2

# The Properties of Matter

## The Big Idea

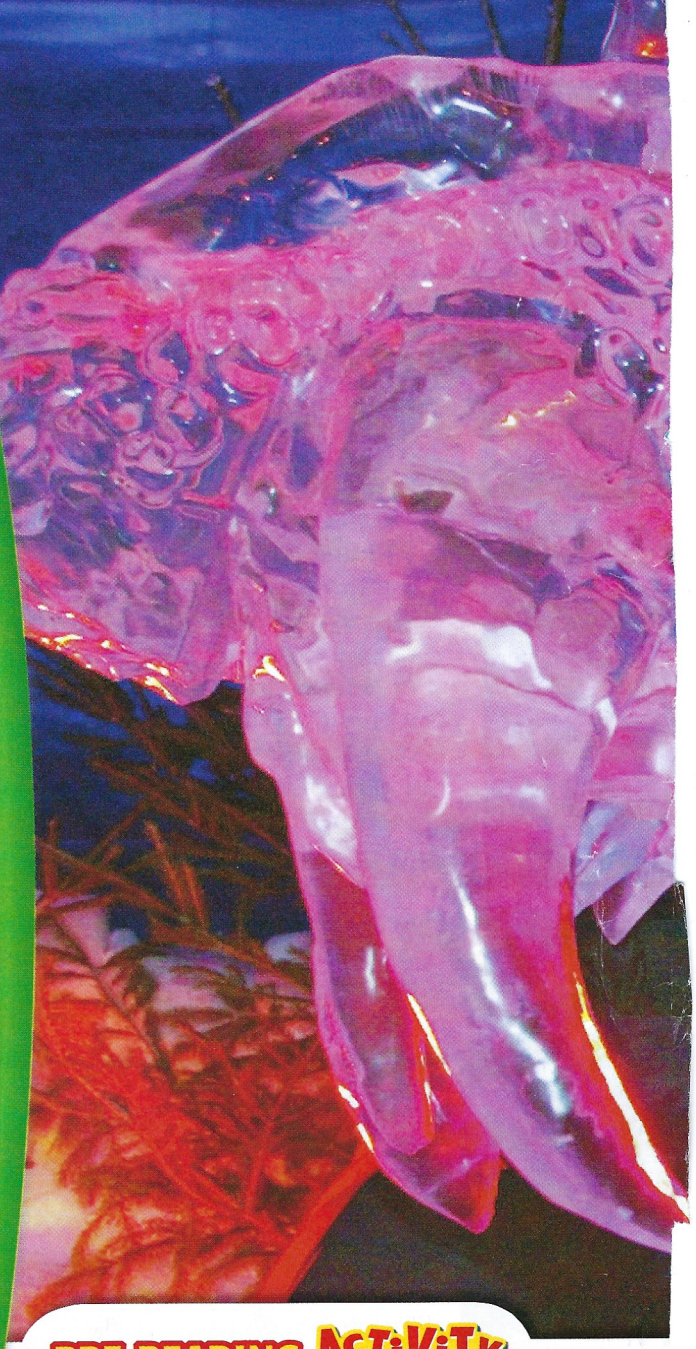
Matter is described by its properties and may undergo changes.

SECTION



## About the PHOTO

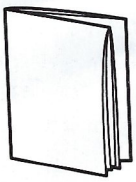
**This giant ice dragon began as a 1,700 kg block of ice! Making the blocks of ice takes six weeks. Then, the ice blocks are stored at −30°C until the sculpting begins. The artist has to work at −10°C to keep the ice from melting. An ice sculptor has to be familiar with the many properties of water, including its melting point.**



## PRE-READING ACTIVITY

FOLDNOTES

**Booklet** Before you read the chapter, create the FoldNote entitled "Booklet" described in the **Study Skills** section of the Appendix. Label each page of the booklet with a main idea from the chapter. As you read the chapter, write what you learn about each main idea on the appropriate page of the booklet.



SECTION 1

# What Is Matter?

What do you have in common with a toaster, a steaming bowl of soup, or a bright neon sign?

You are probably thinking that this is a trick question. It is hard to imagine that a person has anything in common with a kitchen appliance, hot soup, or a glowing neon sign.

### What You Will Learn

- Describe the two properties of all matter.
- Identify the units used to measure volume and mass.
- Compare mass and weight.
- Explain the relationship between mass and inertia.

### Vocabulary

matter
volume
meniscus
mass
weight
inertia

### READING STRATEGY

**Prediction Guide** Before reading this section, write the title of each heading in this section. Next, under each heading, write what you think you will learn.

