Section 2

Measuring Matter

Objectives

After this lesson, students will be able to

K.1.2.1 Differentiate between weight and mass.

K.1.2.2 Identify the units used to express the amount of space occupied by matter.

K.1.2.3 Describe how the density of a material is determined.

Target Reading Skill

Asking Questions Explain that changing a head into a question helps students anticipate the ideas, facts, and events they are about to read.

Answer

Sample questions and answers:

How are weight and mass different? *(Weight is a measure of the force of gravity on an object. Mass is a measure of the amount of matter in an object.)*

What is volume? *(The amount of space that matter occupies)* **How is density determined?** *(By dividing the mass of a sample of matter by its volume)*

All in One Teaching Resources

- Transparency K2

Preteach

Build Background Knowledge L2

Sink or Float

Obtain two bars of soap, one that floats and one that does not. Unwrap the soap. Show students the two bars and ask: **What will happen when I place these bars of soap in a pan of water?** *(Sample answer: They will sink.)*

Put the soap in the water. Let students observe the results and try to explain them.

Section 2

Measuring Matter

Reading Preview

Key Concepts

- What is the difference between weight and mass?
- What units are used to express the amount of space occupied by matter?
- How is the density of a material determined?

Key Terms

- weight • mass
- International System of Units
- volume • density

Target Reading Skill

Asking Questions Before you read, preview the red headings. In a graphic organizer like the one below, ask a *what* or *how* question for each heading. As you read, write the answers to your questions.

Weight and Mass

Question	Answer
How are weight and mass different?	Weight is a measure of . . .

Lab zone Discover Activity

Which Has More Mass?

1. Your teacher will provide you with some small objects. Look at the objects, but do not touch them.
2. Predict which object is lightest, which is second lightest, and so on. Record your predictions.
3. Use a triple-beam balance to find the mass of each object.
4. Based on the masses, list the objects from lightest to heaviest.

Think It Over

Drawing Conclusions How did your predictions compare with your results. Are bigger objects always heavier than smaller objects? Why or why not?

Here's a riddle for you: Which weighs more, a pound of feathers or a pound of sand? If you answered "a pound of sand," think again. Both weigh exactly the same—one pound.

There are all sorts of ways to measure matter, and you use these measurements every day. Scientists rely on measurements as well. In fact, scientists work hard to make sure their measurements are as accurate as possible.

Weight and Mass

Suppose you want to measure your weight. To find the weight, you step on a scale like the one shown in Figure 11. Your body weight presses down on the springs inside the scale. The more you weigh, the more the springs compress, causing the pointer on the scale to turn farther, giving a higher reading. However, your scale would not indicate the same weight if you took it to the moon and stepped on it. You weigh less on the moon, so the springs of the scale would not be compressed as much by your weight.

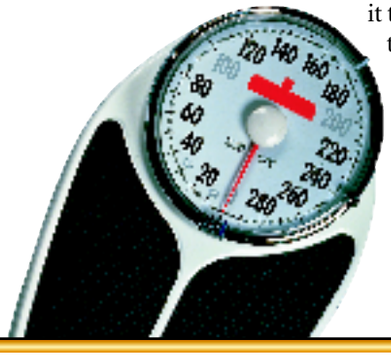


FIGURE 11
Measuring Weight
If you stood on this scale on the moon, it would show that your weight there is less than on Earth.

Lab zone Discover Activity

Skills Focus Drawing conclusions L3

Materials triple-beam balance, objects of different mass, such as rocks, plastic drinking cups, aluminum cans, pencils

Time 15 minutes

Tips Choose objects that are small but heavy (lead weights, small rocks, bolts, or paperweights), and objects that are larger but lightweight (plastic drinking cups, pieces of plastic foam, or empty aluminum cans).

Think It Over Students may predict that the larger objects are heavier, but should conclude that small objects can be heavier than large objects, depending on density (although students may not yet know the term).

Weight Your **weight** is a measure of the force of gravity on you. On Earth, all objects are attracted toward the center of the planet by the force of Earth's gravity. On another planet, the force of gravity on you may be more or less than it is on Earth. On the moon, you would weigh only about one-sixth of your weight on Earth.

