Section 1
What Is Matter?

Key Concept Matter is anything that has mass and takes up space. Matter can be described in terms of its volume, mass, and weight.

What You Will Learn
- All matter has volume and mass.
- Volume is the amount of space taken up by an object.
- Mass is a measure of the amount of matter in an object.
- Weight is a measure of the gravitational force exerted on an object.

Why It Matters
Understanding what matter is and how units are used to describe matter can help you understand the structure of the physical world.

What do you have in common with a toaster, a steaming bowl of soup, or a bright neon sign? You might think that this is a trick question. It is hard to believe that a person has anything in common with a kitchen appliance, hot soup, or a neon sign.

Matter
From a scientific point of view, you have at least one characteristic in common with a toaster, a bowl, soup, steam, and the glass tubing and glowing gas of a neon sign. You and these items are each made of matter. But exactly what is matter? **Matter** is anything that has mass and takes up space.

Matter and Volume
All matter takes up space. The amount of space that an object takes up, or occupies, is known as the object's **volume.** Your fingers, the continent of Africa, and a cloud have volume. And because these things have volume, they cannot occupy the same space at the same time. Even the tiniest piece of dust takes up space. Another piece of dust cannot fit into that space without somehow bumping the first piece out of the way. **Figure 1** shows an example of how two objects cannot be in the same space at the same time.

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.

Liquid Volume

Lake Erie, the smallest of the Great Lakes, has a volume of about 483 trillion liters (483,000,000,000,000 L) of water. Can you picture that much water? Think of a 1.5 L bottle of water. The water in Lake Erie could fill more than 322 trillion 1.5 L bottles. On a smaller scale, an ordinary canned drink has a volume of only 0.355 L, which is about one-third of a liter. You can estimate the volume of the can by using a large measuring cup to measure the amount of liquid that a full can holds.

The liter (L) is the SI unit for volume. Often, small volumes of liquid are expressed in milliliters (mL). Remember that 1 L equals 1,000 mL. Any volume of liquid, from one drop of rain to a bottle

of water to an ocean, can be expressed in liters or milliliters.

Standards Check What are two units that are used to express volume?

Measuring the Volume of Liquids

In class, you may use a graduated cylinder instead of a measuring cup to measure a liquid's volume. Graduated cylinders are used to measure liquid volume when accuracy is needed. The surface of a liquid in any container is curved. The curve at the surface of a liquid is called a **meniscus.** For most liquids, including water, volume should be measured from the lowest point of the meniscus, as **Figure 2** shows. So, you would measure volume by noting where on the container's scale the lowest point of the meniscus is. Because the meniscus curves only slightly, water's meniscus looks flat in a wide-mouthed container.

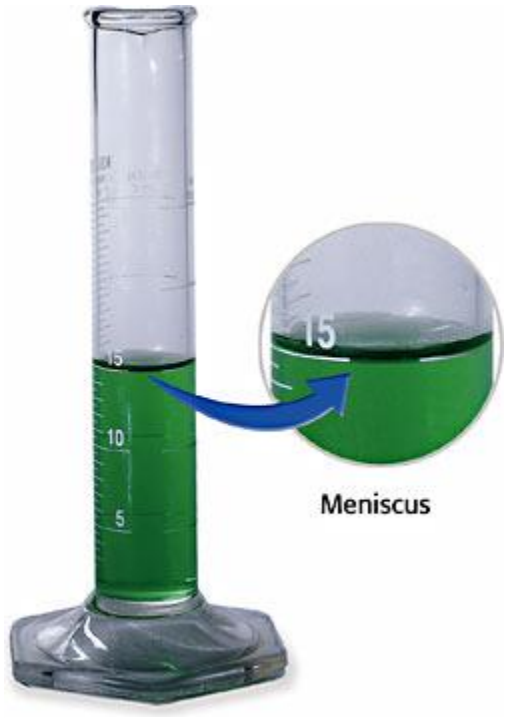

Figure 2 To measure volume correctly, read the scale at the lowest point of the meniscus at eye level. Below, the volume is 15.0 mL.

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 for 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.**

$V = 1\ m \times 1\ m \times 1\ m = 1\ m^3$

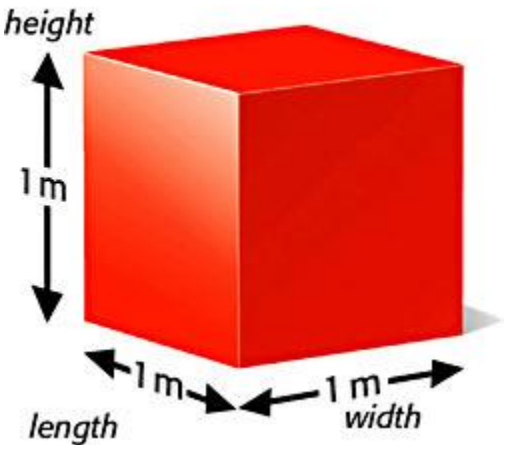

Figure 3 A cube whose length, width, and height are each 1 m has a volume of one cubic meter (1 m^3).

