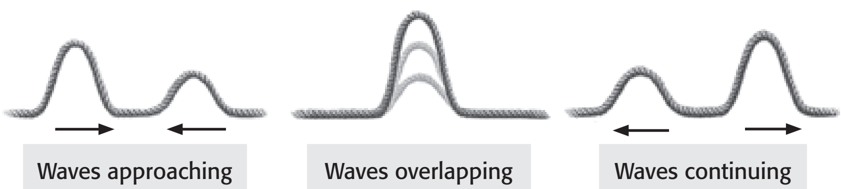
READING CHECK

7. Identify What is the combination of two or more waves to form a single wave called?

____

CONSTRUCTIVE INTERFERENCE

Constructive interference occurs when the crests of one wave overlap with the crests of another wave or waves. The troughs of both waves will also overlap. The energy of the waves adds together to make a higher-energy wave. The new wave has higher crests, deeper troughs, and, therefore, higher amplitude.



Constructive Interference When waves combine by constructive interference, the combined wave has a larger amplitude.

TAKE A LOOK

8. Describe What does the medium do after the waves have overlapped and are continuing their movement?

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DESTRUCTIVE INTERFERENCE

Destructive interference occurs when the crests of one wave overlap with the troughs of another wave. The energy of the new wave is less than the energy of both waves. The new wave has lower amplitude than the original waves. If a crest and trough of the same amplitude meet and cancel, the result is no wave at all. ☑

READING CHECK

9. Describe What parts of a wave overlap during destructive interference?

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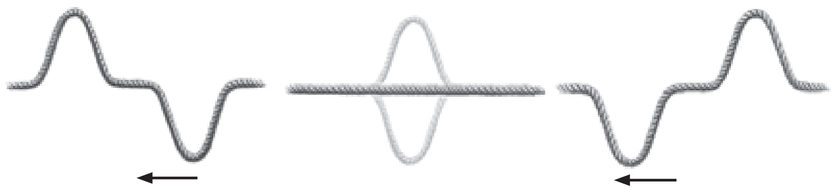

Destructive Interference When two waves with the same amplitude combine by destructive interference, they cancel each other out.

How Is a Standing Wave Created?

In a **standing wave**, the pattern of vibrations makes it appear as if the wave is standing still. A standing wave is caused by interference between a wave and a reflected wave. For example, pluck a guitar string. The string makes a standing wave like the top wave shown in the figure below. ☑

READING CHECK

10. Describe What causes a standing wave?

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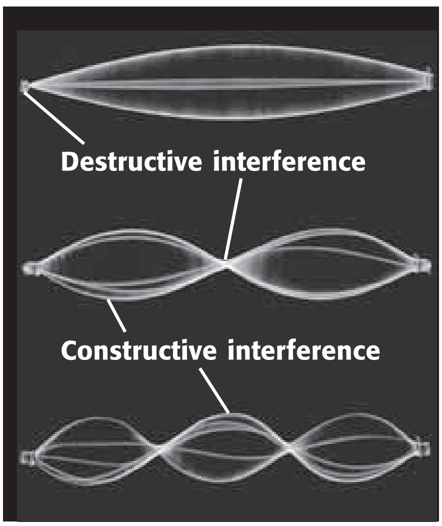

A rope vibrating at certain frequencies can create a standing wave. The initial wave travels down the rope and will be reflected back when it reaches the end. In a standing wave, certain parts of the wave are always at the rest position. This point is caused by destructive interference between the waves. Constructive interference can be seen at points in the wave where there is large amplitude.

TAKE A LOOK

11. Identify Draw two arrows in the bottom figure that show the locations of destructive interference.

Remember, a standing wave only looks as if it is standing still. Waves are actually moving in two directions. Standing waves can be formed with transverse waves or with longitudinal waves.

RESONANCE

Resonant frequencies are the frequencies at which standing waves are created. **Resonance** occurs when two objects naturally vibrate at the same frequency. The resonating object absorbs energy from the vibrating object and vibrates also. For example, when a guitar string is plucked, the wood body vibrates at the same frequency as the string. ☑

When you pluck the guitar string, you hear a musical note. The vibrating wood body makes sound waves in the air. The sound waves that reach your ear make parts of your ear vibrate, so you hear the sound of the note.

READING CHECK

12. Describe When does resonance occur?

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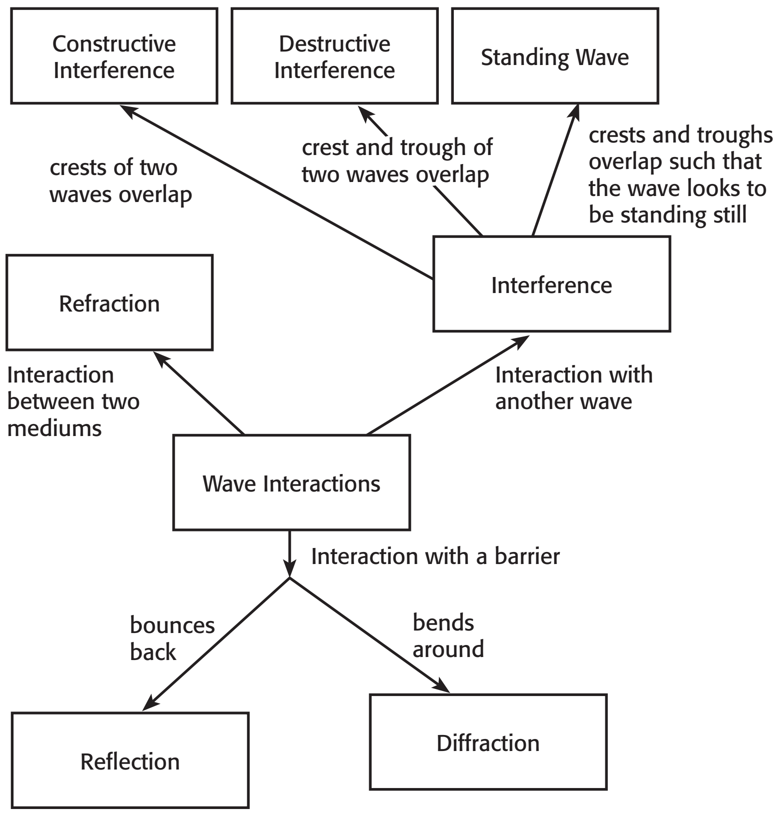
Summary of Wave Interactions



TAKE A LOOK

13. Identify What two interactions can occur when a wave strikes a barrier?

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Name ________________________ Class ______________ Date ______________

Section 3 Review

NSES PS 3a

SECTION VOCABULARY

diffraction a change in the direction of a wave when the wave finds an obstacle or an edge, such as an opening

interference the combination of two or more waves that results in a single wave

reflection the bouncing back of a ray of light, sound, or heat when the ray hits a surface that it does not go through

refraction the bending of a wavefront as the wavefront passes between two substances in which the speed of the wave differs

resonance a phenomenon that occurs when two objects naturally vibrate at the same frequency; the sound produced by one object causes the other object to vibrate.

standing wave a pattern of vibration that simulates a wave that is standing still

1. **Describe** Suppose two students grab an end of a rope. Both shake the rope once in an upward direction to create crests traveling at each other. What would you see when the crests meet? What type of interference does this show?

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2. **Describe** Suppose two students grab an end of a rope. Both shake the rope once, but one makes a crest and the other a trough traveling at each other. What would you see when the crest and trough meet? What type of interference does this show?

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____

3. **Identify** Using the vocabulary words above, fill in the table below by writing which wave interaction most likely caused the situation described.

Wave situation	Wave interaction
The image of an object in a mirror	
A straight pencil appears to bend when the bottom half is placed in a glass of water	
Two rocks dropped in the water a meter apart produce a large wave centered between them	
A radio turned on in one classroom can be heard down the hall in a second classroom	

SECTION 1
What Is Sound?

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is a sound wave?
- How does sound travel?
- How does the human ear hear sound?
- How can you protect your hearing?

National Science Education Standards

PS 3a

What Is a Sound?

Vibrations produce all sounds. A *vibration* is the back-and-forth motion of an object. Regardless of the type of sound, what made the sound, or the intensity of the sound, vibrations are involved. The figure below shows how vibrations in a stereo speaker produce sound. ☑

STUDY TIP

Describe Make a list of loud sounds you hear often, their source, and what exposure to loud sound can cause.

READING CHECK

1. Describe What is a vibration?

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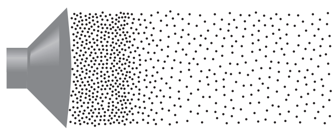
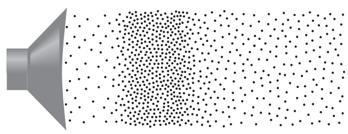
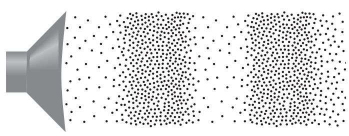


a Electrical signals make a cone in the speaker vibrate. During the first part of the vibration, the cone moves forward. It pushes air particles closer together. This produces an area of high density and air pressure called a *compression.*



b During the second part of the vibration, the cone moves backward. The air particles near the cone become less crowded. This produces an area of low density and air pressure called a *rarefaction.*



c Each vibration of the cone produces a compression and a rarefaction. The compressions and rarefactions travel away from the speaker. This is how the sound from the speaker is transmitted through the air.

TAKE A LOOK

2. Identify For speaker c, circle the compression parts of the wave.

HOW SOUND WAVES TRAVEL

A **sound wave** is a longitudinal wave caused by vibrations that move through a substance. *Longitudinal waves* are made of compressions and rarefactions. The particles in the substance vibrate back and forth along the path that the sound wave travels. Sound is transmitted through the vibrations and collisions of the particles. ☑

READING CHECK

3. Compare What is the path of a sound wave compared with the path of the back-and-forth vibration of the particles in the wave?

____

Sound waves travel in all directions away from their source. However, the particles of a substance are not carried long distances by the sound waves. The particles of the substance only vibrate back and forth. If sound waves did carry particles, then you would be blown over by wind from the speakers at a dance!

You can't see sound waves. However, they can be represented as spheres that spread out in all directions. Each sphere represents one wave (a compression and a rarefaction). In this figure, the sound waves are traveling in all directions from the radio speaker.

SOUND AND MEDIA

Remember that sound waves travel through the movement of particles. If there are no particles, sound waves cannot travel. Another way of saying this is that sound waves can travel only through a medium. A **medium** (plural, *media*) is any substance that a wave can travel through. Most sound waves that you hear travel through the medium of air. However, sound waves can also travel through other media, such as water, metal, and glass.

READING CHECK

4. Describe What is a medium? Does sound need a medium to travel?

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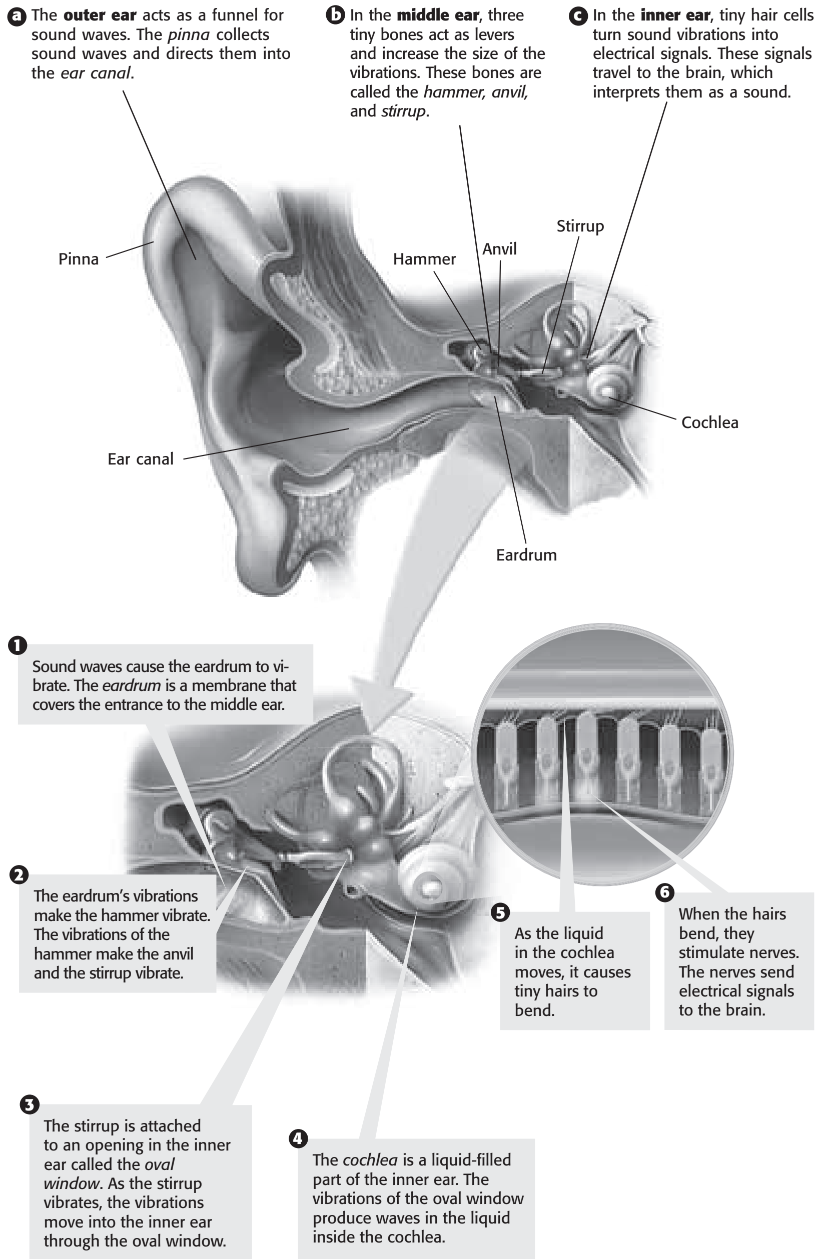
There are no particles in a vacuum, such as outer space. Therefore, sound cannot travel through a vacuum. Sound can travel only through air or other media. ☑

How Do You Detect Sound?

You hear sound with your ears. Your ears change sound waves into electrical signals that allow you to hear. The figure below shows how this happens.



TAKE A LOOK

5. Identify In the inner ear, what types of cells turn sound vibrations into electrical signals?

____

TAKE A LOOK

6. Describe How does the vibrating eardrum pass its vibration to the stirrup?

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MAKING SOUND AND HEARING SOUND

If a tree falls in the forest and no one is around to hear it, does it still make a sound? Yes! Making a sound is different from detecting the sound. When the tree fell and hit the ground, the tree and the ground vibrated. These vibrations produce compressions and rarefactions in the air. Therefore, a sound was produced. The fact that no one heard the tree fall doesn't mean that there was no sound. A sound was made; it just wasn't heard.

Critical Thinking

7. Compare How is making a sound different from detecting a sound?

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When a tree falls in the woods, both the tree and the ground vibrate. The vibrations create compressions and rarefactions in the air. This produces a sound, even if no one is there to hear it.

What Causes Hearing Loss and Deafness?

All parts of the ear must work together to produce the electrical signal that the brain interprets as sound. However, sometimes a part of the ear is damaged and does not work properly. This can cause hearing loss or deafness.

Tinnitus is a common type of hearing loss. People with tinnitus often hear ringing or buzzing in their ear, even when no sound is present. They may also have trouble telling the difference between similar sounds. Therefore, they may have trouble understanding what other people are saying. Fortunately, tinnitus and some other kinds of hearing loss can be prevented. ☑

READING CHECK

8. Identify What two things do people with tinnitus hear?

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CAUSES OF HEARING LOSS

Loud sounds are the most common causes of tinnitus. In the inner ear, loud sounds can damage the hairs and nerve endings in the cochlea. Once hairs and nerves are damaged, they do not grow back. Therefore, damage to the inner ear usually causes permanent hearing loss. ☑

READING CHECK

9. Describe What are two things that loud sounds can do to the inner ear and cause?

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HOW YOU CAN PROTECT YOUR HEARING

Sounds that are too loud can cause hearing loss. How can you tell if a sound is too loud? One sign is that the sound causes you pain. Even short exposures to painfully loud sounds can cause hearing loss. Sounds that are loud, but not quite loud enough to be painful, can also cause hearing loss. If you are exposed to these sounds for a long time, they can damage your ears.

In most cases, it is easy to protect your hearing. The best way to protect your hearing is to stay away from loud sounds whenever you can. The farther away from a sound you are, the lower its *intensity*, or loudness. If you double the distance between yourself and a sound, the intensity of the sound decreases by four times!

Another important way to protect your hearing is to use earplugs. You should wear earplugs whenever you know that you will be hearing loud sounds. For example, you should wear earplugs if you are going to a music concert.

A third way to protect your hearing is to turn down the volume when you listen to headphones. The volume should be low enough that only you can hear the music in your headphones. If someone else can hear your music, it is too loud. ☑

READING CHECK

10. List What are three ways you can prevent hearing loss?

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Turning your radio volume down can help protect your hearing.

Name ______________________ Class ______________ Date ______________

Section 1 Review

NSES PS 3a

SECTION VOCABULARY

medium a physical environment in which phenomena occur	**sound wave** a longitudinal wave that is caused by vibrations and that travels through a material medium

1. **Apply Concepts** A sound wave moving through the air causes particles in the air to move. If air particles are moving, why doesn't this motion create a breeze?

____

____

2. **Identify** Complete the table below. Identify the part of the ear or its function as indicated.

Organ in ear	Work done by the organ
stirrup	
	vibrations of the liquid inside it cause hair cells to bend
hair cells	
ear canal	
	membrane stretched over the opening to the middle ear that vibrates with the sound waves

3. **Describe** What is the main way sound waves cause hearing loss?

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4. **Compare** What is the main difference between the compressions and rarefactions in a sound wave?

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5. **Identify** What is needed for a sound wave to travel?

____

6. **Infer** What would be the most likely effect on hearing if the hammer, anvil, and stirrup could only vibrate a little bit?

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SECTION 2
Properties of Sound

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- How fast does sound travel?
- How are frequency and pitch related?
- How are loudness and amplitude related?

National Science Education Standards
PS 3a

How Fast Does Sound Travel?