Mass Why do you weigh less on the moon than on Earth? The force of gravity depends partly on the mass of an object. The **mass** of an object is the measurement of the amount of matter in the object. If you travel to the moon, the amount of matter in your body—your mass—does not change. But, the mass of the moon is much less than the mass of Earth, so the moon exerts much less gravitational force on you. **Unlike weight, mass does not change with location, even when the force of gravity on an object changes.** For this reason scientists prefer to measure matter by its mass rather than its weight. The mass of an object is a physical property.

Units of Mass To measure the properties of matter, scientists use a system called the **International System of Units.** This system is abbreviated "SI" after its French name, *Système International.* The SI unit of mass is the kilogram (kg). If you weigh 90 pounds on Earth, your mass is about 40 kilograms. Although you will see kilograms used in this textbook, usually you will see a smaller unit—the gram (g). There are exactly 1,000 grams in a kilogram. A nickel has a mass of 5 grams, and a baseball has a mass of about 150 grams.

Reading Checkpoint **What is the SI unit of mass?**

Go Online PHSchool.com
For: More on measuring matter
Visit: PHSchool.com
Web Code: cgd-1012

Equating Units of Mass

1 kg = 1,000 g
1 g = 0.001 kg

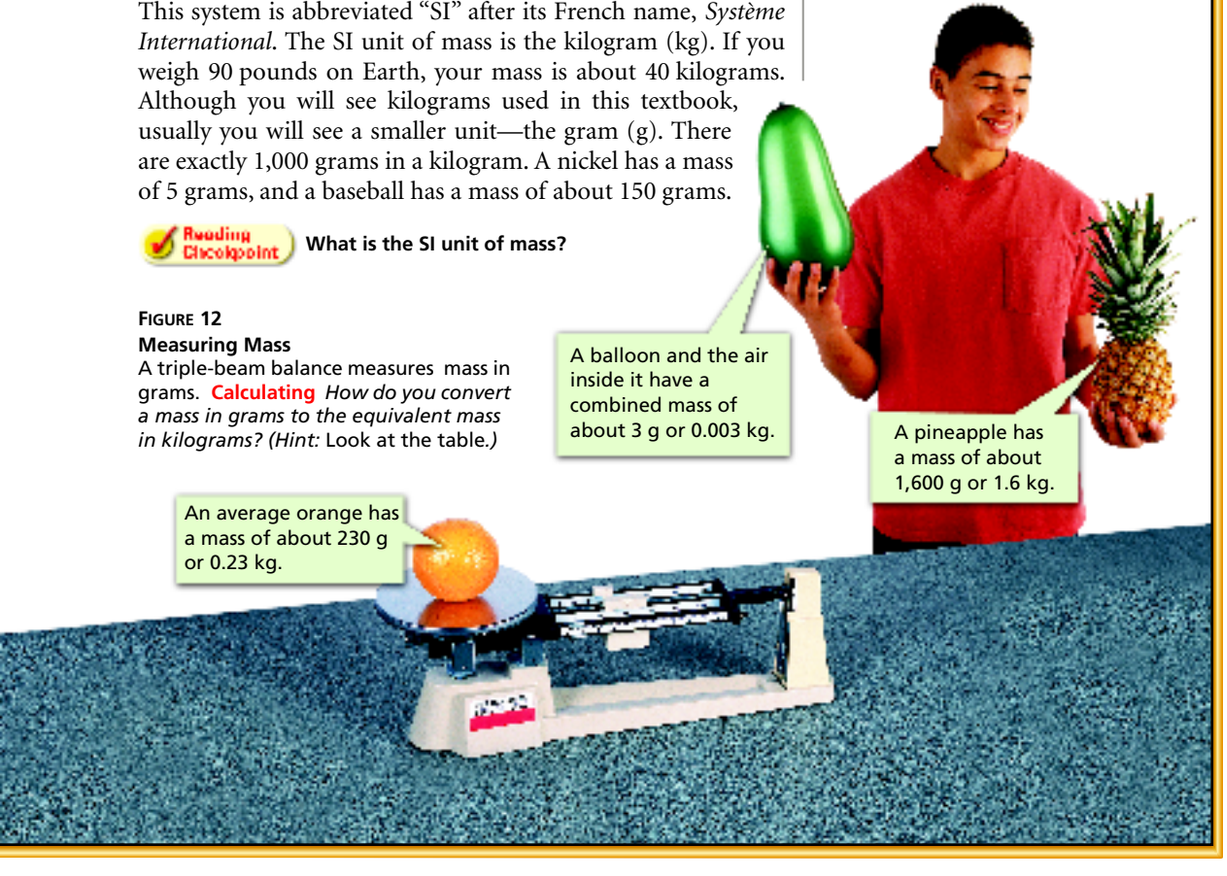


FIGURE 12
Measuring Mass
A triple-beam balance measures mass in grams. **Calculating** *How do you convert a mass in grams to the equivalent mass in kilograms? (Hint:* Look at the table.*)*

Instruct

Weight and Mass

Teach Key Concepts L2

Contrasting Weight and Mass

Focus Tell students that weight and mass measure two different things.

Teach Write the definitions of weight and mass on the board. Ask: **Why do scientists prefer to describe matter by its mass?** *(Unlike weight, mass does not change with location, even when the force of gravity on an object changes.)*

Apply Ask: **What units do scientists use to measure mass?** *(Grams and kilograms)* **learning modality: verbal**

Go Online PHSchool.com
For: More on measuring matter
Visit: PHSchool.com
Web Code: cgd-1012

