

Focus

Overview

This section explains that matter is anything that has volume and mass. Students will explore how the volumes of solids, liquids, and gases are measured. Students learn the difference between mass and weight and learn how both are measured. Finally, students learn about inertia.

Bellringer

Ask students to write what they think some of the ingredients or components are for the following items: a loaf of bread, a textbook, and a bicycle. Discuss the reason for the variety of answers students come up with.

Motivate

Demonstration — GENERAL

Explaining Volume Display common objects such as a rock, a paper clip, a book, a pencil, and a large cardboard box. Point out that the objects are alike because they all take up space. Discuss with students which objects are largest and smallest, and discuss what those terms mean. Then, discuss the connection between “taking up space” and volume. Point out that the amount of space something takes up is its volume.

English Language Learners

Visual/Logical

READING WARM-UP

Objectives

- 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.

Terms to Learn

matter	mass
volume	weight
meniscus	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 anything that has mass and takes up space

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

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.

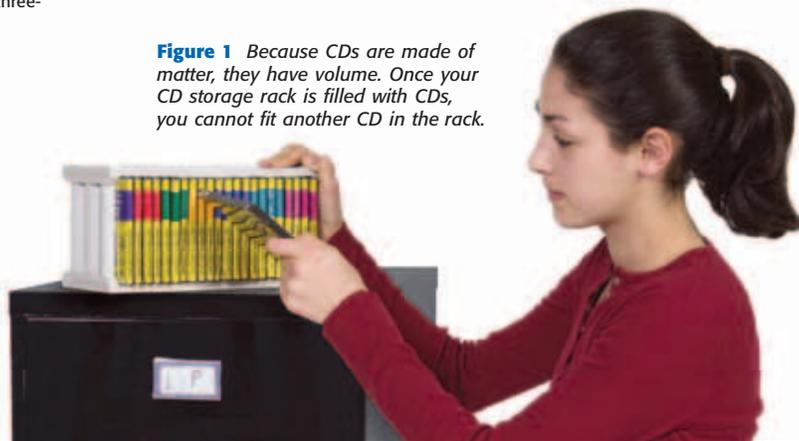
Matter

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.

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.



CHAPTER RESOURCES

Chapter Resource File

- Lesson Plan
- Directed Reading A **BASIC**
- Directed Reading B **SPECIAL NEEDS**

Technology

- Transparencies
- Bellringer
- LINK TO LIFE SCIENCE** Math Focus: Surface Area-to-Volume Ratio

CONNECTION ACTIVITY

Music — GENERAL

Water Music Provide students with several identical glass containers. Tell students to add a different amount of water to each container, and then lightly strike each container with a pen to hear the pitch of the sound it makes. Have students measure the volume of water in each container, and ask them to determine the relationship they see between pitch and the volume of water.

Auditory/Visual English Language Learners

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

SCIENTISTS AT ODDS

Determining Official Standards The official standard kilogram is a cylinder made of platinum-iridium alloy. The mass of the cylinder is supposed to equal the mass of 1 dL³ of pure water at 4°C. Some scientists believe that this cylinder is imprecise and needs to be changed. In fact, the kilogram is the only SI unit that is based on a single physical standard and that can be destroyed or altered. Some scientists now suggest redefining the kilogram as the mass of an exact number of atoms of a particular element.

Answer to Reading Check

liters (L) and milliliters (mL)

Teach

Group Activity — GENERAL

Provide small groups with a variety of jars, bottles, cans, and cartons. Allow students to use a measuring cup or a graduated cylinder to determine the volume of each container. A volume reading is always made at the flattest part of the meniscus—the bottom of the curve for water and the top for mercury. **LS Visual/Interpersonal**

Discussion — GENERAL

Discuss with students the fact that we are surrounded by matter. Have students give examples of matter around them. Ask them to list some characteristics of matter. Discuss with them that air is matter and they are actually pushing air aside as they walk through it.

LS Logical

Quick Lab

MATERIALS

FOR EACH STUDENT

- cup
- piece of paper

FOR EACH GROUP

- beaker or bucket, large
- pencil
- water

Teacher's Notes: Students can feel the air being “moved out of the way” by the water if they hold a finger above the hole while they submerge the cup.