You can use formulas to find the volume of regularly shaped objects. For example, to find the volume (V) of a cube or another rectangular object, use the length (l), width (w), and height (h) of the object in the following equation:

$$V = l \times w \times h$$

But you don't need to know all three measurements to find volume. The area of the base of a cube or another rectangular object is equal to length times width. So, if you know the area (A) and height (h) of the object, you can find the volume (V) of the object by using the following equation:

$$V = A \times h$$

Standards Check What two equations can you use to find the volume

of a rectangular object?

Volume of an Irregularly Shaped Solid Object

How do you find the volume of a solid that does not have a regular shape? One way to find the volume of an irregularly shaped solid object is to use water displacement.

Using Displacement to Find Volume

In **Figure 4,** when a 12-sided object is added to the water in a graduated cylinder, the water level rises. The level rises because the object pushes water out of the way. This process of pushing water out of the way is called *displacement.* The volume of water displaced by the object is equal to the object's volume. Because 1 mL is equal to 1 cm^3, you can give the volume of the water displaced by the object in cubic centimeters. Volumes of liquids can be given in cubic units, but volumes of solids should not be given in liters or milliliters.

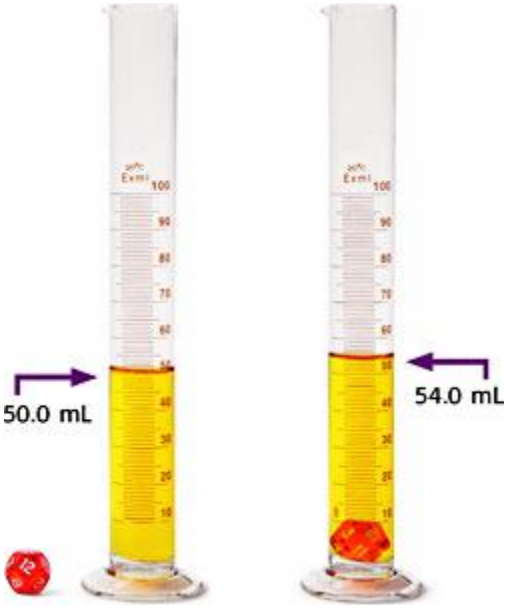

Figure 4 The 12-sided object displaced 4.0 mL of water. **What is the volume of the 12-sided object? What are the correct units to describe this volume?**
Using displacement to find the volume of an object that floats is more difficult. To do so, you must use another object to hold the floating object underwater. Then, you must subtract the volume of the object holding the floating object. Displacement cannot be used to find the volume of something that dissolves in water.

Standards Check Explain how you would measure the volume of a brick that contains holes.

Matter and Mass

Another characteristic of all matter is mass. **Mass** is a measure of the amount of matter that makes up an object. For example, you and a peanut are made of matter. But you are made up of more matter than a peanut is, so you have greater mass. The mass of an object does not change when the object's location changes. The mass of an object changes only when the amount of matter that makes up the object changes.

The Difference Between Mass and Weight

The terms *mass* and *weight* are often used as though they mean the same thing, but they do not. **Weight** is a measure of the gravitational (GRAV i TAY shuhn uhl) force on an object. Gravitational force keeps objects on Earth from floating into space. The gravitational force between an object and Earth depends partly on the object's mass. The greater the mass of an object, the greater the gravitational force on the object and the greater the object's weight. But an object's weight can change depending on the object's location. An object would weigh less on the moon than it does on Earth because the moon has less mass—and therefore 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 measured by using a balance (shown below).
- Mass is expressed in kilograms (kg), grams (g), and milligrams (mg).
- Mass is a measure of the amount of matter in an object.
- Mass is constant for an object no matter where the object is located.

Weig

- Weight is measu a spring scale (s
- Weight is expres newtons (N).
- Weight is a mea gravitational forc
- Weight varies de where the objec to Earth (or any

Measuring Mass and Weight

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

Figure 6 The brick and the sponge take up the same amount of space. But the brick contains more matter, so its mass–and thus its weight–is greater.

The SI unit of mass is the kilogram (kg). Mass is also expressed in grams (g) and milligrams (mg). These units can be used to express the mass of any object. Weight is a measure of gravitational force. The SI unit of force is the newton (N). One newton is equal to the weight on Earth of an object whose mass is about 100 g.

Standards Check What units are often used to express mass?

Section Summary

- Two properties of matter are volume and mass.
- Volume is the amount of space taken up by an object.
- Mass is a measure of the amount of matter in an object.
- The SI unit of volume is the liter (L). The SI unit of mass is the kilogram (kg).
- Weight is a measure of the gravitational force on an object, usually in relation to Earth. Weight is expressed in newtons (N).