Students can review measuring matter in an online activity.

Independent Practice L2

All in One Teaching Resources

- Transparency K40
- Guided Reading and Study Worksheet: *Measuring Matter*

Student Edition on Audio CD

Differentiated Instruction

Gifted and Talented L3

Calculating Weight Invite students to calculate their weight as it would be on the moon. Remind them that they would weigh only about one-sixth (0.16) of their weight on Earth. Then challenge them to calculate their weight as it would be on the surfaces of the other planets. The relative gravitational pulls on the surfaces of the other planets are as follows: Mercury—0.38, Venus—0.91, Mars—0.38, Jupiter—2.54, Saturn—0.93, Uranus—0.8, Neptune—1.2, and Pluto—0.04. Ask: **What is Jupiter's large gravitational pull attributable to?** *(Jupiter has the most mass of any planet in the solar system.)* **learning modality: logical/mathematical**

Monitor Progress L2

Writing Have students write definitions for weight and mass in their own words.

Students can save their definitions in their portfolios. Portfolio

Answer

Figure 12 Divide the mass in grams by 1000 or multiply it by 0.001.

Reading Checkpoint The kilogram is the SI unit of mass.

Volume

Teach Key Concepts L2

Units of Volume

Focus Write the definition of volume.

Teach Ask: **What units can be used to express volume?** *(The liter, milliliter, and cubic centimeter)* **What unit is equal to the cubic centimeter?** *(The milliliter)* Write the formula for volume. Show that the units of the measurements are also multiplied.

Apply Ask: **How can you measure the volume of an object with an irregular shape?** *(By placing it in water in a graduated cylinder and finding the difference in the volume of water before and after the object was added)* **learning modality: visual**

Lab zone Build Inquiry L2

Calculating Volume

Materials calculator, graduated cylinder, metric ruler, objects with regular and irregular shapes, water

Time 15 minutes

Focus Write the formula for volume *(Volume = Length × Width × Height)*.

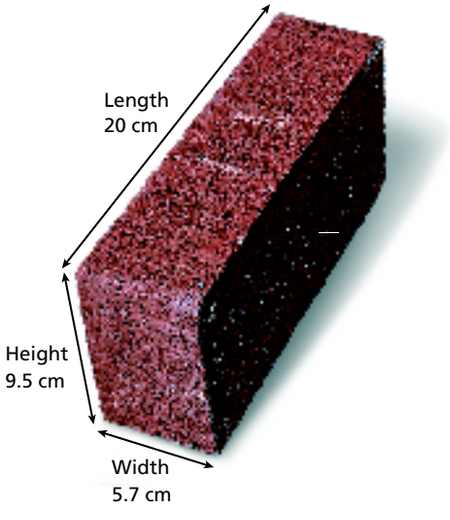
Teach Invite students to measure the volume of various objects, both regular and irregular in shape.