## Matter

From a scientific point of view, you have at least one characteristic in common with these things. You, the toaster, the bowl, the soup, the steam, the glass tubing of a neon sign, and the glowing gas are made of matter. But exactly what is matter? **Matter** is anything that has mass and takes up space. It's that simple! Everything in the universe that you can see is made up of some type of matter.

## Matter and Volume

All matter takes up space. The amount of space taken up, or occupied, by an object is known as the object's **volume.** Your fingernails, the Statue of Liberty, the continent of Africa, and a cloud have volume. And because these things have volume, they cannot share the same space at the same time. Even the tiniest speck of dust takes up space. Another speck of dust cannot fit into that space without somehow bumping the first speck out of the way. **Figure 1** shows an example of how one object cannot share with another object the same space at the same time. Try the Quick Lab on the next page to see for yourself that matter takes up space.

**matter** anything that has mass and takes up space

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

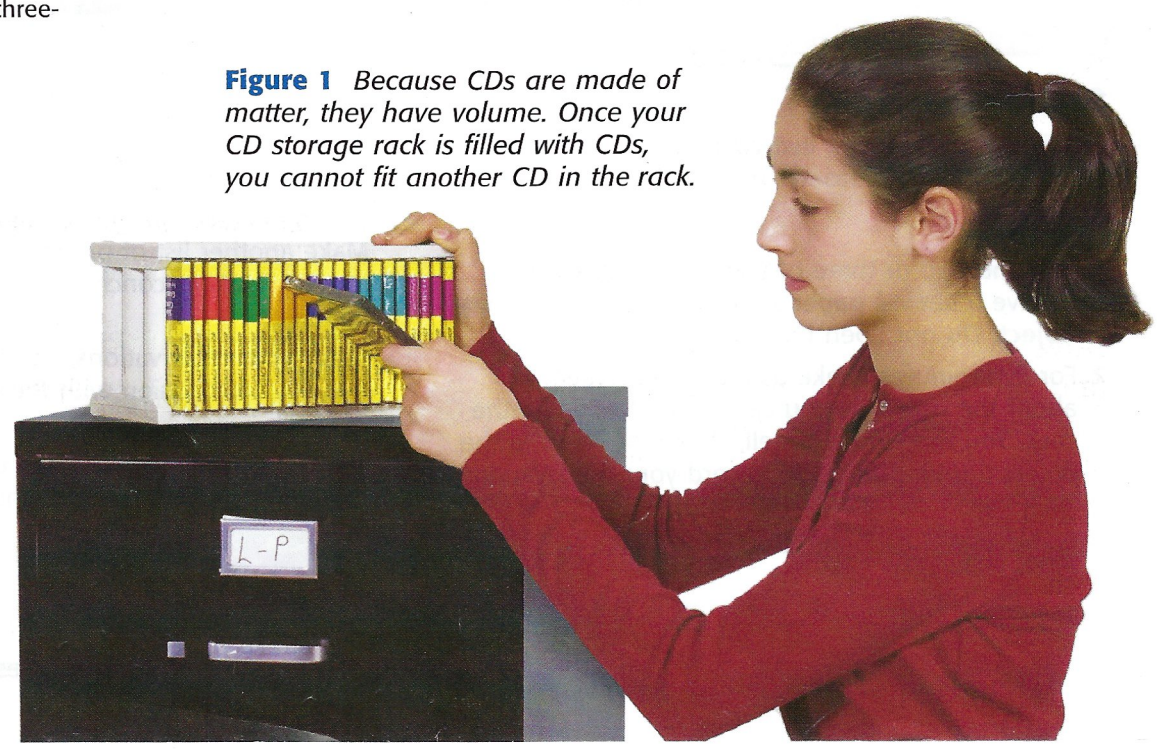



**Figure 1** *Because CDs are made of matter, they have volume. Once your CD storage rack is filled with CDs, you cannot fit another CD in the rack.*

## QUICK LAB

### Space Case

1. Crumple a **piece of paper.** Fit it tightly in the bottom of a **clear plastic cup** so that it won't fall out.
2. Turn the cup upside down. Lower the cup straight down into a **bucket** half-filled with **water.** Be sure that the cup is completely underwater.
3. Lift the cup straight out of the water. Turn the cup upright, and observe the paper. Record your observations.
4. Use the point of a **pencil** to punch a small hole in the bottom of the cup. Repeat steps 2 and 3.
5. How do the results show that air has volume? Explain your answer.