Suppose you are standing at the one end of a pool. You hear two people from the opposite end of the pool yell at the same time. You hear their voices at the same time because the speed of sound depends only on the medium in which the sound travels. So, you hear them at the same time even if one person yelled louder.

The speed of sound depends on the state of the medium. Sound travels faster through solids than through liquids or gases. The speed of sound also depends on the temperature of the medium. Particles of cool materials move more slowly than particles in a warmer material. They also transmit energy more slowly than particles in a warmer medium. Therefore, the speed of sound is slower in cooler media. ☑

Medium	Speed of Sound
Air at 0°C	331 m/s
Air at 20°C	343 m/s
Air at 100°C	366 m/s
Water at 20°C	1,482 m/s
Steel at 20°C	5,200 m/s

It is possible to move faster than the speed of sound. In 1947, pilot Chuck Yeager was the first person to fly an airplane faster than the speed of sound. He flew high in the atmosphere, where the temperature of air is very low.

STUDY TIP
Compare Discuss with a partner experiences you have had with the properties of sound discussed in this section.

READING CHECK
1. Identify The speed of sound is faster in what two media states?

____

How Are Pitch and Frequency Related?

The **pitch** of a sound is how high or low the sound seems to be. The pitch of a sound depends on the frequency of the sound wave. The *frequency* of a sound wave is the number of compressions or rarefactions produced in a certain amount of time. Frequency is often expressed in hertz (Hz). A frequency of 1 Hz is equal to 1 compression or rarefaction per second. ☑

Math Focus
2. Describe What does a frequency of 10 Hz equal?

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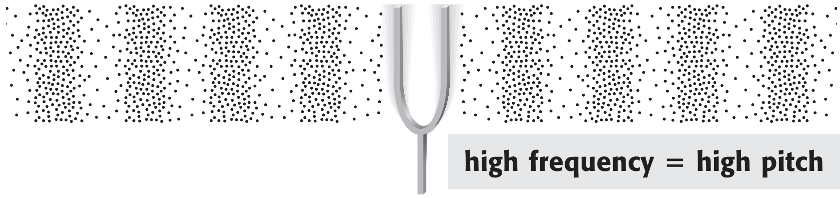

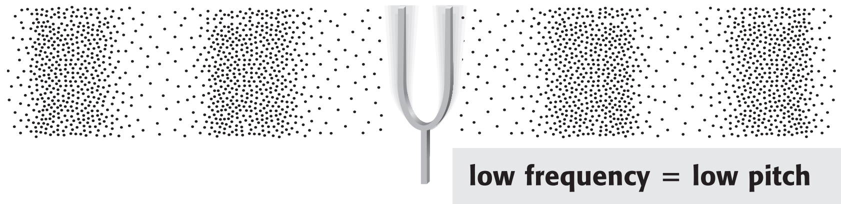

FREQUENCY AND HEARING

Humans, like all animals, can only hear sounds with certain frequencies. For example, a dog whistle produces a sound with a higher frequency than humans can hear. Therefore, dogs will respond to the sound of a dog whistle. Sounds with frequencies too high for people to hear are called *ultrasonic* sounds. ☑

READING CHECK

3. Identify What are sounds with frequency too high for people to hear called?

____

THE DOPPLER EFFECT

You have probably heard the pitch of a police car's siren change as the car passed by you. When the car is moving toward you, the siren seems to have a high pitch. When the car moves past and away from you, the pitch seems to drop. The change in pitch is caused by the *Doppler effect*.

The **Doppler effect** is a change in the pitch of a sound you hear that is caused by motion. If the source of the sound is moving compared to the listener, the pitch seems to change. ☑

READING CHECK

4. Describe What causes the Doppler effect?

____

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Think again about the police car. When the car is behind you, both the sound waves and the car are moving toward you. Therefore, the compressions and rarefactions of these sound waves are pushed closer together. The frequency (pitch) of the sound seems to go up.

After the car passes, it is moving in the opposite direction from the sound waves. Therefore, the compressions and rarefactions of the sound wave are farther apart. The frequency (pitch) of the sound seems to go down. The figure on the next page shows how the Doppler effect works.

a The car is moving toward the sound waves that are traveling in the same direction. The sound waves are pushed closer together. A person in front of the car hears a sound with a high pitch.

b The car is moving away from the sound waves that are traveling in the opposite direction. The sound waves are farther apart. A person behind the car hears a sound with a low pitch.

c The person in the car is moving at the same speed and direction as the sound waves. Therefore, the person in the car always hears the same pitch of sound.

TAKE A LOOK

5. Explain Why do the people at the rear of the car hear a sound of lower frequency than those at the front of the car?

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How Are Loudness and Amplitude Related?

The **loudness** of a sound is a measure of how well the sound can be heard. A sound's loudness depends on the amplitude of the sound wave. The *amplitude* of a wave is a measure of how far particles move when the wave passes them. The larger the amplitude of a sound wave, the louder the sound. The smaller the amplitude of a sound wave, the softer the sound.

The amplitude (and loudness) of a sound wave is determined by the wave's energy. Waves with a lot of energy have larger amplitudes than waves with little energy.

Imagine hitting a drum. When you hit the drum, you transfer energy to it. The energy causes the drum to vibrate. These vibrations produce a sound wave that travels through the air. If you hit the drum harder, more energy is transferred to the drum. The drum's vibrations are larger, so the sound wave has larger amplitude. The drum produces a louder sound.

When energy...	Amplitude...	Loudness...
...increases		...increases
...decreases	...decreases	

STANDARDS CHECK

PS 3a Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.

6. Complete Fill in the missing boxes in the table.

READING CHECK

7. Identify What is the unit used to measure loudness?

____

MEASURING LOUDNESS

Scientists usually use the unit **decibel** (dB) to measure loudness. Soft sounds have low decibel levels. Loud sounds have high decibel levels. The table below shows the decibel levels of some common sounds. ☑

Decibel level	Sound
0	the softest sounds an average person can hear
20	whisper
25	purring cat
60	loudness of a normal speaking voice
80	lawn mover, vacuum cleaner, loud traffic
100	chain saw, snowmobile
115	sandblaster, loud music concert, car horn
120	sound that is loud enough to cause pain
140	jet engine 30 m away
200	rocket engine 50 m away

How Can You "See" Amplitude and Frequency?

Sound waves are invisible. However, you can use a tool called an oscilloscope to "see" sound waves. An *oscilloscope* is a device that can produce graphs to represent sound waves.

HOW AN OSCILLOSCOPE WORKS

The figures on the next page show examples of oscilloscope graphs of sound waves. Notice that these graphs look like transverse waves instead of longitudinal waves. It is easier to see the amplitude and frequency of the sound wave when it is graphed as a transverse wave. The crests of the transverse wave represent compressions. The troughs represent rarefactions. ☑

READING CHECK

8. Describe On an oscilloscope graph, what do the wave crests represent? What do the wave troughs represent?

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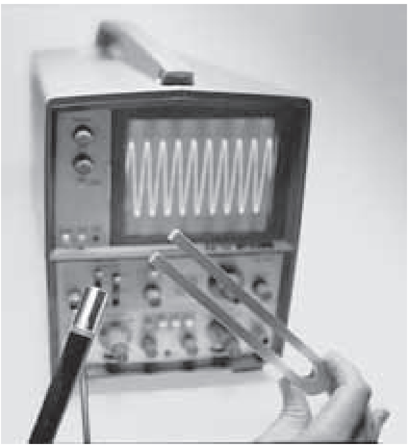
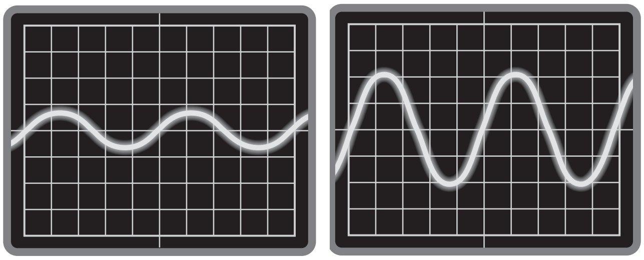


A receiver on an oscilloscope converts a sound wave into an electrical signal. The signal travels to a computer in the oscilloscope. The computer interprets and graphs the sound wave as a transverse wave.

INTERPRETING AN OSCILLOSCOPE GRAPH

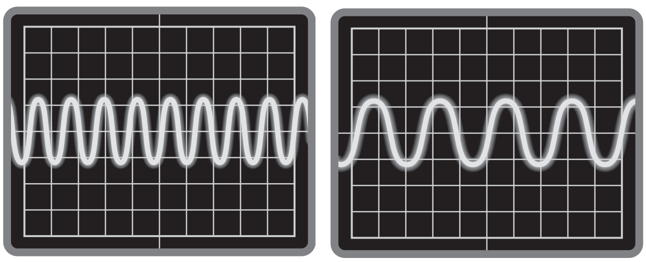
You can use an oscilloscope to learn the pitch (frequency) and loudness (amplitude) of a sound wave. The figures below show how to interpret the graph produced by an oscilloscope.

Image A



The wave in the graph on the right has a larger amplitude than the one on the left. Therefore, the sound represented by the right-hand graph is louder than the one represented by the left-hand graph.

Image B



The wave in the graph on the right has a lower frequency than the one on the left. Therefore, the sound represented by the right-hand graph has a lower pitch than the one represented on the left.

TAKE A LOOK

9. Compare What is the amplitude of the graph on the right compared to the amplitude of the graph on the left? What is the wavelength of the graph on the right compared to the wavelength of the graph on the left?

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10. Compare What is the frequency of the graph on the left compared to the frequency of the graph on the right? What is the wavelength of the graph on the right compared to the wavelength of the graph on the left?

____

____

____

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Name ______________________ Class ______________ Date ______________

Section 2 Review

NSES PS 3a

SECTION VOCABULARY

decibel the most common unit used to measure loudness (symbol, dB) **Doppler effect** an observed change in the frequency of a wave when the source or observer is moving	**pitch** a measure of how high or low a sound is perceived to be, depending on the frequency of the sound wave **loudness** the extent to which a sound can be heard

1. **Explain** In your own words, explain why the sound made by an object moving at you has a higher pitch.

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____

____

2. **Compare** The table below lists several different media sound waves can pass through. Indicate whether a sound wave passing through the media would be expected to travel *faster* or *slower* than air at room temperature.

Medium	Relative speed
A glass window	
A glass of lemonade	
Air on a cold winter day	

3. **Applying Concepts** A drum is struck first with little energy. The drum is then struck with a lot of energy. Which sound will be louder? Why?

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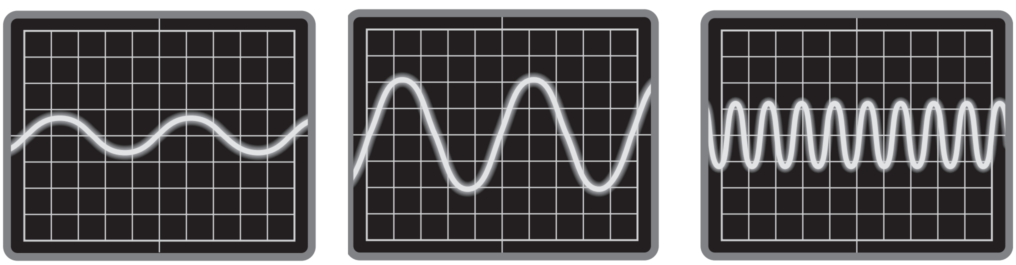
4. **Identify** Below are three screens showing sound waves detected by an oscilloscope. Label the wave that has the *loudest sound*, and label the wave that has the *highest pitch*.



Interactions of Sound Waves

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What produces an echo?
- What causes a sonic boom?
- How do musical instruments amplify sound?

National Science Education Standards
PS 3a

What Happens When Sound Waves Reflect?

Imagine shouting your name in an empty basketball court. A second later, you hear an echo of your voice come back to you. An **echo** is a reflected sound wave. *Reflection* happens when a wave bounces off a barrier.

The loudness of a reflected sound wave depends on the properties of the surface the wave bounces off. Sound waves reflect best off smooth, hard surfaces. Rough, uneven surfaces do not reflect sound waves very well. Therefore, these kinds of surfaces are used in auditoriums and classrooms to prevent echoes. ☑

STUDY TIP
Compare Make a table listing each of the sound wave interactions in this section and their causes.

READING CHECK
1. Describe What happens to cause an echo?

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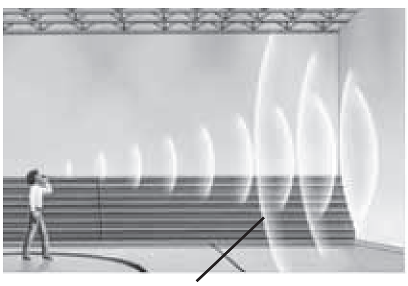

You would hear an echo in this empty gymnasium because sound waves reflect off of its smooth, hard walls.

You would not hear an echo in this auditorium. The sound waves do not reflect as easily from the soft, uneven surfaces of the seats and walls.

TAKE A LOOK
2. Describe What kinds of surfaces do not reflect sound waves easily?

____
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ECHOLOCATION

Many animals use echolocation to find food and to "see" objects that are in their way. **Echolocation** is the use of reflected sound waves to find objects. Animals that use echolocation include bats, dolphins, and some birds. ☑

During echolocation, the animal produces a sound wave. The sound bounces off objects and returns to the animal's ears. Sound waves take longer to return from far away objects than nearby ones.

READING CHECK
3. Describe What is echolocation?

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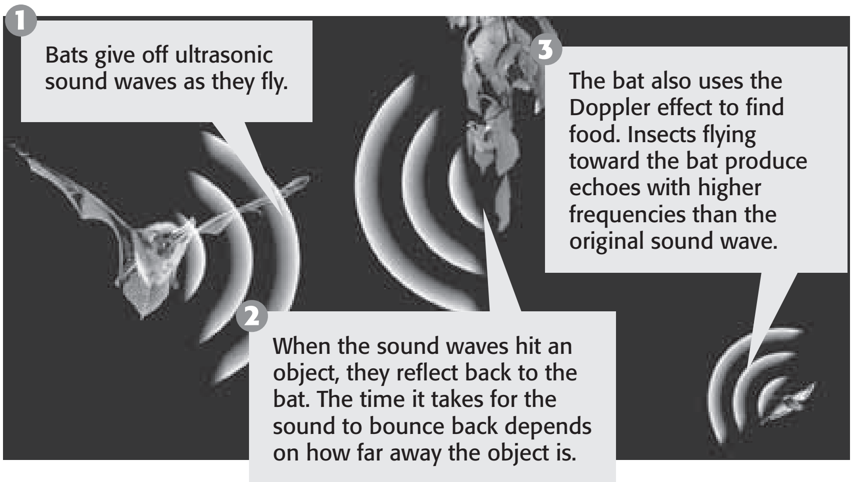

ECHOLOCATION TECHNOLOGY

Sonar (which stands for *so*und *n*avigation *a*nd *r*anging) is a type of electronic echolocation. People use sonar to find objects under water. Sonar usually uses ultrasonic sound waves. Their short wavelengths give more detail about the objects they reflect off of. ☑

Ships use sonar to locate and avoid icebergs and rocks. Scientists use sonar to map the ocean floor. People also use sonar to locate fish.

READING CHECK

4. Identify What kind of sound waves are used by sonar?

____

ULTRASONOGRAPHY

Doctors use a type of echolocation to "see" inside a person's body. In *ultrasonography*, ultrasonic waves reflect off of the patient's internal organs. A computer interprets the reflected waves as images of the organs. Doctors use ultrasonography to look for damage to organs and to check the development of unborn babies. ☑

READING CHECK

5. Identify What do doctors look for when they use ultrasonography?

____

____

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What Is Sound Wave Interference?

Interference happens when two or more waves overlap or combine. There are two main types of interference—constructive interference and destructive interference.

Constructive interference happens when compressions from one wave combine with compressions from another wave. The amplitude of the combined waves increases, so the sound is louder.

Destructive interference happens when compressions from one wave combine with rarefactions from another wave. The amplitude of the combined waves decreases, so the sound is softer.

READING CHECK

6. Describe What is wave interference?

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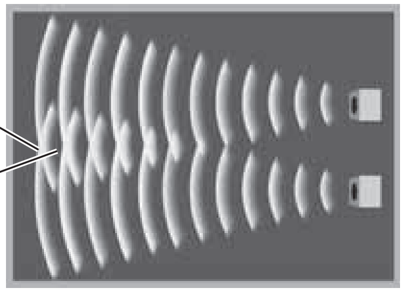
Sound waves from two speakers producing sound of the same frequency combine by both constructive and destructive interference.

Constructive interference happens when compressions from one wave overlap compressions from another wave. The sound is louder because the combined amplitude is greater.



Destructive interference happens when compressions from one wave overlap rarefactions from another wave. The sound is softer because the combined amplitude is smaller.

TAKE A LOOK

7. Identify Circle another point where constructive interference happens. Label it constructive interference. Circle another point where destructive interference happens. Label it destructive interference.

INTERFERENCE AND THE SOUND BARRIER

Some jet planes can travel faster than the speed of sound. As the jet travels close to the speed of sound, the sound waves in front of it get closer together. The waves overlap to produce constructive interference. The overlapping waves produce an area of high air pressure in front of the jet. This area of high pressure is called the *sound barrier*. ☑

READING CHECK

8. Describe What creates the sound barrier?

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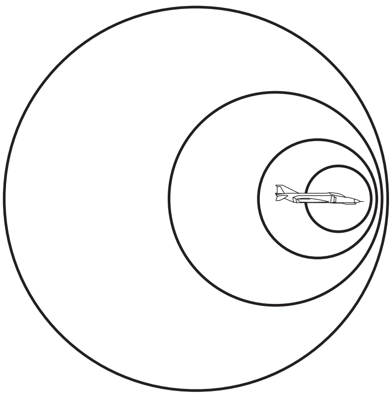


This jet is traveling near the speed of sound. The sound waves in front of the jet are pushed close together. The compression of the air particles produces an area of high pressure. This area is called the sound barrier.