Answers

5. The water could not enter the cup because air occupied the space. Once the hole was punched, the water could force the air out of the cup and occupy the space in the cup.

CONNECTION ACTIVITY
Math — GENERAL

A “Refreshing” Statistic In 1997, Americans consumed an average of 204 L of soft drinks per person. How many cans of soft drinks would that be? Assume that a can holds 355 mL and remember that 1 L = 1,000 mL. (more than 574 cans)

The total volume of soft drinks consumed by Americans in 1997 was approximately 53 billion liters. How many cans of soft drinks would that be? (more than 149 billion cans) **LS Logical**

Answers to Math Focus

- 1,800 cm³
- 95,000 cm³, or 0.095 m³
- 176.08 cm³

Demonstration — GENERAL

Relating Matter, Mass, and Volume Display a variety of classroom objects, such as pencils, books, and notebook paper. Ask students which objects contain the largest amount of matter and thus have the greatest mass. Then, ask which objects contain the smallest amount of matter and thus have the smallest mass. Ask them if the objects that have the greatest volume always have the most mass.

LS Visual/Logical

English Language Learners

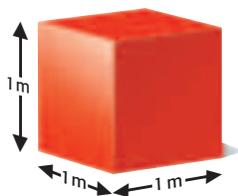


Figure 3 A cubic meter (1 m³) is a cube that has a length, width, and height of 1 m.

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 (m³) and cubic centimeters (cm³) 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:

$$\text{volume} = \text{length} \times \text{width} \times \text{height}$$

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 cm³, 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.



Figure 4 The 12-sided object displaced 15 mL of water. Because 1 mL = 1 cm³, the volume of the object is 15 cm³.

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

MATH FOCUS

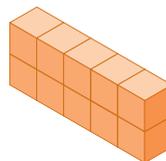
Volume of a Rectangular Solid What is the volume of a box that has a length of 5 cm, a width of 1 cm, and a height of 2 cm?

Step 1: Write the equation for volume.

$$\text{volume} = \text{length} \times \text{width} \times \text{height}$$

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

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



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?

WEIRD SCIENCE

Mauna Loa, in Hawaii, is the world's most active volcano. The volume of lava that has flowed from the volcano is enough to pave a four-lane highway that reaches around the world 30 times.

Answer to Reading Check

You could measure the volume of an apple by submerging it in a container of water and measuring the volume of the water that the apple displaces.

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.

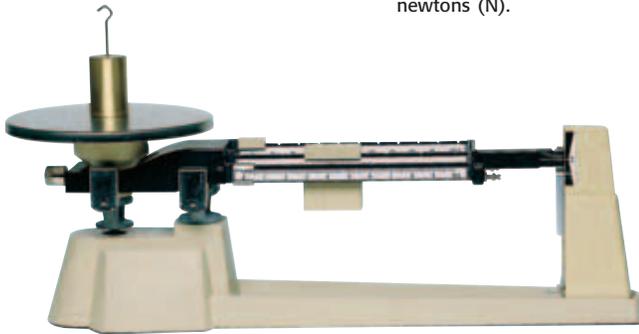
Figure 5 Differences Between Mass and Weight

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).



Science Bloopers

Watch Your Units! In July 1983, an Air Canada Boeing 767 airliner with 69 people on board ran out of fuel in mid-flight. Before leaving their previous stop, the crew had calculated that the plane had enough fuel to make it to the final destination. However, members of the plane's crew miscalculated the mass of the fuel because they used pounds instead of kilograms! Fortunately, the plane made a safe landing in Manitoba, Canada.

MISCONCEPTION ALERT

Varying Volume of Gas Students may not understand that a gas not only can expand to fill its container but also can be compressed, or squeezed, to fill a smaller container. Scuba divers' tanks contain compressed air. A 2.24 m³ scuba tank holds enough air for an average adult to breathe underwater for 30 to 45 min.