Apply Ask: **How do you convert milliliters to liters?** *(By dividing the volume in milliliters by 1,000)* Have students convert all their volume measurements from milliliters and cubic centimeters to liters. **learning modality: logical/mathematical**

Equating Units of Volume

1 L = 1,000 mL
1 mL = 0.001 L
1 mL = 1 cm^3

FIGURE 13
Finding Volume
The volume of a regular solid can be found by measuring its dimensions and multiplying the values.
Interpreting Tables *What volume of water in milliliters would this brick displace if submerged?*



Volume = 20 cm x 9.5 cm x 5.7 cm
= 1,083 cm^3

Volume

You learned in Section 1 that all matter has mass and takes up space. The amount of space that matter occupies is called its **volume.** It's easy to see that solids and liquids take up space. Gases have volume, too. Watch a balloon as you blow into it. You're actually increasing the volume of gas in the balloon with your breath.

Units of Volume **Common units of volume include the liter (L), milliliter (mL), and cubic centimeter (cm^3).** Some plastic soda bottles hold 1 liter of liquid. Volumes smaller than a liter are usually given in milliliters. A milliliter is one one-thousandth of a liter and is exactly the same volume as 1 cubic centimeter. A teaspoonful of water has a volume of about 5 milliliters, and an ordinary can of soda contains 355 milliliters of liquid. In the laboratory, volumes of liquid are usually measured with a graduated cylinder.

Calculating Volume The volumes of solid objects are usually expressed in cubic centimeters. Suppose you want to know the volume of a rectangular object, such as the brick shown in Figure 13. First, you measure the brick's length, width, and height (or thickness). Then, you multiply these values.

Volume = Length × Width × Height

Measurements always have units. So, when you multiply the three measurements, you must multiply the units as well as the numbers.

Units = cm × cm × cm = cm^3

How can you measure the volume of an irregular object, such as a piece of fruit or a rock? One way is to submerge the object in water in a graduated cylinder. The water level will rise by an amount that is equal to the volume of the object in milliliters.

Reading Checkpoint **How are milliliters related to cubic centimeters?**

Density

Samples of two different materials may have the same volume, but they don't necessarily have the same mass. Remember the riddle about the sand and the feathers? A kilogram of sand takes up much less space than a kilogram of feathers. The volumes differ because sand and feathers have different densities—an important property of matter. **Density** relates the mass of a material in a given volume. Often, density is expressed as the number of grams in one cubic centimeter. For example, the density of water at room temperature is stated as "one gram per cubic centimeter (1 g/cm^3)." This value means that every gram of water has a volume of 1 cm^3. Notice that the word *per* is replaced by the fraction bar in the units of density. **The bar tells you that you can determine the density of a sample of matter by dividing its mass by its volume.**

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

Math Sample Problem

Calculating Density

A small block of wood floats on water. It has a mass of 200 g and a volume of 250 cm^3. What is the density of the wood?

1 Read and Understand

What information are you given?

Mass of block = 200 g

Volume of block = 250 cm^3

2 Plan and Solve

What quantity are you trying to calculate?

The density of the block = ■

What formula contains the given quantities and the unknown quantity?

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

Perform the calculation.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{200\ \text{g}}{250\ \text{cm}^3} = 0.80\ \text{g/cm}^3$$

3 Look Back and Check

Does your answer make sense?

The density is lower than 1.0 g/cm^3, which makes sense because the block can float.

Math Practice

1. A sample of liquid has a mass of 24 g and a volume of 16 mL. What is the density of the liquid?
2. A piece of solid metal has a mass of 43.5 g and a volume of 15 cm^3. What is the density of the metal?