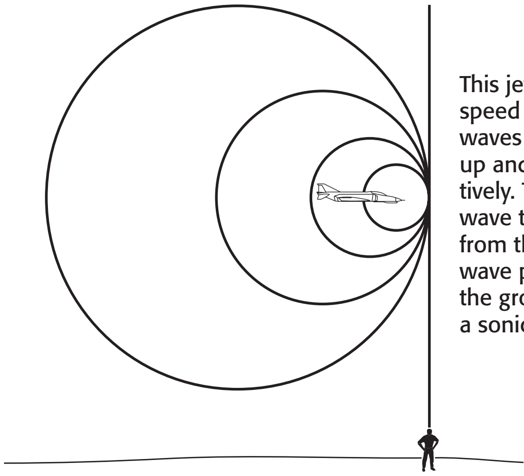
When the jet reaches the speed of sound, the waves in front of it pile up on top of each other. This produces a great deal of constructive interference. The amplitude of the wave gets very large. The amplified wave travels out from behind the jet as a *shock wave*. When this shock wave passes by a person on the ground, the person hears a **sonic boom**. ☑

Sonic booms can be loud enough to hurt your ears or break windows. The vibrations created by a sonic boom can make the ground shake. The figure on the next page shows how the compression of the air produces a sonic boom.

READING CHECK

9. Identify What is heard when a shock wave passes a person on the ground?

____



This jet is traveling at the speed of sound. The sound waves in front of the jet pile up and interfere constructively. This produces a shock wave that travels out away from the jet. When the shock wave passes the person on the ground, the person hears a sonic boom.

STANDING WAVES

Waves with the same frequency can interfere to produce a standing wave. A **standing wave** is a pattern of vibrations that look like a wave that is standing still. Standing waves form because the waves travel in both directions in the medium. Where the waves interfere constructively, they produce an area of high amplitude. Where the waves interfere destructively, they produce an area of low amplitude. ☑

You can see one standing wave in a plucked guitar string below. This wave is caused by the *fundamental*, or main, frequency of the sound the vibrating string makes. If you make the string vibrate at higher frequencies, you can see more standing waves. Only some frequencies will produce standing waves in a string of a certain length. The frequencies that produce two or more standing waves are called *resonant frequencies*. ☑

READING CHECK

10. Describe What is a standing wave?

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READING CHECK

11. Identify What is the name of the main frequency that makes the sound produced by a vibrating string?

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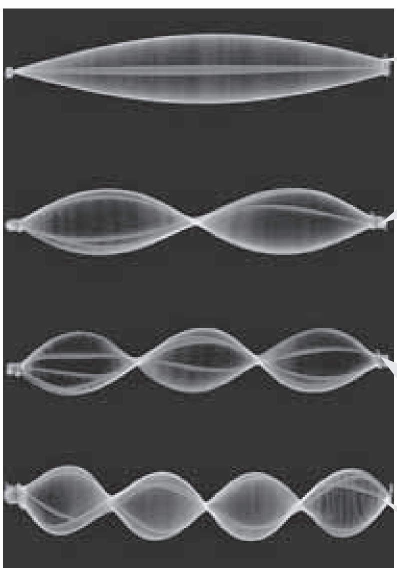

This string vibrates in only one standing wave. The frequency of the sound the string produces is the fundamental frequency.

This string is vibrating in two standing waves. The frequency of the sound the string produces is two times the frequency of the fundamental. This frequency is called the *first overtone*.

This string is vibrating to produce the *second overtone*. Its frequency is three times the fundamental frequency.

This string is vibrating to produce the *third overtone*. Its frequency is four times the fundamental frequency.

Math Focus

12. Infer The frequency of the fifth overtone on a vibrating string is ____ times the string's fundamental frequency.

____

How Do Sound Waves Resonate?

Resonance happens when a vibrating object causes a second object to vibrate. The second object vibrates with larger amplitude than the first object. Therefore, resonance causes a sound to be amplified.

To understand resonance, imagine being pushed on a swing. You swing at a certain frequency, the fundamental frequency of the swing. You always travel from the highest to the lowest point in the same amount of time. Now, imagine that someone continues to push you as you swing. If the person pushes you at the fundamental frequency of the swing, you will swing higher and higher. In other words, the pushes cause resonance in your swinging.

STANDARDS CHECK

PS 3a Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.

13. Explain How is resonance of a swing an example of energy being transferred?

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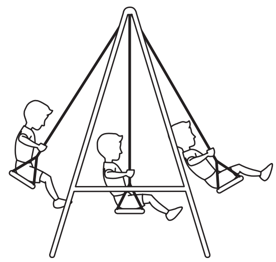
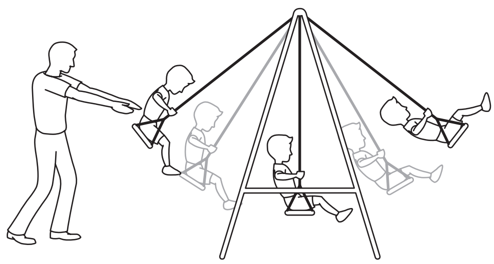


A person on a swing will swing at a certain frequency.



When the swing is pushed, it swings higher and higher. The amplitude of the swing increases because of pushes at the fundamental frequency of the swing.

RESONANCE AND MUSICAL INSTRUMENTS

Musical instruments use resonance to make sound. For example, string instruments resonate then they are played. A guitar or a violin is an example of a string instrument. When the strings are plucked, they vibrate. The sound waves resonate inside the body of the instrument. This causes the sound to be amplified.

When you blow air through the mouthpiece of a flute, you make the air in the mouthpiece vibrate. These vibrations resonate inside the instrument. The sound of the instrument is amplified. ☑

READING CHECK

14. Describe What happens to the sound inside a musical instrument due to resonance?

____

Name ______________________ Class ______________ Date ____________

Section 3 Review

NSES PS 3a

SECTION VOCABULARY

echo a reflected sound wave **echolocation** the process of using reflected sound waves to find objects; used by animals such as bats **interference** the combination of two or more waves that results in a single wave	**resonance** a phenomenon that occurs when two objects naturally vibrate at the same frequency; the sound produced by one object causes the other object to vibrate **sonic boom** the explosive sound heard when a shock wave from an object traveling faster than the speed of sound reaches a person's ears **standing wave** a pattern of vibration that simulates a wave that is standing still

1. Describe How does a bat use sound waves to hunt for food?

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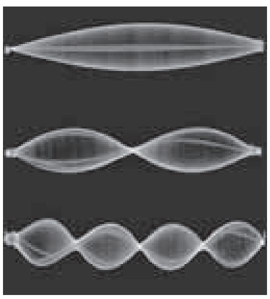
2. Recall The image below shows a series of resonant frequencies. Label the points of maximum destructive interference and constructive interference in the standing waves shown. What do you expect the relationship between the fourth overtone and the fundamental to be?



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3. Identify Indicate whether *reflection*, *constructive interference*, or *destructive interference* contributes to each of the following sound wave interactions.

Sound wave	Wave interaction
A jet produces a shock wave	
Ultrasonography can "see" a patient's heart	
Sonar locates fish under water	

4. Explain Why is resonance important to musical instruments?

____

Name ______________________ Class ____________ Date ___________

CHAPTER 21 The Nature of Sound

SECTION 4

Sound Quality

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- Why do different instruments sound different?
- How is noise different from music?

What Is Sound Quality?

Imagine that someone plays a sound with a certain pitch on a piano. Then, the person plays the same pitch, but on a violin. Both sounds, or notes, have the same fundamental frequency. However, it is easy to tell the difference between the two notes. This is because the note an instrument plays is made of more than just the fundamental frequency.

A single note from an instrument is actually made of several different pitches. The main pitch is the fundamental pitch. The note also contains several overtones. Each instrument produces different overtones. Therefore, each instrument produces a different-sounding note. The instruments have different sound qualities. **Sound quality** is the result of combining several pitches through interference of the waves. ☑

STUDY TIP

Discuss With a partner, discuss what kinds of music you enjoy listening to. List which musical instruments have the sound you like the best. Describe how each produces its sound.

READING CHECK

1. Describe What causes the same note played on a guitar and a piano to have a different sound?

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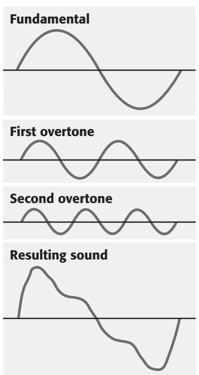
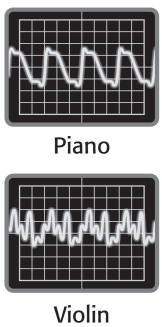


The note produced by an instrument is a result of combining several different pitches. The fundamental pitch is the main pitch of the note. When the overtones and the fundamental pitch are combined, they produce a sound with a certain sound quality.



The piano and the violin are both playing the same note. These oscilloscope images show why the two notes sound different. The notes have different overtones, so they have different sound qualities.

TAKE A LOOK

2. Identify What is happening to sound waves to cause the resulting sound of a musical instrument?

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How Do Instruments Make Sounds?

All instruments produce sound by vibrating. The shape of an instrument affects its sound quality. The three main types of instruments are string instruments, wind instruments, and percussion instruments. Each type of instrument produces sound in a different way.

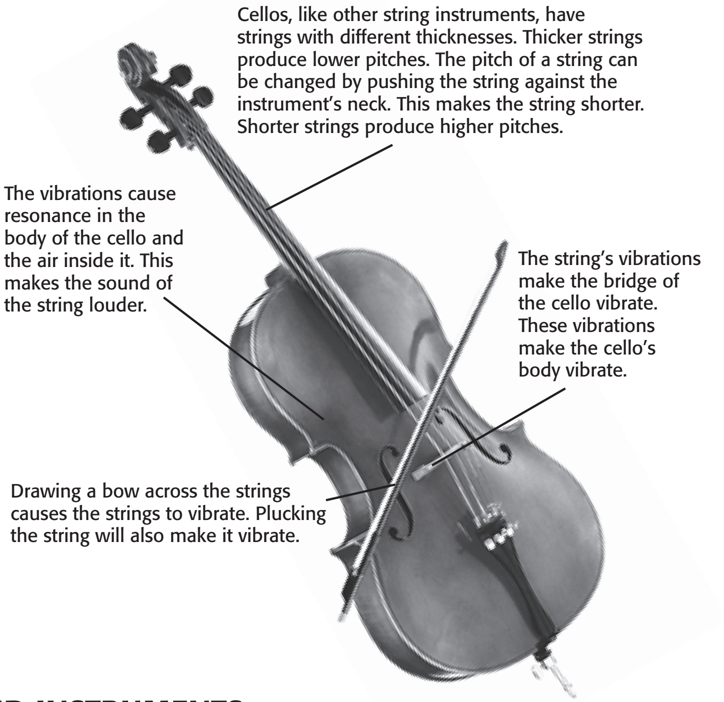
STRING INSTRUMENTS

String instruments produce sound when their strings vibrate. You can make a string vibrate by plucking it, as with a guitar or a banjo. You can also make a string vibrate using a bow, as with a violin or a cello.

Critical Thinking

3. Infer What length strings produce lower pitches?

____



WIND INSTRUMENTS

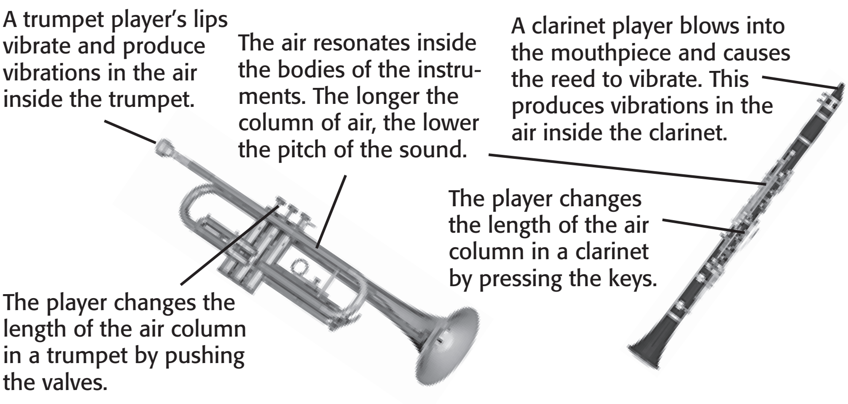
Wind instruments produce sound when the air inside a column vibrates. You can make the air inside a wind instrument vibrate by blowing into it. The vibration creates resonance inside the instrument. Covering the keys changes the length of the column of vibrating air. This changes the pitch of the sound. ☑

There are two groups of wind instruments: woodwinds and brass. Woodwinds include saxophones, oboes, flutes, and recorders. Brass instruments include French horns, trombones, tubas, and trumpets.

READING CHECK

4. Identify What does pressing the keys of a wind instrument do to the sound?

____



TAKE A LOOK

5. Identify What produces the vibrations in the air inside a trumpet?

____

6. Identify What produces the vibrations in the air inside a clarinet?

____

PERCUSSION INSTRUMENTS

Percussion instruments produce sound when they are struck. Striking the instrument causes part of it to vibrate. The pitch of the sound depends on the size of the instrument. Larger percussion instruments usually have a lower pitch. Drums, bells, and cymbals are percussion instruments. ☑

The player hits the skin of a drum with a drumstick. This makes the skin vibrate, producing a sound.

The player can strike a cymbal to make it vibrate. Some cymbals, like this one, vibrate when they strike each other.

Larger drums produce lower pitches.

READING CHECK

7. Identify What is done to produce the sound of a percussion instrument?

____

How Are Music and Noise Different?

Noise is any sound that is a random mix of frequencies. Most sounds you hear are noises. The sound of a car driving down the road is an example of a noise. ☑

You can use an oscilloscope to "see" the difference between a musical sound and noise. A note from an instrument produces a sound wave with a repeating pattern. Noise produces complex sound waves with no pattern.

READING CHECK

8. Describe What is noise?

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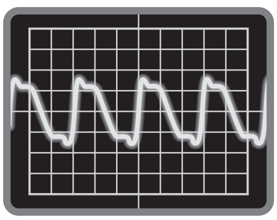
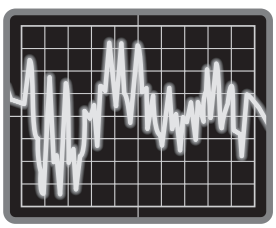
____



This image shows the oscilloscope graph for a piano note. Notice that the sound wave has a repeating pattern. This is a musical sound.

Piano



This image shows the oscilloscope reading for a loud clap. Notice that the sound wave has no repeating pattern. This is a noise.

A sharp clap

TAKE A LOOK

9. Compare What is the difference in the pattern for a piano note and a clap shown by an oscilloscope graph?

____

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Name ______________________ Class ______________ Date ____________

Section 4 Review

SECTION VOCABULARY

noise a sound that consists of a random mix of frequencies	**sound quality** the result of the blending of several pitches through interference

1. **Describe** Why do a flute and a violin have different sound qualities?

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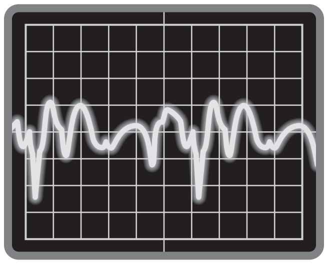
2. **Apply Concepts** The screen below shows the sound waves recorded by an oscilloscope. Is this sound a musical sound or a noise? Explain your answer.



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3. **Apply Concepts** A cello produces notes of lower pitch than a violin. Explain why you would expect the larger cello to produce lower pitched notes than the smaller violin.

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4. **Identify** Label each description of a musical instruments as a string instrument, wind instrument or percussion instrument.

Instrument description	Type of instrument
Music is produced when air vibrates in a column.	
Music is produced when the instrument is struck.	
Music is produced by plucking or bowing to create vibrations.	

SECTION 1

What Is Light?

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What are the two parts of an electromagnetic wave?
- Why is light energy important to life on Earth?

National Science Education Standards

PS 3a, 3f

What Is an Electromagnetic Wave?

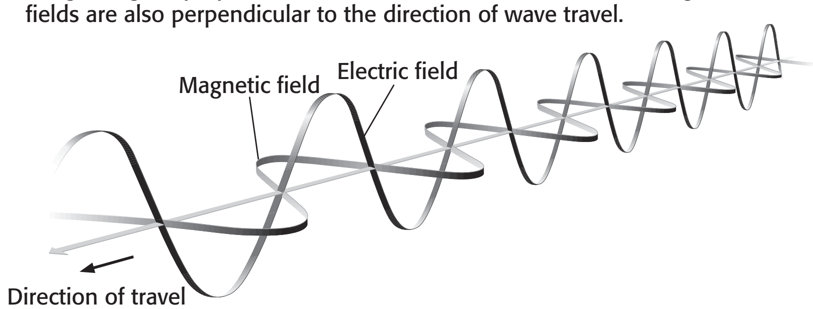
You can see light from the sun and other sources, such as light bulbs. Light is a type of energy that travels as a wave. However, light waves are different from other kinds of waves, such as water waves. Light is a kind of wave called an **electromagnetic wave**, or *EM wave*. Unlike water and sound waves, electromagnetic waves can travel through a vacuum. They do not need a medium in order to travel.

An electromagnetic wave is made of vibrating electric and magnetic fields. The figure below shows how an electric field and a magnetic field combine to produce an electromagnetic wave.

STUDY TIP

Summarize Think about how the headings of this section fit together. Use the headings to write a summary of its major points.

Electromagnetic waves are made of electric and magnetic fields vibrating at right angles (perpendicular) to each other. The electric and magnetic fields are also perpendicular to the direction of wave travel.



TAKE A LOOK

1. Draw The magnetic field is perpendicular to the electric field. Draw two perpendicular lines here.

ELECTRIC FIELD

An *electric field* surrounds every charged object. The electric field around an object attracts objects with an opposite electric charge. The electric field *repels*, or pushes away, like-charged objects. When you see two objects stuck together by static electricity, you are observing the effects of an electric field.

Critical Thinking

2. Infer Two objects are stuck together by static electricity. One object has a positive charge. Does the other object have a positive or a negative charge?

____

Say It

Discuss Have you ever gotten an electric shock that wasn't from a battery or a wall outlet? Share your experiences with a small group.

Sometimes, you can see the effects of an electric field. The hair on the girl's head stands up because of an electric field.

MAGNETIC FIELD

A *magnetic field* surrounds every magnet. Every magnet has two *poles*, or ends: a north pole and a south pole. The north pole of one magnet is attracted to the south pole of another magnet. If you place two magnets together with their north poles near each other, they push each other away. Magnetic fields also pull paperclips and iron filings toward magnets.