Why Cells Are Microscopic

Use the teaching transparency "Math Focus: Surface Area to Volume Ratio" to show students that as an object of a particular shape increases in size, its volume grows proportionately more than its surface area does. In living cells, oxygen, nutrients, and waste must pass through the cell membrane at a rate sufficient for the cell to carry out its functions. Most cells are microscopic in size and have a high surface area-to-volume ratio, so the cytoplasm in the cell is close enough to the cell membrane for substances to enter and exit the cell quickly. Remind students that because cells require a large surface-area-to-volume ratio, larger organisms do not generally have larger cells; they have more cells than smaller organisms. **Visual/Logical**

INCLUSION Strategies

- **Developmentally Delayed**
- **Attention Deficit Disorder**
- **Hearing Impairment**

Give students a chance to move around while they explore the idea "lighter than air." Begin with two like-sized balloons. Fill one with helium. Blow the other up with air to the same size as the helium-filled balloon. Choose two students who especially need opportunities to move around during class. Hand the balloons to the students, ask them to let go of the balloons on the count of three, and then count to three for them. As the balloon filled with air sinks to the floor and the helium balloon rises to the ceiling, discuss that helium is lighter than air. **Kinesthetic**

Close

Reteaching BASIC

Provide students with graduated cylinders, spring scales, and triple-beam balances. Have students take turns explaining step-by-step how to measure the volume and the mass of a given substance. Help them observe the difference between mass and weight using a spring scale. LS Logical

Quiz GENERAL

Ask students whether these questions are true or false.

1. The volume of a marble can be measured with a graduated cylinder. (true)
2. Volumes of solids can be expressed in liters or milliliters. (false)
3. Weight and mass are the same thing. (false)

Alternative Assessment GENERAL



An Alternate Universe

Have students write a short science-fiction story about a universe in which matter does not behave in the ways described in this section. Ask them to consider what life would be like in this kind of universe. Some examples are a universe where gravity does not exist; a universe where objects repel rather than attract one another; and a universe where inertia becomes greater as mass decreases. LS Visual

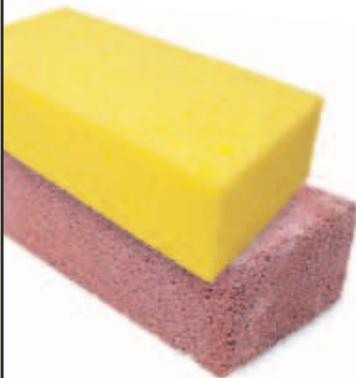


Figure 6 The brick and the sponge take up the same amount of space. But the brick has more matter in it, so its mass—and thus its weight—is greater.

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.

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

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.

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?



Answers to Math Focus

1. 13,620 N
2. 4.25 N

Answer to Reading Check

kilograms (kg), grams (g), and milligrams (mg)

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

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

Understanding Key Ideas

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

Math Skills

- 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?
- 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

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

SciLINKS
Developed and maintained by the
National Science Teachers Association

For a variety of links related to this chapter, go to www.scilinks.org

Topic: What Is Matter?
SciLinks code: HSM1662

Answers to Section Review

- Sample answer: You can measure the volume of a liquid by pouring it into a graduated cylinder and reading the scale at the bottom of the meniscus.
- Sample answer: Mass is a measurement of how much matter is in an object. Weight is a measurement of how much gravitational force is exerted on an object's mass. Inertia is what causes an object to remain at rest or remain in motion. The more mass an object has, the greater its inertia.
- d
- a
- c
- d
- Mass is a measure of inertia. The more mass an object has, the more inertia it has.
- 145 cm³
- 4 N
- Not all objects that have large masses have large weights because the weight of an object can change depending on where it is located in the universe. Mass remains the same everywhere in the universe. So, a massive object in space may not have a large weight.
- The elephant's weight on the moon would be only one-sixth of its weight on Earth. This difference is due to the moon having only one-sixth the gravitational force of the Earth.

CHAPTER RESOURCES

Chapter Resource File

- Section Quiz **GENERAL**
- Section Review **GENERAL**
- Vocabulary and Section Summary **GENERAL**
- SciLinks Activity **GENERAL**
- Datasheet for Quick Lab