## Liquid Volume

Lake Erie, the smallest of the Great Lakes, has a volume of approximately 483 trillion (that's 483,000,000,000,000) liters of water. Can you imagine that much water? Think of a 2-liter bottle of soda. The water in Lake Erie could fill more than 241 trillion 2-liter soda bottles. That's a lot of water! On a smaller scale, a can of soda has a volume of only 355 milliliters, which is about one-third of a liter. You can check the volume of the soda by using a large measuring cup from your kitchen.

Liters (L) and milliliters (mL) are the units used most often to express the volume of liquids. The volume of any amount of liquid, from one raindrop to a can of soda to an entire ocean, can be expressed in these units.

**Reading Check** **What are two units used to measure volume?** (*See the Appendix for answers to Reading Checks.*)

## Measuring the Volume of Liquids

In your science class, you'll probably use a graduated cylinder instead of a measuring cup to measure the volume of liquids. Graduated cylinders are used to measure the liquid volume when accuracy is important. The surface of a liquid in any container, including a measuring cup or a large beaker, is curved. The curve at the surface of a liquid is called a **meniscus** (muh NIS kuhs). To measure the volume of most liquids, such as water, you must look at the bottom of the meniscus, as shown in **Figure 2.** Note that you may not be able to see a meniscus in a large beaker. The meniscus looks flat because the liquid is in a wide container.

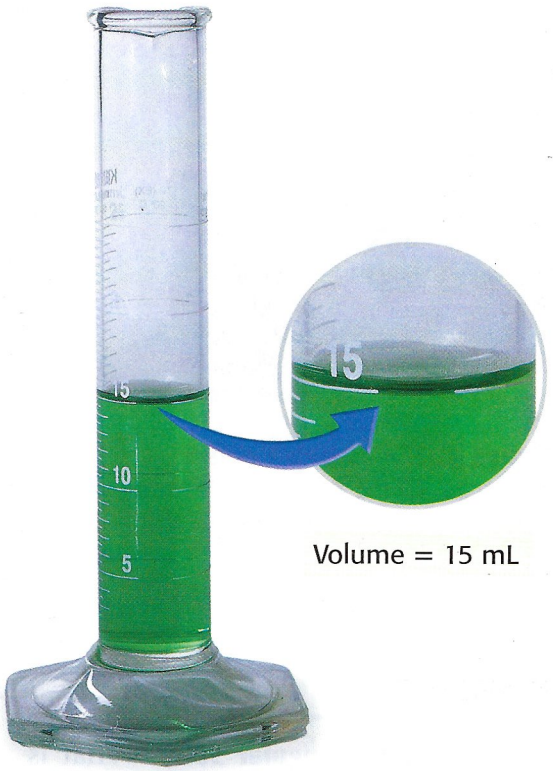



**Figure 2** *To measure volume correctly, read the scale of the lowest part of the meniscus (as shown) at eye level.*

**meniscus** the curve at a liquid's surface by which one measures the volume of the liquid

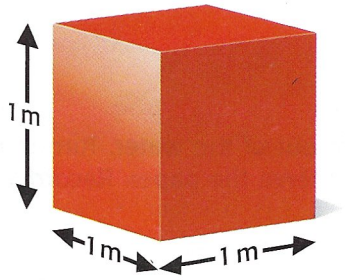



**Figure 3** *A cubic meter (1 $m^3$) is a cube that has a length, width, and height of 1 m.*

## Volume of a Regularly Shaped Solid Object

The volume of any solid object is expressed in cubic units. The word *cubic* means "having three dimensions." In science, cubic meters ($m^3$) and cubic centimeters ($cm^3$) are the units most often used to express the volume of solid things. The 3 in these unit symbols shows that three quantities, or dimensions, were multiplied to get the final result. You can see the three dimensions of a cubic meter in **Figure 3.** There are formulas to find the volume of regularly shaped objects. For example, to find the volume of a cube or a rectangular object, multiply the length, width, and height of the object, as shown in the following equation:

$$volume = length \times width \times height$$

**Figure 4** *The 12-sided object displaced 15 mL of water. Because 1 mL = 1 $cm^3$, the volume of the object is 15 $cm^3$.*

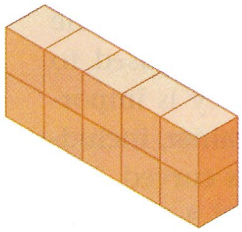
## Volume of an Irregularly Shaped Solid Object

How do you find the volume of a solid that does not have a regular shape? For example, to find the volume of a 12-sided object, you cannot use the equation given above. But you can measure the volume of a solid object by measuring the volume of water that the object displaces. In **Figure 4,** when a 12-sided object is added to the water in a graduated cylinder, the water level rises. The volume of water displaced by the object is equal to its volume. Because 1 mL is equal to 1 $cm^3$, you can express the volume of the water displaced by the object in cubic centimeters. Although volumes of liquids can be expressed in cubic units, volumes of solids should not be expressed in liters or milliliters.