READING CHECK

3. Predict What will two magnets do if you place the north pole of one near the south pole of the other?

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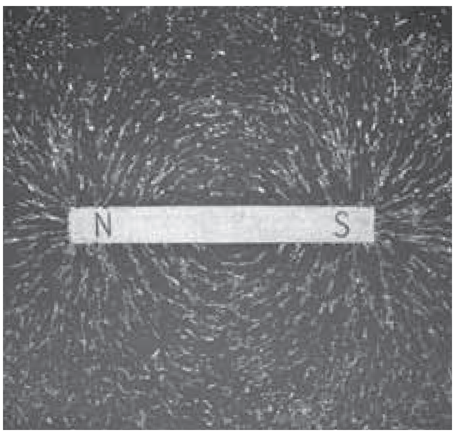

The magnetic field surrounding the magnet causes the iron filings to form arcs around it.

PRODUCTION OF EM WAVES

The vibration of an electrically charged particle can produce an EM wave. When the electrically charged particle vibrates, it moves back and forth a little. This movement makes the electric field surrounding it vibrate, too. The vibration of the electric field creates a magnetic field. The vibration of an electric field and a magnetic field together produces an EM wave.

The EM wave carries energy. It is the same energy released by the charged particle when it vibrated. Light energy is carried in an EM wave. The transfer of light or other forms of energy as EM waves is called **radiation**.

READING CHECK

4. Identify What does a charged particle do that makes the electric field around it vibrate?

____

5. Identify What is created when an electric field vibrates?

____

6. Identify What is produced when electric and magnetic fields vibrate together?

____

How Does Light Travel?

Light traveling in a vacuum is faster than anything else scientists have discovered. In space, which is almost a vacuum, light travels at 300,000 km/s. Light travels slightly slower in air, glass, water, and other materials.

Light travels about 880,000 times faster than sound. You can observe this fact by watching and listening to a thunderstorm. Thunder and lightning are both produced at the same time. Usually, you see lightning before you hear thunder, because light travels faster.

TAKE A LOOK

7. Identify Which travels faster, light waves or sound waves?

____

LIGHT FROM THE SUN

Even though light travels quickly, it takes about 8.3 min for it to travel from the sun to the Earth. Obviously, Earth is a very long way from the sun. You can use the equation for speed to calculate the distance from the Earth to the sun.

1. Write the equation for speed.

$$speed = distance \div time$$

2. To solve for *distance*, multiply *speed* by *time*.

$$speed \times time = distance$$

3. Replace *speed* with 300,000 km/s, replace *time* with 8.3 min, and multiply.

$$300{,}000 \text{ km/s} \times 8.3 \text{ min} \times 60 \text{ s/min} = 150{,}000{,}000 \text{ km}$$

Although Earth is 150 million km from the sun, light waves from the sun are our major source of energy. Plants use light from the sun to make food from carbon dioxide and water. Animals get energy from the sun by eating plants or by eating animals that eat plants. Fossil fuels store energy from the sun because they formed from plants and animals that lived millions of years ago. ☑

READING CHECK

8. List What are three things that store the sun's energy on Earth?

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Name ______________________ Class ______________ Date ____________

Section 1 Review

NSES **PS 3a, 3f**

SECTION VOCABULARY

electromagnetic wave a wave that consists of electric and magnetic fields that vibrate at right angles to each other	**radiation** the transfer of energy as electromagnetic waves

1. **Describe** How can vibrations produce an electromagnetic wave?

2. **Compare and Contrast** How are light waves different from ocean waves?

3. **Explain** Use the terms *transfer*, *EM wave*, *energy*, and *sun* to explain the radiation of sunlight.

4. **Apply Concepts** Sound waves need a medium, or material, to travel in. Electromagnetic waves do not. Why is it important that EM waves can travel without a medium?

5. **Apply Concepts** What is the main way that your body obtains energy from the sun?

6. **Recall** Why do you see a lightning bolt before hearing thunder?

SECTION 2
The Electromagnetic Spectrum

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is the electromagnetic spectrum?
- What are the ranges of different types of EM waves?
- How are the different ranges of EM waves used?

National Science Education Standards
PS 3a, 3f

What Is the Electromagnetic Spectrum?

Remember that light is an electromagnetic wave. However, light is not the only kind of electromagnetic wave. The **electromagnetic spectrum** is made up of all the kinds of electromagnetic (EM) waves.

Scientists divide the EM spectrum into regions according to wavelength. We are most familiar with the region of visible light. X rays and microwaves are two of the other regions. Although we divide the EM spectrum into regions, there is no clear division between each region. Some regions even overlap.

All electromagnetic waves travel at the same speed in a vacuum. However, they have different wavelengths and different frequencies. The speed of a wave is equal to its wavelength multiplied by its frequency.

$$\textit{speed} = \textit{wavelength} \times \textit{frequency}$$

Two waves traveling at the same speed can have a different wavelength if the frequency is also different. A wave with a larger wavelength has a smaller frequency.

STUDY TIP

Organize Use the figure on this page, or draw one like it in your notebook. Under each type of EM wave, write its range. Under that, write its uses.

Math Focus

1. Calculate All light travels at 300,000 km/s in a vacuum. Red light has a wavelength of 700 nm. Violet light has a wavelength of 400 nm. Which of these two colors of light has the higher frequency?

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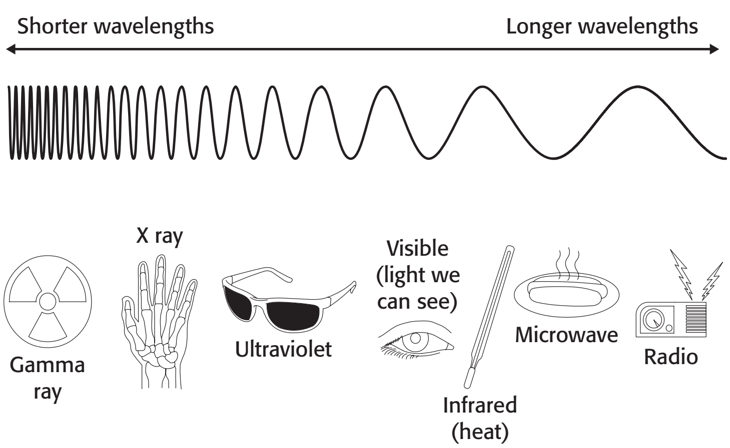

The electromagnetic spectrum is arranged from short to long wavelength. This is the same as arranging from high to low frequency.

What Do We Use Radio Waves For?

Radio waves are EM waves that have wavelengths longer than 30 cm. They have some of the longest wavelengths and lowest frequencies of all EM waves. Radio waves are used for broadcasting radio and television signals.

BROADCASTING RADIO SIGNALS

Radio waves are not sound waves. However, radio stations use radio waves to carry sound information. They do this by changing the amplitude or the frequency of the waves. Changing the amplitude or the frequency is called *modulation*. ☑

READING CHECK

2. Apply Ideas Do radio stations send out sound waves? Explain.

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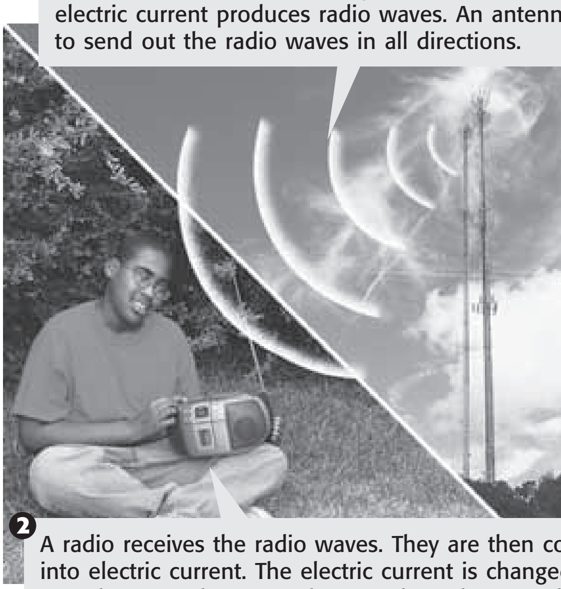
1 First, the sound wave is changed into electric current. The electric current produces radio waves. An antenna is used to send out the radio waves in all directions.



Radio waves themselves cannot be heard. They carry energy that can be changed into sound.

2 A radio receives the radio waves. They are then converted back into electric current. The electric current is changed back into sound waves. They carry the sound you hear on the radio.

AM and FM radio waves are different in several ways. The abbreviation *AM* stands for "amplitude modulation." AM radio stations change the amplitude of the waves so the waves can carry information. *FM* stands for "frequency modulation." FM radio stations change the frequency of the waves so the waves can carry information.

AM radio waves have longer wavelengths than FM radio waves. The AM radio waves can bounce off the atmosphere. This means that AM radio waves can travel farther than FM radio waves. However, FM radio waves are less affected by electrical noise in the atmosphere. Therefore, music from an FM station often sounds clearer than music from an AM station.

Critical Thinking

3. Apply Ideas While driving through Idaho, you are listening to a radio station from Maine. Is the station likely to be AM or FM? Explain your answer

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BROADCASTING TELEVISION SIGNALS

Television stations also use radio waves. Television signals are often carried on radio waves that have shorter wavelengths. These waves can carry more information.

A TV broadcast uses both amplitude and frequency modulation. Frequency-modulated waves carry the sound. Amplitude-modulated waves carry the pictures. ☑

READING CHECK

4. Summarize Give two ways that people use radio waves.

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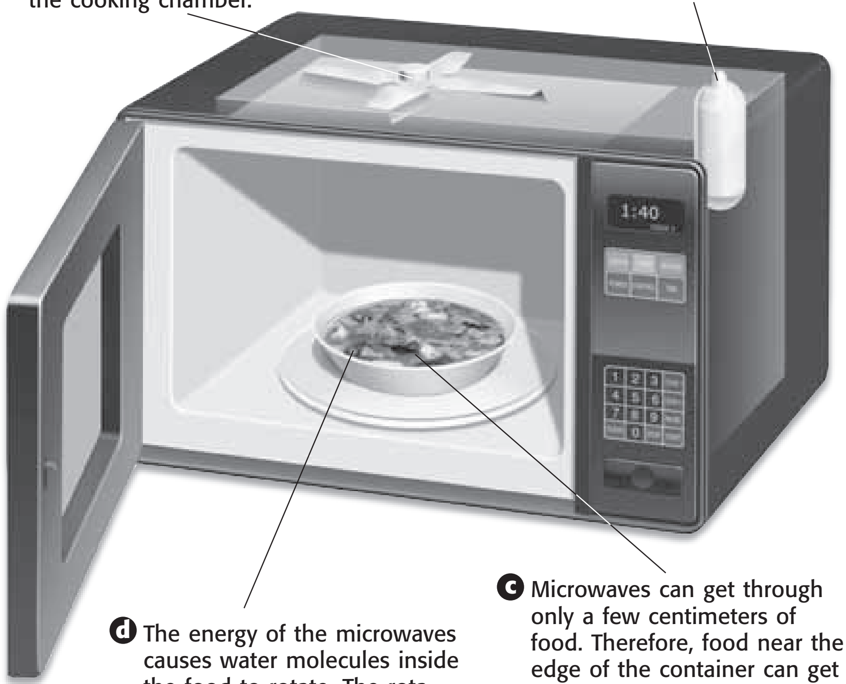
What Do We Use Microwaves For?

Microwaves have wavelengths between 0.1 cm and 30 cm. They have a shorter wavelength and higher frequency than radio waves. Microwave ovens produce microwaves to cook or heat up your food. Microwaves are also used in radar and in communication.

How a Microwave Oven Works



b The microwaves are reflected off a metal fan and evenly spread out in the cooking chamber.

a A device called a *magnetron* produces microwaves by accelerating, or speeding up, charged particles.

c Microwaves can get through only a few centimeters of food. Therefore, food near the edge of the container can get hotter than the very center.

d The energy of the microwaves causes water molecules inside the food to rotate. The rotation of the water molecules causes the temperature of the food to increase.

TAKE A LOOK

5. Infer Why do microwave cooking directions tell you to stir the food?

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COMMUNICATION

Microwaves can be used to send information over long distances. Cellular phones use microwaves to send and receive signals. TV signals and other signals sent to communication satellites in space are also carried by microwaves.

RADAR

Radar (*ra*dio *d*etection *a*nd *r*anging) uses microwaves to detect the speed and location of objects. A radar device sends out microwaves toward an object. The microwaves bounce off the object and travel back to the radar device. The device uses the time it took the waves to return to determine the speed and location of the object.

People use radar in many different ways. Air traffic controllers use it to help airplanes take off and land safely. Ship navigators use radar to find their way at night. Police officers use radar to detect the speed of cars. ☑

READING CHECK

6. List Give three jobs in which microwaves are used for radar.

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Police officers often use radar to detect the speed of a car. The radar gun is used to determine whether a car is traveling faster than the speed limit.

What Do We Use Infrared Waves For?

Infrared means "below red." *Infrared waves* have wavelengths between 700 nm (the wavelength of red light) and 1 mm. A nanometer (nm) is equal to 0.000000001 m.

Infrared waves are also called *infrared light*. Humans cannot see infrared light, but we can feel it. Your skin absorbs infrared waves from the sun. The energy of the waves causes the particles in your skin to vibrate more. You feel the waves as an increase in your skin temperature.

Almost all objects give off infrared waves. Warmer objects give off more infrared waves than cooler objects. Some devices can detect infrared waves and change them into signals you can see. Infrared binoculars, for example, change infrared waves into visible light waves. These binoculars can be used to watch animals at night. You can also use special film to photograph heat.

Critical Thinking

7. Analyze Rattlesnakes use infrared waves to hunt. How can a snake find a mouse in the grass without looking?

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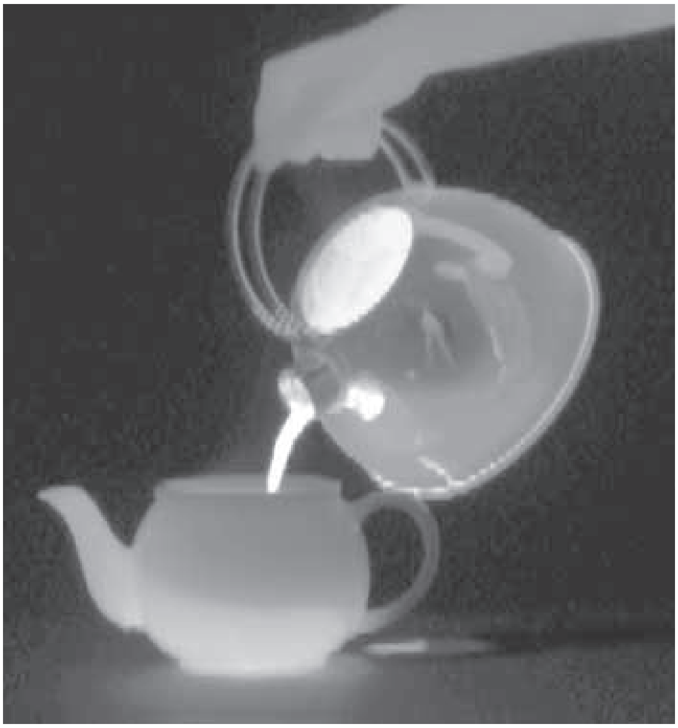


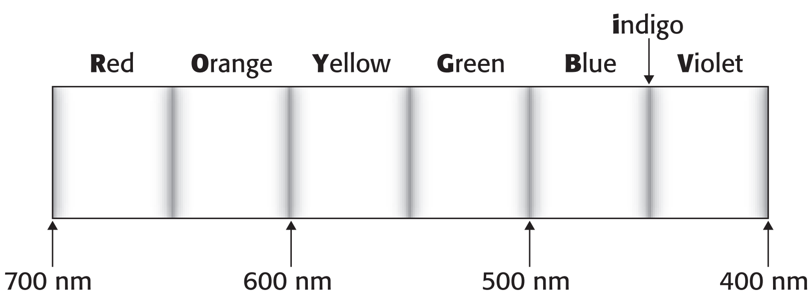
This is a photo of boiling water being poured from a kettle into a teapot. The photo was taken with a film sensitive to infrared waves. The boiling water is hotter than the hand pouring it. Therefore, the hot water is brighter in the photo.

What Is Visible Light?

Visible light is the narrow range of wavelengths between 400 nm and 700 nm. These are the only wavelengths in the EM spectrum that humans can see. ☑

All of the wavelengths of visible light combine to make *white light*. Sunlight is white light. Light from most light bulbs is also white light.

The range of colors humans can see is called the *visible spectrum*. We see different wavelengths of visible light as different colors. The longest wavelength is red, and the shortest wavelength is violet.



The visible spectrum contains all the colors of visible light. You can use the imaginary name ROY G. BiV to help remember the order of the colors in the spectrum. The letter *i* stands for the color indigo. Indigo is a dark blue.

READING CHECK

8. Identify Which part of the EM spectrum can humans see?

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TAKE A LOOK

9. Draw and Color Draw a stick figure, with a hat and shoes, in the space below. This is Roy G. BiV. Color his hat red and write "700 nm" in red next it. Color his shoes violet and write "400 nm" in violet next to them.

What Is Ultraviolet Light?

Ultraviolet light (UV light) has wavelengths between 60 nm and 400 nm. Most of the UV light from the sun does not reach the surface of the Earth. The atmosphere blocks out most UV light. However, enough UV light does get through the atmosphere to affect us. Ultraviolet light has important benefits, but it also can be dangerous.

STANDARDS CHECK

PS 3f The sun is a major source of energy for changes on the earth's surface. The sun loses energy by emitting light. A tiny fraction of that light reaches the earth, transferring energy from the sun to the earth. The sun's energy arrives as light with a range of wavelengths, consisting of visible light, infrared, and ultraviolet radiation.

10. Identify Relationships Is sunlight the same thing as visible light? Explain.

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POSITIVE EFFECTS OF UV LIGHT

Small amounts of UV light are good for your body. When UV light shines on skin cells, they produce vitamin D. This vitamin allows your intestines to absorb calcium. Without calcium, your teeth and bones would be very weak. In addition, UV waves from UV lamps are used to kill bacteria on food and surgical tools.

Negative Effects of UV Light

Danger	Effect	How to protect yourself
Damage to skin cells	short-term: sunburn long-term: wrinkles, skin cancer	Wear sunscreen with a high SPF (*s*un *p*rotection *f*actor). Wear hats, long-sleeved shirts, and long pants or skirts.
Damage to eyes	short-term: sore eyes, temporary vision problems long-term: permanent vision problems, blindness	Wear sunglasses. Wear a hat with a wide brim. Never look at the sun.

What Do We Use X Rays For?

X rays have wavelengths between 0.001 nm and 60 nm. The short wavelength of X rays allows them to pass through many materials. Doctors use X rays to see bones.

X-ray machines are also used for security in airports and some public buildings. X rays allow security officers to see inside bags or containers without opening them.

Too much X-ray exposure is dangerous. X rays can hurt or kill living cells. A medical patient getting an X ray may wear an apron lined with lead. X rays cannot pass through lead. The lead protects the parts of the body that don't need to be X-rayed. ☑

READING CHECK

11. Explain Why may patients getting X rays wear lead aprons?

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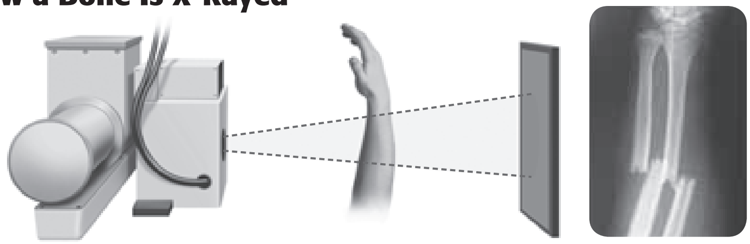
How a Bone Is X-Rayed



❶ X rays travel through skin and muscle but are absorbed by bones.

❷ X rays that pass through the skin and muscle strike the film.

❸ X rays that pass through skin and muscle make dark areas on the film. Bright areas show the shapes of the bones.

TAKE A LOOK

12. Explain How can X-ray films allow doctors to see bones inside the body?

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What Do We Use Gamma Rays For?

Gamma rays are EM waves with wavelengths shorter than 0.1 nm. They pass through most materials very easily. Gamma rays are used to treat some forms of cancer. Doctors focus the rays on tumors inside the body to kill the cancer cells. This treatment often has good effects, but it can have bad effects, too. Some healthy cells may be killed.

Gamma rays are also used to kill harmful bacteria in foods such as meat and fresh fruits. The gamma rays do not harm the food, and they do not stay in the food. Therefore, food that has been treated with gamma rays is safe for you to eat.

Summary of Ranges and Uses of Waves in the EM Spectrum

Wavelength	Type of wave	Uses
longer than 30 cm		radio and TV
0.1 cm to 30 cm		microwave ovens, cell phones, communication satellites, radar
700 nm to1 mm	infrared waves	
		human sight
60 nm to 400 nm	ultraviolet light	
0.001 nm to 60 nm	X rays	medical X rays, security
shorter than 0.1 nm		killing cancer cells, killing bacteria in food

TAKE A LOOK

13. Fill In Complete the summary of this section by filling in the empty boxes.

Name ______________________ Class ______________ Date ____________

Section 2 Review

NSES PS 3a, 3f

SECTION VOCABULARY

electromagnetic spectrum all of the frequencies or wavelengths of electromagnetic radiation	

1. **Compare** Give three differences between ultraviolet light and visible light.

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2. **Identify** Give the region of the EM spectrum for each EM wave described.

Description	Region of EM spectrum
Used by police officers to detect the speed of cars by radar	
Energy from the sun that can cause sunburn	
Used in a device that takes images of bones	
Carry television signals to your home	
Can produce rainbows when there are water droplets in the sky	

3. **Recall** Gamma rays can be both helpful and harmful. List one way gamma rays are helpful, and one way they are harmful.

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4. **Apply Concepts** After being outside on a cloudy day, you discover you have a sunburn. If the sun is behind clouds, how did you get a sunburn?

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SECTION 3

Interactions of Light Waves

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- How does reflection affect the way we see objects?
- What happens to light when it passes from one material into another?
- How do light waves interact with each other?

National Science Education Standards
PS 3c

What Is Reflection?

Light bounces off some objects and passes through others. **Reflection** happens when light bounces off an object. Light reflects off objects all around you. You see the objects because the reflected light travels to your eyes.

You can use the law of reflection to predict where a light wave will travel after it reflects. The *law of reflection* states that the angle of incidence of light is equal to the angle of reflection. The *angle of incidence* is the angle at which a light beam hits an object. The *angle of reflection* is the angle at which the light bounces off the object. The law of reflection states that these two angles are equal. ☑

STUDY TIP

Organize Concepts As you read, make a Concept Map in your notebook. Try to include the vocabulary terms and the terms in italics.

READING CHECK

1. Apply Ideas If a light beam hits a mirror at a 30° angle, what is the angle of incidence?

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2. Apply Ideas What is the angle of reflection?

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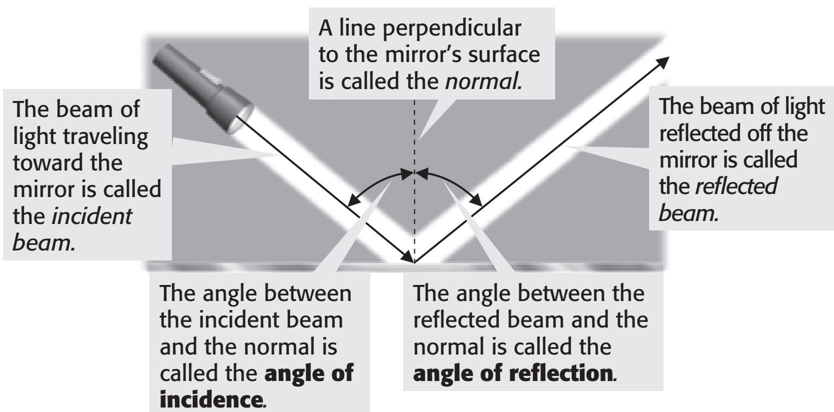
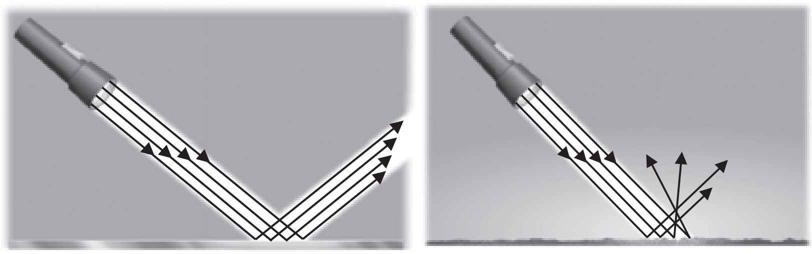
The Law of Reflection



REGULAR REFLECTION AND DIFFUSE REFLECTION

Light reflects off most objects, such as mirrors and walls. Why can you see your reflection in a mirror, but not in a wall? The answer has to do with the surface the light reflects from. Some objects, such as mirrors, reflect all the light beams at the same angle. This is called *regular reflection*. Regular reflection allows you to see an image in a mirror or shiny piece of metal.

Some objects, such as walls, reflect the light beams at many different angles. This is called *diffuse reflection*. Diffuse reflection prevents you from seeing images reflected off walls, furniture, or other rough surfaces.



Regular reflection occurs when light beams are reflected at the same angle. When your eye detects the reflected beams, you can see a reflection on the surface.

Diffuse reflection occurs when light beams reflect at many different angles. You can't see a reflection because not all of the reflected light is directed toward your eyes.

TAKE A LOOK

3. Identify Circle the image that shows how light reflects from a mirror.

SEEING OBJECTS

You can see some objects because they produce light. You can see other objects because they reflect light. *Luminous* objects are light sources. Flames, light bulbs, and the sun are examples of luminous objects. *Illuminated* objects are visible because they reflect light. The reflected light travels from the objects to your eyes. The moon is an illuminated object. You see the moon because it reflects light from the sun to your eyes. ☑

READING CHECK

4. Compare and Contrast What is the difference between a luminous object and an illuminated object?

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You can see the body of a firefly because it is illuminated.

You can see the tail of a firefly because it is luminous.

How Is Light Absorbed and Scattered?

When you shine a flashlight, you can observe the light beam spread out and become dim farther from the flashlight. The light beam becomes dim because of absorption. It spreads out because of scattering.

LIGHT ABSORPTION

Absorption is the transfer of light energy into an object or a particle of matter. Air is full of particles, such as water droplets or dust. When light shines through the air, these particles absorb some of the light energy. The farther light travels from its source, the more its energy is absorbed by particles. Therefore, light is dimmer farther from its source. ☑

READING CHECK

5. Explain What makes a beam of light become dimmer as it travels away from its source?

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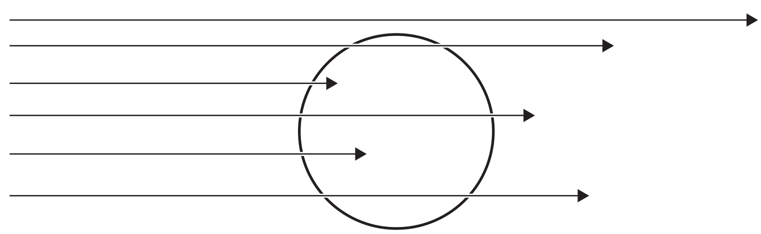

When light is absorbed by a particle, the light beam loses energy and becomes dim.

LIGHT SCATTERING

Scattering is the interaction of light with an object that changes the light's direction or energy. When light collides with a particle in the air, the light scatters in all directions.

The scattering of visible light makes the sky look blue. Light with shorter wavelengths is scattered more than light with longer wavelengths. Blue light is scattered more by the atmosphere than red light. The red light passes more easily through the atmosphere. Therefore, the sky looks blue. ☑

READING CHECK

6. Explain Why is the sky blue?

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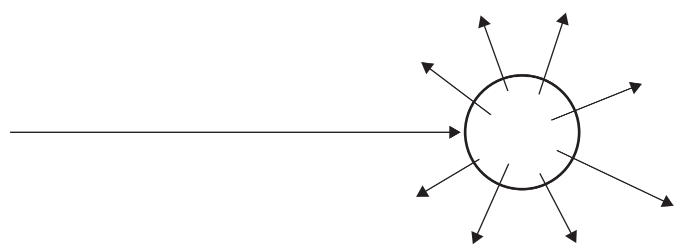
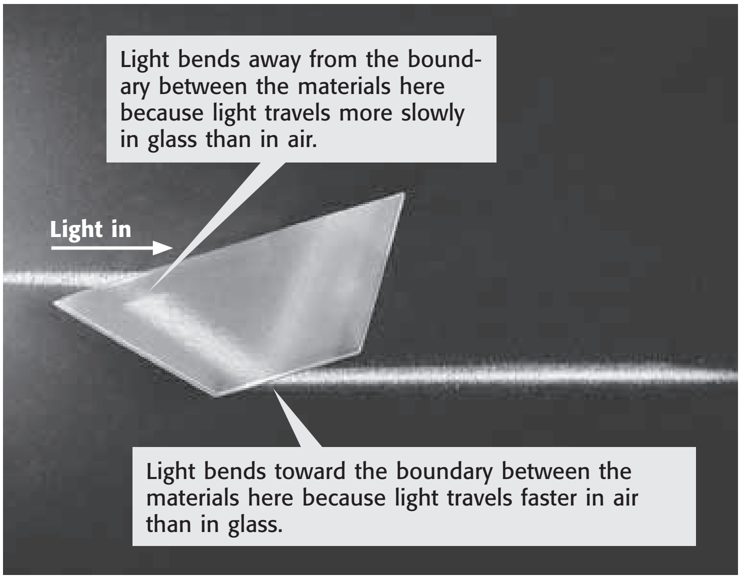


When light collides with a particle, it scatters in all directions. Scattering allows you to see objects outside a beam of light.

What Is Refraction?

Refraction happens when a wave bends as it passes from one material into another. Light travels at different speeds through different materials. Therefore, passing from one material to another can change its direction. Light travels faster in a vacuum than in matter. Light travels faster in air than in glass or water.



TAKE A LOOK

7. Apply Concepts Which way will light bend when it passes from air to water? Explain your answer.

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OPTICAL ILLUSIONS

Light from a light source or reflected from an object travels in a straight line through the air to you. Your brain expects light to always travel in a straight line. However, when you look at an object under water, the light refracts, or bends. Because it doesn't travel in a straight line, you may see an optical illusion, such as the one shown below.

Critical Thinking

8. Infer What is an optical illusion?

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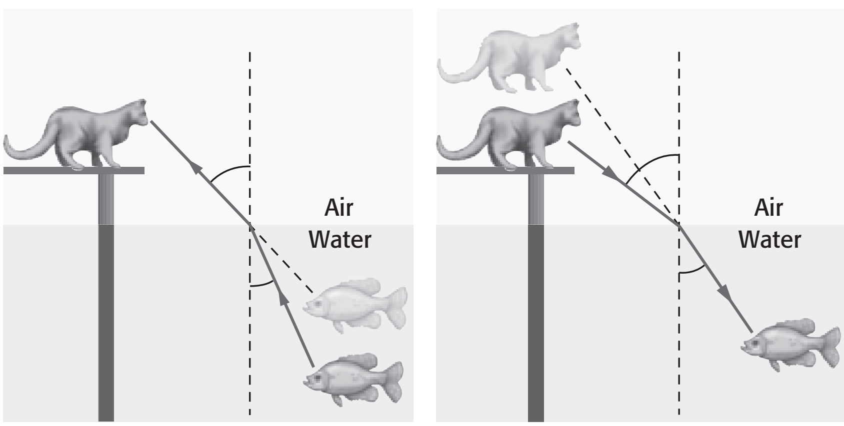

Because of refraction, the cat and the fish see optical illusions. To the cat, the fish appears closer than it really is. To the fish, the cat appears farther away than it actually is.

SEPARATING COLORS

White light contains all of the colors of visible light. Each color has a different wavelength. Different wavelengths travel at the same speed in a vacuum, but they travel at different speeds in glass. Therefore, some colors refract more than others when they travel through the glass. Colors with the shortest wavelengths refract the most. Colors with the longest wavelengths refract the least. ☑

READING CHECK

9. Identify What happens to light when it hits a prism?

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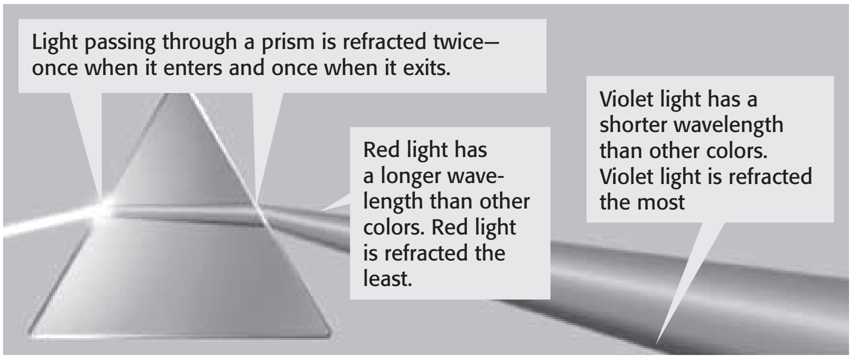

A prism is a piece of glass that uses refraction to separate white light into the colors of visible light.

What Is Diffraction?

Diffraction happens when waves bend around a barrier or through an opening. The amount a wave bends depends on two things: its wavelength and the size of the barrier or opening. Waves diffract the most when the barrier or opening is the same size as the wavelength or smaller.

The wavelength of visible light is very small. It is about 100 times thinner than a human hair. Therefore, a light wave won't bend much unless it passes through a very narrow opening or around a sharp edge.

Critical Thinking

10. Compare and Contrast How are diffraction and refraction of light alike? How are they different?

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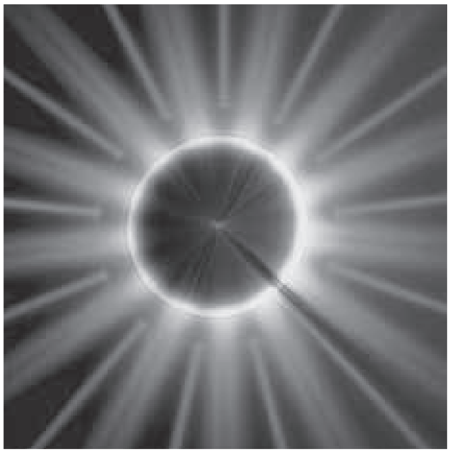
DIFFRACTION YOU CAN SEE

You will not often see light waves diffracting around objects. For example, you can't see the objects that are around the corner of a building. However, you can see some effects of light diffraction. For example, diffraction makes the edges of a shadow look blurry.



This image shows light diffracting. A single wavelength of light is passing around the sharp edge of a tiny disk.

TAKE A LOOK

11. Describe Compared to the wavelength of the light, how large is the disk?

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What Is Wave Interference?

Interference happens when two or more waves combine to form a single wave. Interference occurs when two waves overlap. When waves overlap, they can combine by constructive interference or destructive interference. ☑

READING CHECK

12. Identify What are the two kinds of interference?

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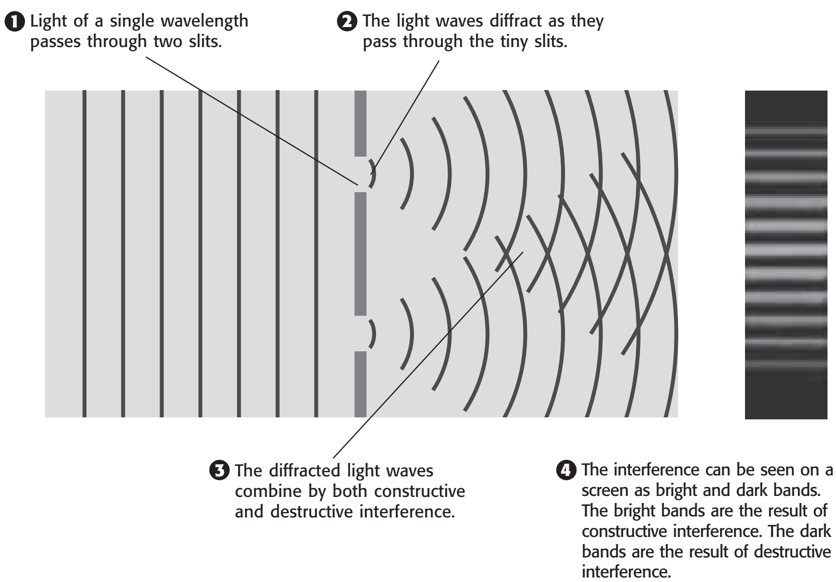
Constructive interference produces a wave with a larger amplitude than the original waves. Waves that combine by constructive interference create one wave with a stronger intensity. For example, light waves that combine by constructive interference produce one brighter light wave.