**Reading Check** **Explain how you would measure the volume of an apple.**

## MATH FOCUS

**Volume of a Rectangular Solid** What is the volume of a box that has a length of 5 cm, a width of 1 cm, and a height of 2 cm?



**Step 1:** Write the equation for volume.

$$volume = length \times width \times height$$

**Step 2:** Replace the variables with the measurements given to you, and solve.

$$volume = 5\ cm \times 1\ cm \times 2\ cm = 10\ cm^3$$

### Now It's Your Turn

1. A book has a length of 25 cm, a width of 18 cm, and a height of 4 cm. What is its volume?
2. What is the volume of a suitcase that has a length of 95 cm, a width of 50 cm, and a height of 20 cm?
3. A CD case is 14.2 cm long, 12.4 cm wide, and 1 cm deep. What is its volume?

## Matter and Mass

Another characteristic of all matter is mass. **Mass** is the amount of matter in an object. For example, you and a peanut are made of matter. But you are made of more matter than a peanut is, so you have more mass. The mass of an object is the same no matter where in the universe the object is located. The only way to change the mass of an object is to change the amount of matter that makes up the object.

**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

### The Difference Between Mass and Weight

The terms *mass* and *weight* are often used as though they mean the same thing, but they don't. **Weight** is a measure of the gravitational (GRAV i TAY shuh nuhl) force exerted on an object. Gravitational force keeps objects on Earth from floating into space. The gravitational force between an object and the Earth depends partly on the object's mass. The more mass an object has, the greater the gravitational force on the object and the greater the object's weight. But an object's weight can change depending on its location in the universe. An object would weigh less on the moon than it does on Earth because the moon has less gravitational force than Earth does. **Figure 5** explains the differences between mass and weight.

**Figure 5** Differences Between Mass and Weight

**Mass**

- Mass is a measure of the amount of matter in an object.
- Mass is always constant for an object no matter where the object is located in the universe.
- Mass is measured by using a balance (shown below).
- Mass is expressed in kilograms (kg), grams (g), and milligrams (mg).

**Weight**

- Weight is a measure of the gravitational force on an object.
- Weight varies depending on where the object is in relation to the Earth (or any large body in the universe).
- Weight is measured by using a spring scale (shown at right).
- Weight is expressed in newtons (N).

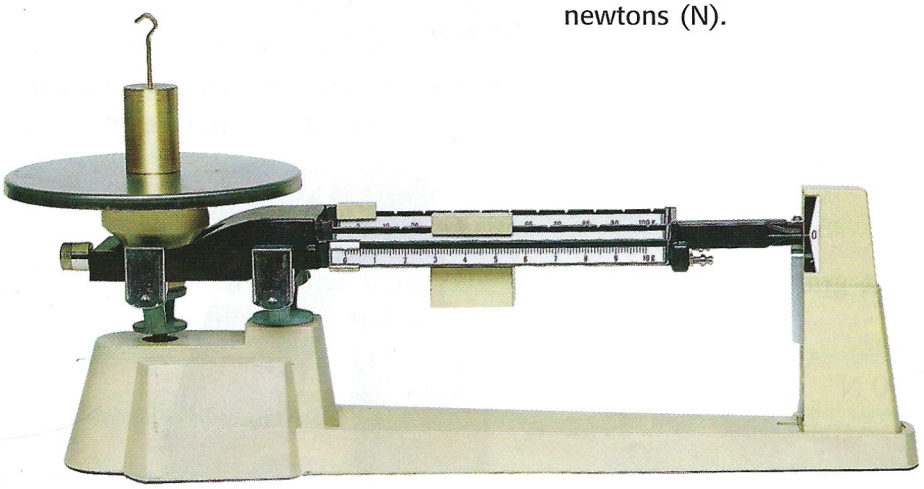


**Figure 6** *The brick and the sponge take up the same amount of space. But the brick has more matter in it, so its mass—and thus its weight—is greater.*

## Measuring Mass and Weight

The brick and the sponge in **Figure 6** have the same volume. But because the brick has more mass, a greater gravitational force is exerted on the brick than on the sponge. As a result, the brick weighs more than the sponge.