Destructive interference produces a wave with a smaller amplitude than the original waves. Waves that combine by destructive interference create one wave with a weaker intensity. For example, light waves that combine by destructive interference produce one dimmer light wave.

Constructive and Destructive Interference



TAKE A LOOK

13. Identify What kind of interference produces the dark bands?

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LIGHT INTERFERENCE YOU CAN SEE

The experiment shown in the last figure used only one wavelength of light. However, the light you see around you every day is white light. White light contains many different wavelengths. The many waves don't usually combine in total destructive or constructive interference. This is why you do not usually see the effects of interference. ☑

READING CHECK

14. Explain Why do we not usually see the effects of constructive and destructive light interference?

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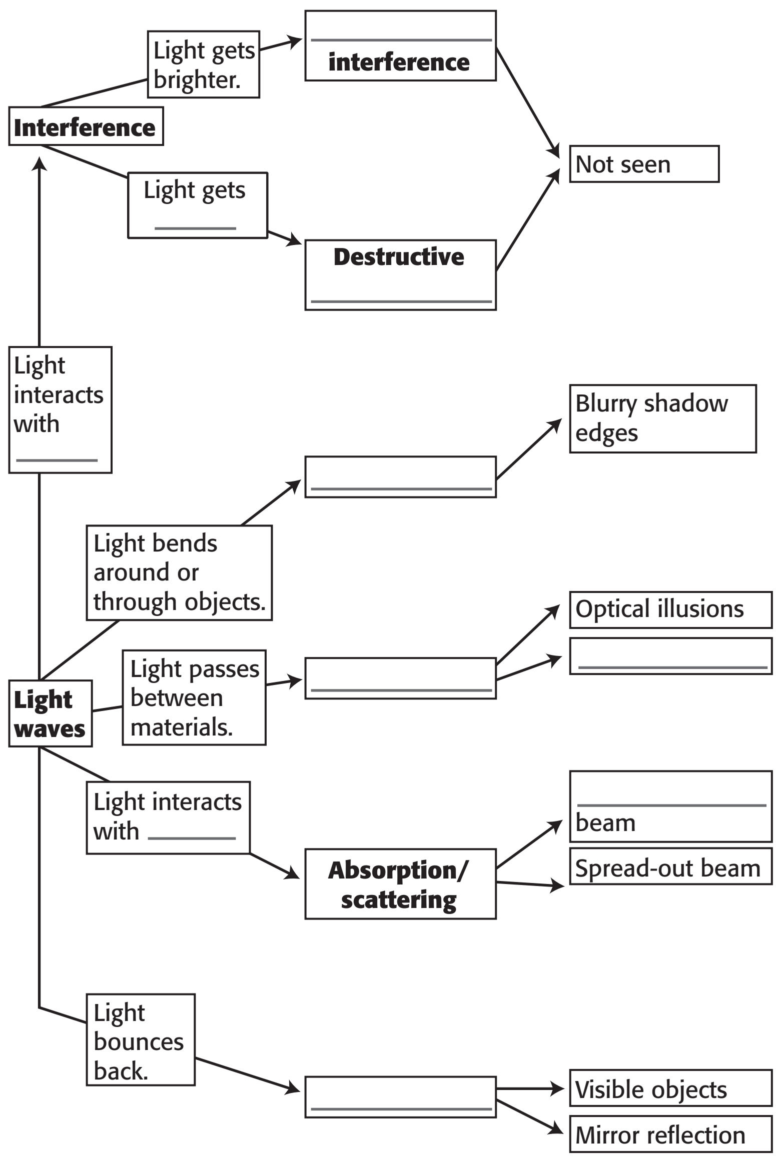
Light Wave Interaction



TAKE A LOOK

15. Describe Complete the Flow Chart with the information from this section.

Name ______________________ Class ______________ Date ______________

Section 3 Review

NSES PS 3c

SECTION VOCABULARY

absorption in optics, the transfer of light energy to particles of matter

diffraction a change in the direction of a wave when the wave finds an obstacle or an edge, such as an opening

interference the combination of two or more waves that results in a single wave

reflection the bouncing back of a ray of light, sound, or heat when the ray hits a surface that it does not go through

refraction the bending of a wavefront as the wavefront passes between two substances in which the speed of the wave differs

scattering an interaction of light with matter that causes light to change its energy, direction of motion, or both

1. Explain Why is a beam of light wider and dimmer when it hits a wall than when it leaves the flashlight?

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2. Describe Use the vocabulary words to name the type of wave interaction that causes each condition.

Condition	Wave Interaction
A log is sticking up from the water. It looks as if its top and bottom are not attached.	
The edge of a shadow is blurry.	
You can see your image in the mirror.	
A beam of light becomes dimmer farther away from its source.	

3. Apply Ideas In a dark room, you can see the image on the screen of a television. However, you cannot see the table the television is sitting on. Why can you see the image but not the table?

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4. Explain Why can you see your reflection in the bowl of a spoon but not in a piece of cloth?

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CHAPTER 22 The Nature of Light

SECTION 4

Light and Color

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What are three ways light interacts with matter?
- How is an object's color related to its interaction with light?
- What happens when colors of light or pigments mix?

National Science Education Standards

PS 3a, 3c

How Can Light Interact with Matter?

Remember that most light around us every day is white light. Why, then, do most objects not look white? The answer has to do with how light interacts with matter. When light strikes any form of matter, it can interact with the matter in three main ways. The light can be reflected, absorbed, or transmitted.

Reflection happens when light bounces off an object. Light reflects off objects all around you. If light was not reflected by objects, you wouldn't see them.

Absorption happens when light energy moves into matter. Absorption causes a beam of light to become dimmer farther from the source. Absorption of light can also make things feel warmer.

Transmission happens when light passes through matter. The transmission of light through air allows you to see the world around you. The transmission of light through a glass allows you to see the liquid inside it.

STUDY TIP

Discuss Write down questions you have about this section as you read. Then, share your questions and answers with a small group.

Critical Thinking

1. Apply Concepts If all the light hitting a window were reflected, would you be able to see through it? Explain your answer.

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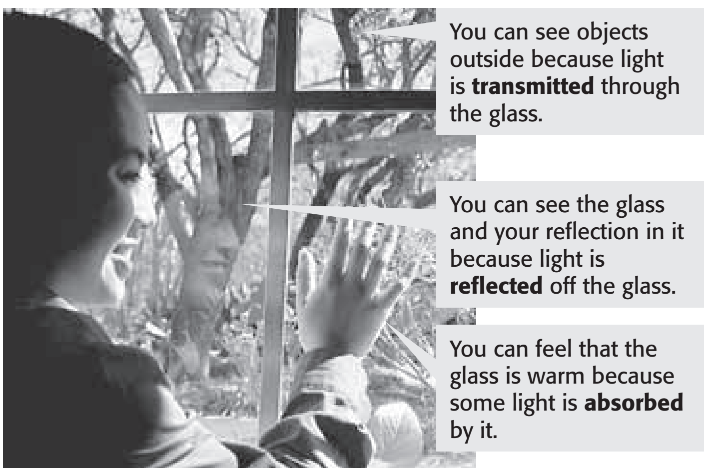

Light can interact with matter in several ways at the same time. Light is transmitted, reflected, and absorbed when it strikes a glass window.

TAKE A LOOK

2. Identify Give three ways that light can interact with matter.

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How Do Different Types of Matter Interact with Light?

Matter can be sorted into three types based on how light interacts with it. Matter can be transparent, translucent, or opaque.

Light is easily transmitted through **transparent** matter. You can see objects clearly when you view them through something that is transparent. Glass, air, and pure water are all examples of transparent matter. ☑

READING CHECK

3. Define Write your own definition for *transparent*.

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Translucent matter transmits some light but scatters other light as it passes through. Objects seen through translucent matter look blurry. Tissue paper, muddy water, and wax paper are examples of translucent matter.

Opaque matter does not transmit any light. You cannot see through something that is opaque. Metal, wood, and books are examples of opaque matter.

Critical Thinking

4. Apply Concepts Fog, rain, and snow are all made of water. Which one is transparent, which is translucent, and which is opaque?

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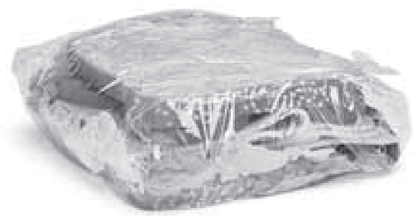

Transparent plastic makes it easy to see the sandwich inside.

Opaque aluminum foil does not allow you to see the sandwich inside without unwrapping it.

Translucent wax paper makes it a little harder to see the sandwich inside.

What Determines the Color of an Object?

Remember that we see the different wavelengths of visible light as different colors. Long wavelengths, around 700 nm, look red. Short wavelengths, around 400 nm, look violet. Other wavelengths give other colors, such as pink and teal.

The color of an object depends on the wavelengths of light that reach your eyes. Light can reach your eyes after being reflected off an object. Light can also reach your eyes after being transmitted through an object. ☑

READING CHECK

5. Identify What is the wavelength of the light you see when you look at a red shirt? At a red bottle?

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COLORS OF OPAQUE OBJECTS

A colored opaque object absorbs some light wavelengths and reflects other light wavelengths. The light that is absorbed by the object does not reach your eyes. Only the reflected light reaches your eyes. The colors that are reflected by an opaque object determine its color. ☑

READING CHECK

6. Identify What determines the color of an opaque object?

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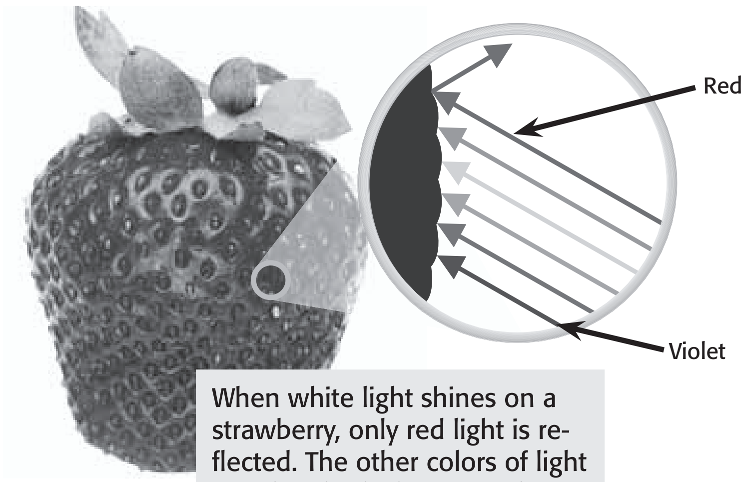

When white light shines on a strawberry, only red light is reflected. The other colors of light are absorbed. Therefore, the strawberry looks red to you.

What about solid white or black objects? When all the colors of light are reflected, the object looks white. When all the colors of light are absorbed, the object looks black.

The white hairs on the cow reflect all the colors of light. The black hairs on the cow absorb all the colors of light.

TAKE A LOOK

7. Predict Which part of the cow's hair do you think would feel warmer, the black part or the white part? Explain your answer.

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COLOR TRANSMITTED THROUGH OBJECTS

The colors of transparent and translucent objects depend on the light that is transmitted through them. A normal glass window is colorless because it transmits all the colors that strike it. A green glass bottle is green because it transmits only the green light that strikes it. The other colors are absorbed.

What Happens When Colors of Light Mix?

White light is the combination of all colors of light. You can also get light that looks white by combining only three colors: red, blue, and green. Red, blue, and green are the *primary colors of light*. They can be combined in different ways to create many other colors. ☑

The combination of colors of light is called *color addition.* When two primary colors of light are combined, you see a *secondary color of light*. The three secondary colors of light are cyan, magenta, and yellow. Cyan light is blue plus green, magenta light is blue plus red, and yellow light is red plus green.

READING CHECK

8. Identify What are the primary colors of light?

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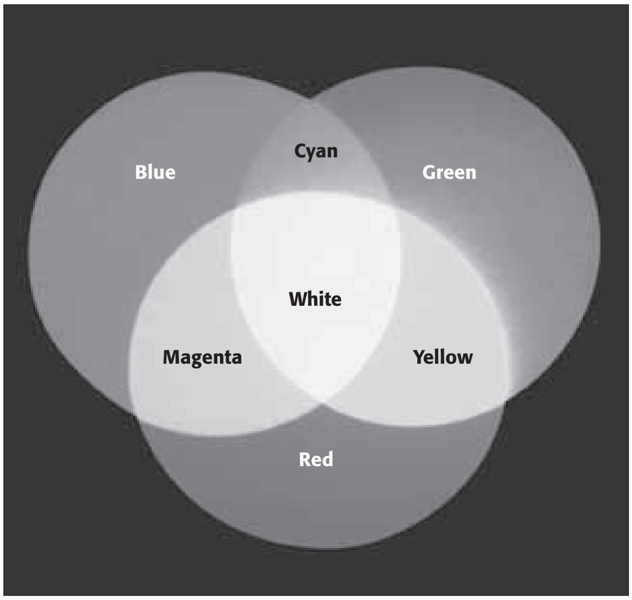

The primary colors of light are red, blue, and green. They combine to create white light. The secondary colors of light are cyan, magenta, and yellow. The secondary colors of light are created when two primary colors of light are put together.

TAKE A LOOK

9. Apply Ideas How could you use primary light colors to make a yellow spotlight for your school play?

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COLOR TELEVISION

The colors you see on a television are produced by the primary colors of light and color addition. A TV screen contains many groups of tiny red dots, green dots, and blue dots. Each dot glows when it is signaled. The colors of the glowing dots combine to makes all the colors you see on the screen.

What Happens When Colored Pigments Mix?

Mixing light colors is different from mixing pigments. The colors in paint and ink are pigments, not light. When you mix red, blue, and green paint, you do not make white paint.

PIGMENT COLORS

A **pigment** is a substance that gives an opaque object its color. A pigment absorbs some colors of light and reflects others. The color of the pigment, and the object, is the color of light that reflects back to you. ☑

Almost all objects contain pigment. Plants contain the pigment chlorophyll, which makes most of them green. In non-green plants, the green pigment is covered up by other pigments. People have a pigment called melanin in their skin. A tan is an increase in the pigment melanin.

READING CHECK

10. Explain Why do pigments look colored?

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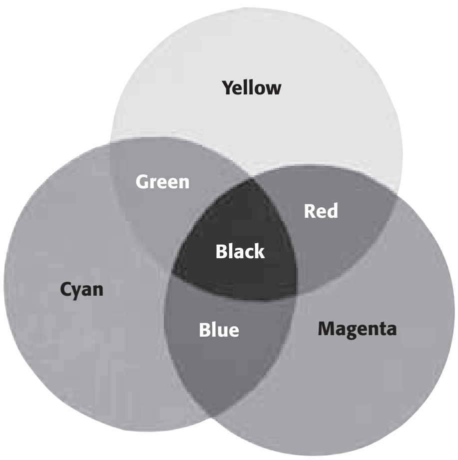
MIXING PIGMENTS

Each pigment absorbs at least one color of light. When pigments are combined, they absorb more colors of light. Therefore, fewer colors of light are reflected. Because more colors of light are absorbed, mixing pigments is called *color subtraction*. That is, colors are subtracted from the light that is reflected.

The primary pigment colors are not the same as the primary colors of light. The *primary pigments* are yellow, cyan, and magenta. These three pigments can produce every color you see.



The primary pigments are yellow, cyan, and magenta. They combine to create the color black. The secondary pigments are red, blue, and green. The secondary pigments are created through color subtraction when two primary pigments are mixed.

TAKE A LOOK

11. Explain Why can't you combine primary pigments to paint a yellow backdrop for your school play?

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12. Identify What are the three primary pigments?

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COLOR IN PRINT

When you see a color print, as in a magazine, it has been made from the three primary pigments. They can be overlapped to produce all the colors the image needs. Black pigment is sometimes used to provide contrast.

Section 4 Review

NSES PS 3a, 3c

SECTION VOCABULARY

opaque describes an object that is not transparent or translucent	**transmission** the passing of light or other form of energy through matter
pigment a substance that gives another substance or a mixture its color	**transparent** describes matter that allows light to pass through with little interference
translucent describes matter that transmits light but that does not transmit an image	

1. **Explain** Why does grass look green? Use the words *reflect* and *absorb* in your answer.

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2. **Identify** Give two examples of translucent objects and two examples of opaque objects.

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3. **Compare** Explain how the mixing of light colors is different from the mixing of pigments. Use the terms *color addition* and *color subtraction* in your answer.

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4. **Explain** What determines the color of a transparent object?

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5. **Identify** What are the three primary pigment colors?

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Mirrors and Lenses

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What is a ray diagram?
- How is light reflected by different types of mirrors?
- How is light refracted by different types of lenses?

National Science Education Standards
PS 3c

How Can You Show the Paths of Light Waves?

Do you wear glasses, or know someone who does? The lenses in glasses *refract*, or bend, light waves. They help to focus images into your eyes. How do eye doctors know what shape to make the lenses? To determine the shape of the lens, the doctor must know how the light will travel through the glass. Doctors and other scientists use symbols to represent how light waves travel.

Remember that light waves are electromagnetic waves. They travel away from their source in all directions. They travel in straight lines until they interact with matter. Since light waves travel in straight lines, you can use a *ray* to show the path it takes. A ray looks like a straight arrow. ☑

You can combine rays into *ray diagrams* to show the path of light after it reflects or refracts. Remember that *reflection* happens when light waves bounce off an object such as a mirror. *Refraction* happens when light waves bend as they move from one medium to another.

STUDY TIP

Compare After you read this section, make a chart comparing different kinds of mirrors. In the chart, describe each kind of mirror and the image or images it can form.

READING CHECK

1. Describe What kind of path does a light ray take if it does not interact with matter?

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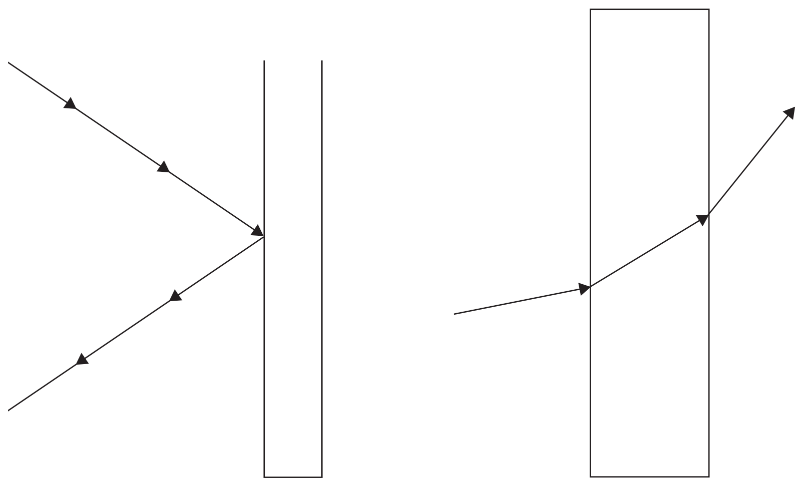

A ray can be used to show changes in the direction of a light wave. The left-hand image shows a ray changing direction as it is reflected. The right-hand image shows a ray changing direction as it is refracted.

TAKE A LOOK

2. Identify What happens to the path of a light wave when it enters a different medium?

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How Do Different Mirrors Reflect Light?

You probably know that mirrors reflect light. However, not all mirrors reflect light in the same way. The shape of a mirror changes the way light reflects off it. For example, your reflection in a bathroom mirror looks different than your reflection in a spoon. Scientists classify mirrors based on shape. The three shapes of mirrors are plane, concave, and convex. ☑

READING CHECK

3. Identify How do scientists classify mirrors?

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PLANE MIRRORS

A **plane mirror** is a mirror that has a flat surface. Most mirrors, such as your bathroom mirror, are plane mirrors. The image you see in a plane mirror is right side up. It looks the same size as the object that produced it. However, the image in a plane mirror is reversed left to right, as shown below.

TAKE A LOOK

4. Describe How is the image in a plane mirror different from the object that forms it?

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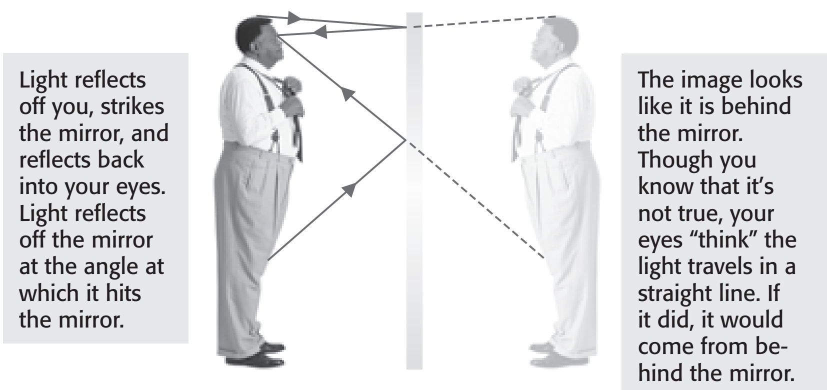
Plane mirrors form virtual images. A *virtual image* is an image that light does not travel through. The virtual image looks like it is behind the mirror. It seems to be the same distance behind the mirror as the original object is in front of the mirror.



The rays show how light reaches your eyes. The dotted lines show where the light appears to come from.

TAKE A LOOK

5. Identify What kind of images do plane mirrors form?

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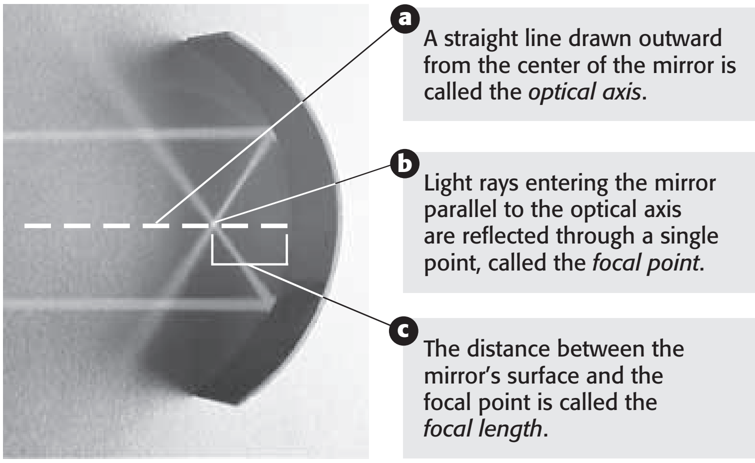
CONCAVE MIRRORS

A **concave mirror** curves away from you in the middle. The inside of the bowl of a shiny spoon is a concave mirror. Concave mirrors form different images than plane mirrors. The image depends on three things: the optical axis, the focal point, and the focal length of the mirror. The figure below shows how light reflects off a concave mirror. ☑



Concave mirrors can form virtual images as plane mirrors do. Concave mirrors can also form real images. A *real image* is an image that light passes through. A real image can be projected onto a screen. A virtual image cannot.

The kind of image that a concave mirror forms depends on its focal length and where the object is. A virtual image forms when the object is between the focal point and the mirror. The virtual image is right-side-up. A real image forms when the focal point is between the object and the mirror. The real image is upside-down.

An object at the focal point will not produce an image. This is because all light waves that pass through the focal point reflect parallel to the optical axis. Therefore, they never cross. If you put a light source at the focal point of a concave mirror, light reflects outward in a bright beam. Therefore, concave mirrors are used in car headlights and flashlights.

READING CHECK

6. Define What is a concave mirror?

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TAKE A LOOK

7. Compare How is the focal point different from the focal length?

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Critical Thinking

8. Apply Concepts A concave mirror has a focal length of 50 cm. An object is placed 40 cm from the mirror. Describe the image that forms.

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RAY DIAGRAMS AND CONCAVE MIRRORS

You can use a ray diagram to determine what kind of image a concave mirror will form. Follow along in the diagram below to learn how to do this. First, draw two rays from the top of the object to any two places on the surface of the mirror. Then, draw reflections of those rays. If the reflecting rays cross in front of the mirror, the image is a real image. If they do not, the image is a virtual image. ☑

READING CHECK

9. Describe Where do reflected rays meet to form a real image?

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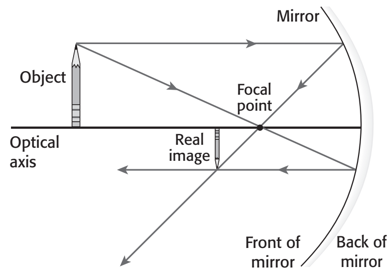

If the reflecting rays cross in front of the mirror, any image will be real.

TAKE A LOOK

10. Compare Give two differences between the real image and the virtual image in the figure.

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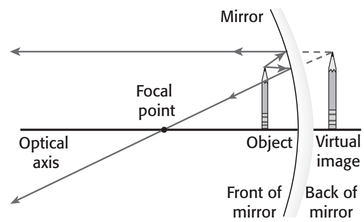

If the reflecting rays do not cross in front of the mirror, any image will be virtual.

CONVEX MIRRORS

A **convex mirror** curves toward you in the middle. The back of a shiny spoon is a convex mirror. The images formed by convex mirrors are different from the images formed by other mirrors. All images formed by convex mirrors are virtual, right-side-up, and smaller than the original object. ☑

Convex mirrors let you see a large area all together by making the image of the area smaller. Security mirrors in stores are convex mirrors. Convex mirrors are also used as side mirrors on cars and trucks.

READING CHECK

11. Describe What kinds of images do all convex mirrors form?

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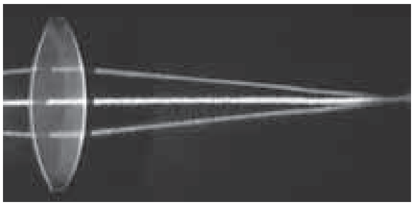
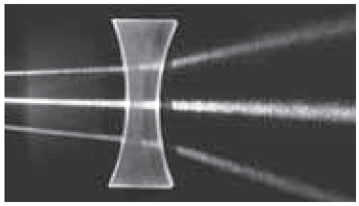
How Do Different Lenses Refract Light?

A **lens** is a transparent object that forms an image by refracting light. Like mirrors, lenses are classified by their shape. The two shapes of lenses are concave and convex. Like a mirror, a lens has a focal point and an optical axis.

When light rays pass through a **convex lens,** the rays are refracted toward each other.



When light rays pass through a **concave lens,** the rays are refracted away from each other.



TAKE A LOOK

12. Describe What happens to light rays when they pass through a convex lens?

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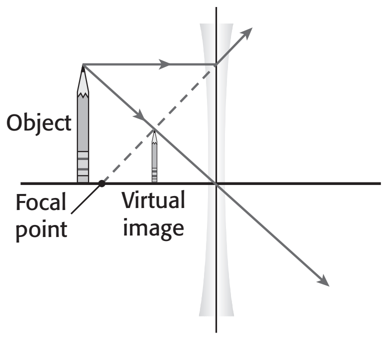
A **concave lens** is thinner in the middle than at the edges. Concave lenses always form virtual images. The refracted rays from a concave lens never meet. Concave lenses are used in microscopes and in some eyeglasses.



A concave lens forms a virtual image. The image is smaller than the object.

TAKE A LOOK

13. Identify Compared to the object, on which side of a concave lens does the image form?

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A **convex lens** is thicker in the middle than at the edges. A magnifying glass is a convex lens. When light travels into a convex lens, it bends toward the center of the lens. It bends toward the center again on its way out of the lens.

Convex lenses can form different kinds of images. If the object is less than one focal length from the lens, a virtual image forms. The image is larger than the object, as shown below. If the object is more than two focal lengths from the lens, a real image forms. The image is smaller than the object and appears upside-down. If the object is between one and two focal lengths from the lens, a real image forms. The image is larger than the object.

Critical Thinking

14. Apply Concepts A convex lens has a focal length of 30 cm. An object is 45 cm from the lens. Describe the image that forms.

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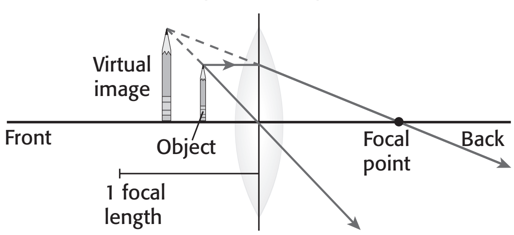

If an object is less than 1 focal length away from a convex lens, a **virtual image** is formed. The image is larger than the object.

Name ______________________ Class ______________ Date ______________

Section 1 Review

NSES PS 3c

SECTION VOCABULARY

concave lens a lens that is thinner in the middle than at the edges

concave mirror a mirror that is curved inward like the inside of a spoon

convex lens a lens that is thicker in the middle than at the edges

convex mirror a mirror that is curved outward like the back of a spoon

lens a transparent object that refracts light waves such that they converge or diverge to create an image

plane mirror a mirror that has a flat surface

1. **Describe** Explain why the image formed by a plane mirror appears to be behind the mirror.

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2. **Compare** How is a virtual image from a convex lens different from one produced by a convex mirror?

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3. **Describe** What happens to light rays that pass through a concave lens?

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4. **Identify** Indicate the mirror that matches the description provided.

Description	Mirror type
Forms only virtual images smaller than the object	
Forms only virtual images the same size as the object	
May form a virtual image larger than the object	

5. **Apply Concepts** How far away from a magnifying glass should you hold an object to make it appear larger? Explain your answer.

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Name ________________________________ Class ________________ Date ______________

CHAPTER 23 Light and Our World

SECTION 2

Light and Sight

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- What are the parts of the human eye?
- How does the human eye work?
- What are some common vision problems?

National Science Education Standards

PS 3c

How Does the Human Eye Detect Light?

When you look around, you can see objects both near and far. You can also see the different colors of the objects. You see objects that produce their own light because your eyes detect the light. You see all other objects because light reflects off the objects and enters your eyes.

Your eye has several parts that work together so you can see. Light travels through the cornea and the pupil. The convex *lens* refracts the light to focus a real image on the *retina*, or back of your eye. Tiny muscles in your eye change the thickness of the lens. Changing the thickness of the lens allows you to focus on objects at different distances from your eye.

Receptors in the retina called *rods* and *cones* detect light. Rods can detect very dim light. Cones detect colors in bright light. The figure below gives more details about how your eye works.

STUDY TIP

Describe As you read this section, make a flowchart showing how light travels through your eye.

STANDARDS CHECK

PS 3c Light interacts with matter by transmission (including refraction), absorption, or scattering (including reflection). To see an object, light from that object—emitted or scattered from it—must enter the eye.

Word Help: interact
to act upon one another

1. Explain How do you see objects that do not produce their own light?

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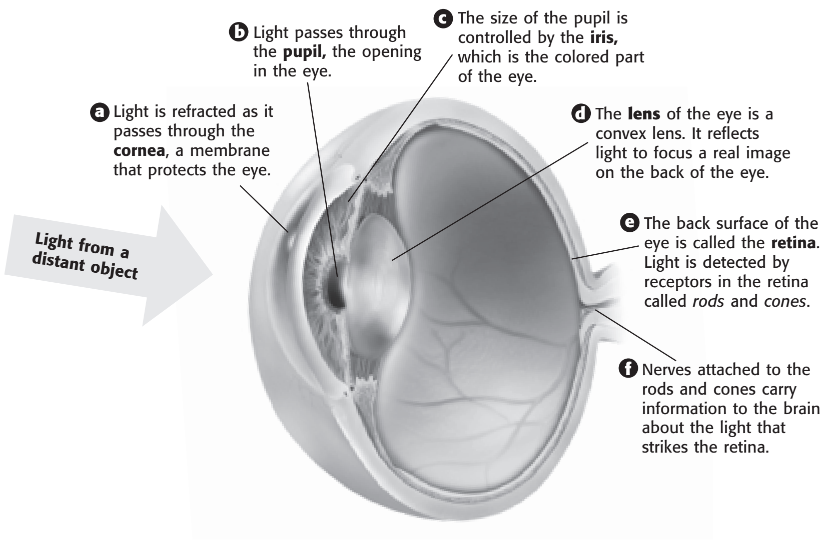
How Your Eyes Work



What Are Some Common Vision Problems?

Say It

Discuss In a small group, talk about different types of vision problems.

People with normal vision can clearly see objects close up or far away. People with normal vision can also clearly see all colors of visible light. However, the eye is complex, and it is common for people to have problems with their vision.

NEARSIGHTEDNESS

Remember that the lens of the eye focuses light on the retina. Muscles that control the shape of the lens allow the eye to focus on objects nearby and far away.

Nearsightedness happens when a person's eye is too long. The lens focuses light in front of the retina. A nearsighted person can only see an object clearly if it is nearby. Objects that are far away look blurry. ☑

READING CHECK

2. Define What is nearsightedness?

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FARSIGHTEDNESS

Farsightedness happens when a person's eye is too short. The lens focuses light behind the retina. A farsighted person can only see an object clearly if it is far away. Objects nearby look blurry. Both nearsightedness and farsightedness can be corrected with lenses, as shown below.

Critical Thinking

3. Compare How is nearsightedness different from farsightedness? Give two ways.

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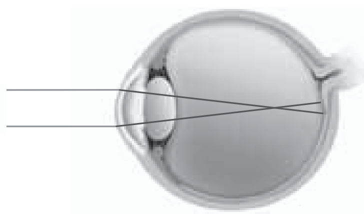
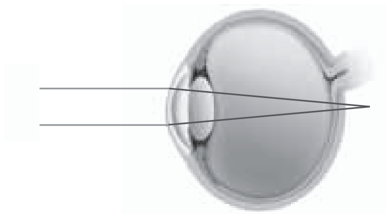
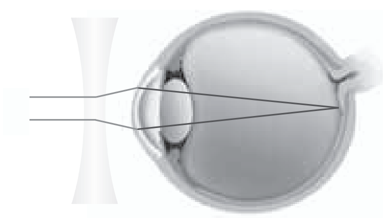
Correcting Nearsightedness and Farsightedness



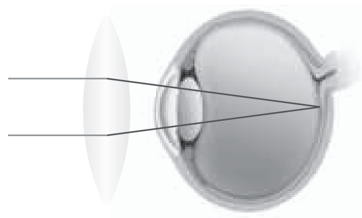
Nearsightedness happens when the eye is too long. The lens focuses light in front of the retina.



Farsightedness happens when the eye is too short. The lens focuses light behind the retina.



A **concave lens** placed in front of a nearsighted eye refracts the light outward. The lens in the eye can then focus the light on the retina.



A **convex lens** placed in front of a farsighted eye refracts the light inward. The lens in the eye can then focus the light on the retina.

TAKE A LOOK

4. Identify What type of lens is used to correct farsightedness?

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SURGERY FOR VISION CORRECTION

Surgery can be used to correct nearsightedness or farsightedness. During this kind of surgery, an eye surgeon reshapes the patient's cornea using a laser. Remember that the cornea refracts light. Therefore, reshaping the cornea changes how light is focused on the retina. ☑

READING CHECK

5. Explain Why does reshaping the cornea change a person's vision?

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First, an eye surgeon uses a machine to measure the patient's cornea. Then, the surgeon uses a very precise laser to reshape the cornea. The eye then focuses light correctly, and the patient gains perfect or nearly perfect vision.

There are some risks associated with surgery to correct vision. People who have had surgery may suffer from double vision. They may have trouble seeing at night. A few people lose their vision permanently. In addition, people under 20 years old should not have vision-correction surgery because their eyes are still changing.