The SI unit of mass is the kilogram (kg), but mass is often expressed in grams (g) and milligrams (mg), too. These units can be used to express the mass of any object in the universe.

Weight is a measure of gravitational force and is expressed in the SI unit of force, the *newton* (N). One newton is about equal to the weight of an object that has a mass of 100 g on Earth. So, if you know the mass of an object, you can calculate the object's weight on Earth. Weight is a good estimate of the mass of an object because, on Earth, gravity doesn't change.

**Reading Check** **What units are often used to measure mass?**

## Inertia

Imagine kicking a soccer ball that has the mass of a bowling ball. It would be not only painful but also very difficult to get the ball moving in the first place! The reason is inertia (in UHR shuh). **Inertia** is the tendency of an object to resist a change in motion. So, an object at rest will remain at rest until something causes the object to move. Also, a moving object will keep moving at the same speed and in the same direction unless something acts on the object to change its speed or direction.

**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

### MATH FOCUS

**Converting Mass to Weight** A student has a mass of 45,000 g. How much does this student weigh in newtons?

**Step 1:** Write the information given to you.

$$45{,}000 \text{ g}$$

**Step 2:** Write the conversion factor to change grams into newtons.

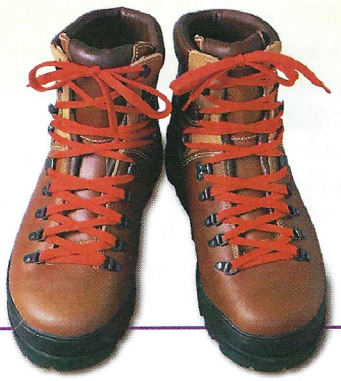
$$1 \text{ N} = 100 \text{ g}$$

**Step 3:** Write the equation so that grams will cancel.

$$45{,}000 \text{ g} \times \frac{1 \text{ N}}{100 \text{ g}} = 450 \text{ N}$$

**Now It's Your Turn**

1. What is the weight of a car that has a mass of 1,362,000 g?
2. Your pair of boots has a mass of 850 g. If each boot has exactly the same mass, what is the weight of each boot?



## Mass: The Measure of Inertia

Mass is a measure of inertia. An object that has a large mass is harder to get moving and harder to stop than an object that has less mass. The reason is that the object with the large mass has greater inertia. For example, imagine that you are going to push a grocery cart that has only one potato in it. Pushing the cart is easy because the mass and inertia are small. But suppose the grocery cart is stacked with potatoes, as in **Figure 7.** Now the total mass—and the inertia—of the cart full of potatoes is much greater. It will be harder to get the cart moving. And once the cart is moving, stopping the cart will be harder.

**Figure 7** *Because of inertia, moving a cart full of potatoes is more difficult than moving a cart that is empty.*

# SECTION Review

## Summary

- Two properties of matter are volume and mass.
- Volume is the amount of space taken up by an object.
- The SI unit of volume is the liter (L).
- Mass is the amount of matter in an object.
- The SI unit of mass is the kilogram (kg).
- Weight is a measure of the gravitational force on an object, usually in relation to the Earth.
- Inertia is the tendency of an object to resist being moved or, if the object is moving, to resist a change in speed or direction. The more massive an object is, the greater its inertia.

### Using Key Terms

1. Use the following terms in the same sentence: *volume* and *meniscus*.
2. In your own words, write a definition for each of the following terms: *mass*, *weight*, and *inertia*.

### Understanding Key Ideas

3. Which of the following is matter?
   - **a.** dust
   - **b.** the moon
   - **c.** strand of hair
   - **d.** All of the above
4. A graduated cylinder is used to measure
   - **a.** volume.
   - **b.** weight.
   - **c.** mass.
   - **d.** inertia.
5. The volume of a solid is measured in
   - **a.** liters.
   - **b.** grams.
   - **c.** cubic centimeters.
   - **d.** All of the above
6. Mass is measured in
   - **a.** liters.
   - **b.** centimeters.
   - **c.** newtons.
   - **d.** kilograms.
7. Explain the relationship between mass and inertia.

### Math Skills

8. A nugget of gold is placed in a graduated cylinder that contains 80 mL of water. The water level rises to 225 mL after the nugget is added to the cylinder. What is the volume of the gold nugget?
9. One newton equals about 100 g on Earth. How many newtons would a football weigh if it had a mass of 400 g?

### Critical Thinking

10. **Identifying Relationships** Do objects with large masses always have large weights? Explain.
11. **Applying Concepts** Would an elephant weigh more or less on the moon than it would weigh on Earth? Explain your answer.