COLOR DEFICIENCY

About 5% to 8% of men and 0.5% of women in the world have *color deficiency*. Color deficiency is also called colorblindness. People with color deficiencies cannot tell the difference between some colors. Scientists have not yet found a way to correct color deficiencies.

Math Focus

6. Calculate About how many times more men than women have color deficiencies?

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Color deficiency happens when the cones in the retina do not work properly. Remember that cones detect visible light. There are three kinds of cones named for the colors they detect most. The three kinds of cones are red, green, and blue. Each kind of cone can detect many colors of light, but they detect one the most. ☑

READING CHECK

7. Identify What causes color deficiency?

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A person who has normal color vision can detect all colors of visible light. In people with color deficiencies, the cones respond to the wrong wavelengths of visible light. The cones detect the wrong colors. People whose cones detect the wrong colors see certain colors as a different color. For example, red and green may both look like shades of yellow.

Name ______________________ Class ______________ Date ______________

Section 2 Review

NSES PS 3c

SECTION VOCABULARY

farsightedness a condition in which the lens of the eye focuses distant objects behind rather than on the retina	**nearsightedness** a condition in which the lens of the eye focuses distant objects in front of rather than on the retina

1. **Describe** How does a convex lens correct the vision of someone who is farsighted?

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2. **Identify** Complete the table by indicating the part of the eye that matches the description.

Description	Part of eye
Focuses light on the retina	
Controls the size of the pupil	
Membrane protecting the eye	
Has receptors called rods and cones	

3. **Identify** Which part of the eye is involved in color deficiency? How does it cause a person to have color deficiency?

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4. **Apply Concepts** A person has no problems reading a book, but cannot read the chalkboard from the back of the room. Is the person nearsighted or farsighted? Explain your answer.

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5. **Identify** Give two kinds of vision problems that can be corrected by surgery.

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SECTION 3

Light and Technology

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- How do optical instruments work?
- How does a laser work?
- What are some uses for light technology?

National Science Education Standards

PS 3c

What Are Optical Instruments?

Optical instruments are devices that use mirrors and lenses to manipulate light. People use optical instruments to help them see things. Optical instruments can help people see things that are far away. They can also help people see things that are very small. Some optical instruments can record images.

STUDY TIP

Summarize As you read this section, make a chart comparing cameras, telescopes, and microscopes. In your chart, describe how each device uses mirrors and lenses.

CAMERAS

The camera is probably the optical instrument you are most familiar with. People use cameras to record images. A camera has three main parts: a lens, a shutter, and an aperture. Digital cameras use light sensors to record images. Other cameras, like the one shown below, use film to record images. ☑

READING CHECK

1. Identify What are the three main parts of a camera?

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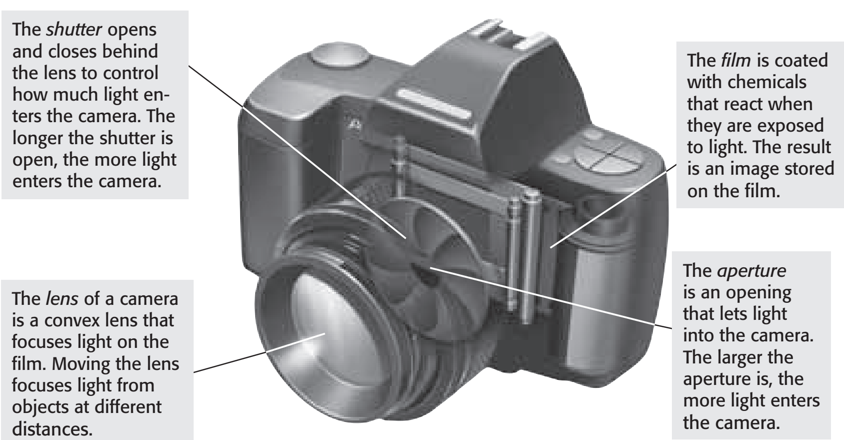
How a Camera Works



TAKE A LOOK

2. Explain How does film record an image?

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In a digital camera, light sensors send an electrical signal to a computer in the camera. The signal contains the data needed to recreate the image. The data is stored in the camera's computer or on a memory card, stick, or disk.

Critical Thinking

3. Infer Why are telescopes that use mirrors called reflecting telescopes, and those that use lenses called refracting telescopes?

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TAKE A LOOK

4. Compare How are refracting telescopes and reflecting telescopes similar?

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Critical Thinking

5. Apply Concepts Lasers are always made of a single color of light. Why is this?

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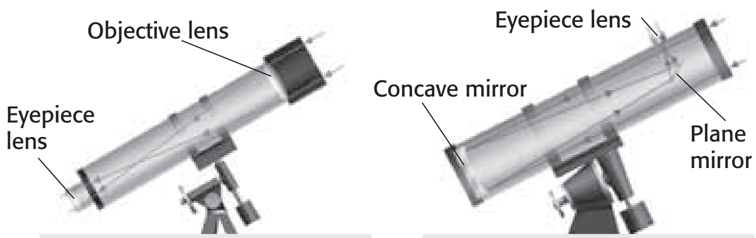
TELESCOPES

Telescopes allow people to see detailed images of objects that are far away. Astronomers use telescopes to study objects in outer space, such as moons, planets, and stars. Telescopes allow astronomers to see details they cannot see with only their eyes.

There are two types of telescopes. *Refracting telescopes* collect light with lenses. *Reflecting telescopes* collect light with mirrors.

How Refracting and Reflecting Telescopes Work



A **refracting telescope** has two convex lenses. Light enters through the objective lens and forms a real image. This real image is then magnified by the eyepiece lens. You see this magnified image when you look through the eyepiece lens.

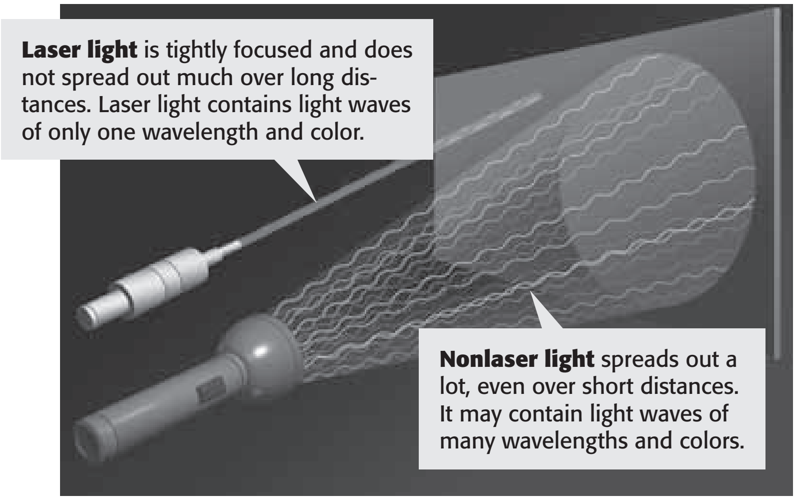
A **reflecting telescope** has a concave mirror that collects and focuses light to form a real image. The light strikes a plane mirror that directs the light to the convex eyepiece lens. The eyepiece lens magnifies the real image.

LIGHT MICROSCOPES

Scientists use microscopes to see magnified images of tiny, nearby objects. Simple light microscopes are similar to refracting telescopes. They have two convex lenses. The objective lens is close to the object being studied. The eyepiece lens is the lens people look through.

What Are Lasers?

A **laser** is a device that produces intense light of only one wavelength. Laser light is different from other visible light. One important difference is that laser light is coherent. When light waves are *coherent*, they move together as they travel. The crests and troughs of coherent light waves are aligned. The individual waves travel and act as one wave.



TAKE A LOOK

6. Identify Which kind of light spreads out more over long distances, laser light or nonlaser light?

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HOW LASERS PRODUCE LIGHT

The word laser stands for *l*ight *a*mplification by *s*timulated *e*mission of *r*adiation. *Amplification* is the increase in the brightness of the light. *Radiation* is energy transferred as electromagnetic waves. ☑

What is stimulated emission? In an atom, an electron can move from one energy level to another. Light of a specific wavelength is released when an electron moves from a high energy level to a lower one. This is called *emission*. The light that is emitted is called a *photon*.

An atom with an electron in a high energy level is called an *excited* atom. *Stimulated emission* happens when a photon strikes an excited atom and makes the atom emit another photon. The new photon has the same wavelength as the first photon. The two photons travel away from the atom together, as shown in the figure below.

READING CHECK

7. Identify What does the word *laser* stand for?

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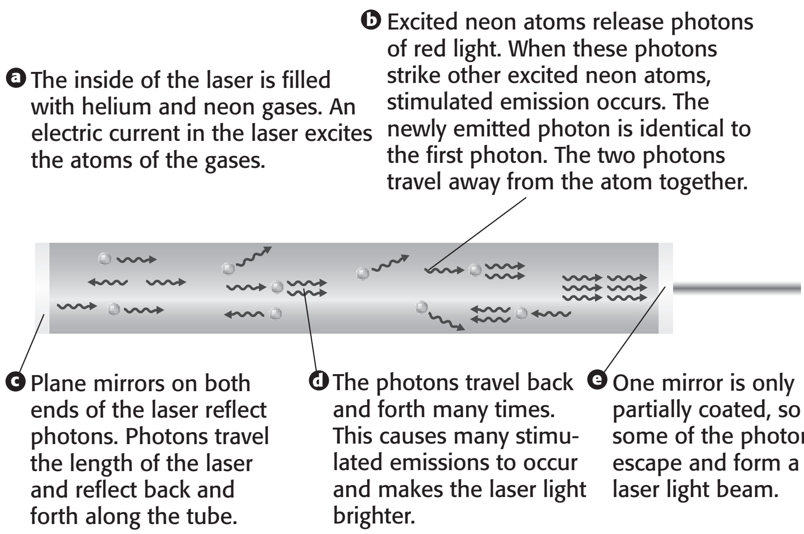
How a Helium-Neon Laser Works



TAKE A LOOK

8. Explain How do mirrors increase the brightness of laser light?

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USES OF LASERS

Lasers have several uses. A common use for lasers is to make holograms. A **hologram** is a piece of film that produces a three-dimensional image of an object. Holograms are similar to photographs because both are images recorded on a film. However, unlike a photograph, holograms are not on the surface of the film. Instead, the images appear in front or behind the film. If you move the hologram, you can see the image from different angles. ☑

Lasers are also used for many other things. For example, we can use lasers to cut metal, cloth, and other materials. Doctors use lasers in surgery. CD and DVD players use lasers to read information off the disk.

READING CHECK

9. Compare How is a hologram different from a photograph?

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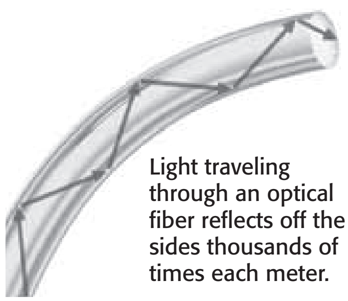
What Are Optical Fibers?

An *optical fiber* is a thin, glass wire that transmits light over long distances. Optical fibers are like pipes that carry light. Light stays inside an optical fiber because of total internal reflection. *Total internal reflection* happens when light reflects along the inside surface of the material through which it travels.

How Optical Fibers Work



Light traveling through an optical fiber reflects off the sides thousands of times each meter.

Math Focus

10. Calculate A light beam reflects off a particular optical fiber 3,000 times per meter. How many reflections will happen in 20 meters of fiber?

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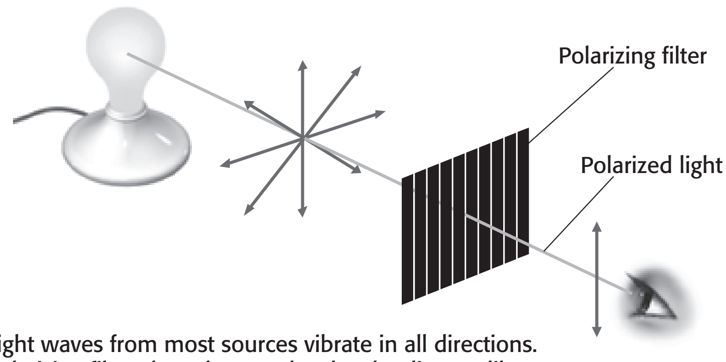
People use optical fibers in many ways. They most commonly use them in fiber-optic cables, which carry telephone signals. Optical fibers are used to connect computers to networks. They can also allow doctors to see inside a patient's body without major surgery. Information travels through the fibers as flashes of light. Optical fibers can transmit many different pieces of information at once.

What Is Polarized Light?

Most light waves vibrate in all directions. *Polarized light* is made of light waves that vibrate in only one plane.

Light can become polarized in several ways. When light reflects off a horizontal surface, the light is polarized horizontally. Polarizing sunglasses have filters that polarize light vertically. The filters only allow light vibrating vertically to pass through them, as shown below.



Light waves from most sources vibrate in all directions. Polarizing filters have long molecules that line up like parallel slits. Light waves must be vibrating in the same direction as the slits to pass through the polarizing filter.

TAKE A LOOK

11. Predict Would light that was polarized horizontally pass through the slits in the figure? Explain your answer.

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How Can We Use Light to Communicate?

Many people think that talking on the telephone has nothing to do with light. However, cordless telephones and cellular telephones use a form of light technology. Remember that light is an electromagnetic wave. There are many different kinds of electromagnetic waves. Radio waves and microwaves are also kinds of electromagnetic waves. Both kinds of waves are used in communication technology. ☑

READING CHECK

12. Identify What are two kinds of electromagnetic waves that people use in communication technology?

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CORDLESS TELEPHONES

Cordless telephones combine two technologies: a regular telephone and a radio. There are two parts to a cordless telephone: the base and the handset.

The base is connected to a telephone jack. The base receives the call through the phone line. It changes the signal to a radio wave and sends the signal to the handset.

The handset changes the radio signal to sound that you can hear. The handset also changes the sound of your voice to a radio wave. The radio wave is sent back to the base. Then, the base passes the signal to the telephone line. The figure on the next page shows how this works.

The base receives an electrical signal through the telephone line.	→	The base converts the electric signal into a radio wave.
The headset converts the radio wave into a sound wave that you can hear.	←	The base transmits the radio wave to the handset.
The headset converts your voice into a radio wave.	→	The base receives the radio wave, converts it to an electrical signal, and transmits it through the telephone line.

TAKE A LOOK

13. Describe Give two things that the headset of a cordless telephone does.

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CELLULAR TELEPHONES

A cellular telephone is similar to the headset of a cordless telephone. Both send and receive signals. Cellular telephones receive signals from tower antennas instead of from a base. Tower antennas are located all over the country. Cellular telephones use microwaves to send information. ☑

READING CHECK

14. Explain What kind of electromagnetic waves do cellular phones use to send information?

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You can make and receive calls with a cellular telephone. Antennas around the world let you make calls almost everywhere.

SATELLITE TELEVISION

Satellite television also uses electromagnetic waves. Satellite television companies broadcast microwave signals from satellites in space. Broadcasting from space allows more people to receive the signals than broadcasting from an antenna on Earth. ☑

Small satellite dishes outside houses or apartments collect the signals. The signals are then transmitted to the customer's television set. Usually, the reception from satellite television is better than the reception from broadcasts using an antenna.

READING CHECK

15. Explain Why do television companies broadcast signals from satellites in space?

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THE GLOBAL POSITIONING SYSTEM

The Global Positioning System (GPS) is a network of 27 satellites that orbit Earth. These 27 satellites constantly send microwave signals to Earth. A GPS receiver on Earth can pick up the microwave signals. The receiver can use the signals from four satellites to calculate its exact position. ☑

GPS was originally designed for use by the United States military. Now, anyone in the world with a GPS receiver can receive GPS signals and use the system.

GPS can be used to avoid getting lost or to have fun. Some uses for GPS are:

- Cars with GPS supply road maps to their drivers.
- Hikers and campers use GPS to travel in the wilderness.
- People can use GPS for treasure-hunt games.

READING CHECK

16. Identify What kind of signal does a GPS satellite transmit?

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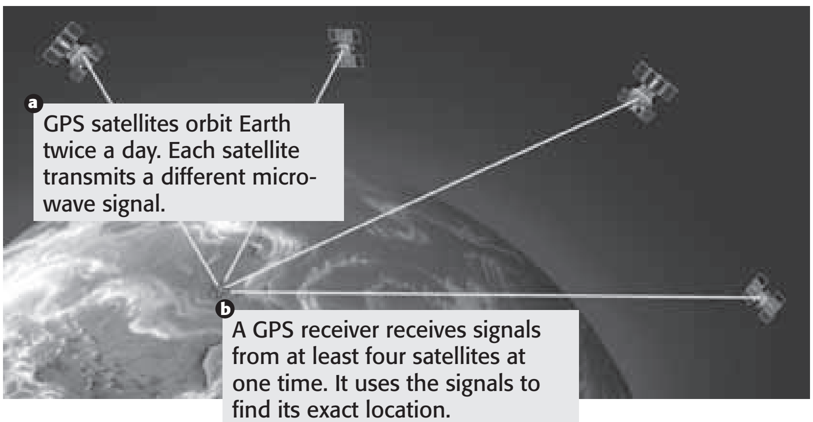
The Global Positioning System



TAKE A LOOK

17. Describe How many satellite signals does a GPS receiver need to calculate its position?

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Communication device	**How it works**
Cordless telephone	Radio waves travel between the handset and the base.
Cellular telephone	Microwaves transmit data between antennas in towers and in the phone.
Satellite television	Microwaves transmit data from satellites in space to antennas on Earth.
Global Positioning System	Microwave signals are transmitted by satellites to receivers on Earth's surface.

Name ______________________ Class ______________ Date ______________

Section 3 Review

NSES PS 3c

SECTION VOCABULARY

hologram a piece of film that produces a three-dimensional image of an object; made by using laser light	**laser** a device that produces intense light of only one wavelength and color

1. **Compare** How are laser light and nonlaser light different? Give two ways.

2. **Compare** How are simple light microscopes similar to refracting telescopes? How are they different?

3. **Apply Concepts** As you rotate a pair of polarizing sunglasses the glare off the hood of a car becomes brighter and dimmer. Why?

4. **Describe** How does light travel through an optical fiber?

5. **List** Identify two common ways microwaves are used in commication technology.

6. **Identify** Give three uses of lasers.

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