Density

Teach Key Concepts L2

Density

Focus Explain that density is the mass of a material in a given volume.

Teach Write the formula for density on the board. Explain that the units most often used for density are grams per cubic centimeter.

Apply Ask: **What causes some materials to float in water, while others sink?** *(Materials that are less dense than water will float. Materials that are more dense will sink.)* **learning modality: verbal**

Math Sample Problem

Math Skill Calculating density

Focus Point out that density is a ratio of two quantities, mass and volume.

Teach Ask: **What measurements are given in the problem?** *(Mass and volume)* Show students how to set up the equation and insert the given quantities. Ask: **Do the given quantities have the proper units?** *(Yes)* **Would it be correct to use milliliters as the unit for volume?** *(Yes. One milliliter is equal to one cubic centimeter.)*

All in One Teaching Resources

- Transparency K3

Math Practice

Math Skill Calculating density

Answers

1. 1.5 g/mL

2. 2.9 g/cm^3

Differentiated Instruction

Special Needs L1

Comparing Densities Set up a station with a container of water and objects of different densities. Include solid objects as well as liquids. Ask: **If an object is less dense than water, would you expect it to sink or float?** *(Float)* **If it is more dense?** *(Sink)* Invite students to compare the densities of the objects with water. Have them record their observations in a chart with the columns *Less Dense* and *More Dense*. **learning modality: kinesthetic**

Monitor Progress L2

Skills Check Have students write problems that are solved using the formulas for volume and density. Students can exchange problems and solve them.

Answers

Figure 13 1,083 mL

Reading Checkpoint One milliliter and one cubic centimeter are exactly the same volume.

Monitor Progress L2

Answer

Reading Checkpoint The oils in salad dressings have densities lower than that of water.

Assess

Reviewing Key Concepts

1. a. Mass is the measure of the amount of matter in an object. **b.** The mass of an object is constant. Its weight, however, can vary from place to place because weight is a measure of the force of gravity on the object. **2. a.** Volume **b.** 1,000 milliliters equal one liter. **c.** 620 cm^3 (rounded from 619.65 cm^3) **3. a.** Mass and volume **b.** Sample answer: Put the solid substance in water. If it sinks, it is more dense than water. If it floats, it is less dense than water. **c.** Sample answer: Using a balance, measure the mass of an empty balloon. Fill the balloon with air. (Students may suggest using a pump rather than blowing into the balloon because exhaled air differs from atmospheric air.) Measure the mass of the filled balloon. The difference in the two values is the mass of the air. Then measure the volume of the balloon using the water displacement method. Calculate the density of the air by dividing the mass by the volume.

Reteach L1

Have students write the formula for density. They should include the units for each measurement and a description of how each measurement is made.

Performance Assessment L2

Drawing Have students use diagrams to describe how to find the density of a small, irregularly shaped solid.

All in One Teaching Resources

- Section Summary: *Measuring Matter*
- Review and Reinforce: *Measuring Matter*
- Enrich: *Measuring Matter*

FIGURE 14
Density Layers
The density of water is less than corn syrup but greater than vegetable oil.

Sinking or Floating? Suppose you have a solid block of wood and a solid block of iron. When you drop both blocks into a tub of water, you can see right away that the wood floats and the iron sinks. You know the density of water is 1 g/cm^3. Objects with densities greater than that of water will sink. Objects with lesser densities will float. So, the density of this wood is less than 1 g/cm^3. The density of the iron is greater than 1 g/cm^3.

Watch a bottle of oil-and-vinegar salad dressing after it has been shaken. You will see oil droplets rising above the vinegar. Finally, the oil forms a separate layer above the vinegar. What can you conclude? You're right if you said that the oil is less dense than vinegar.

Using Density Density is a physical property of a substance. So, density can be used to identify an unknown substance. For example, suppose you were hiking in the mountains and found a shiny, golden-colored rock. How would you know if the rock was really gold? Later at home, you could look up the density of gold at room temperature. Then measure the mass and volume of the rock and find it density. If the two densities match, you would have quite a find!

Reading Checkpoint **Why does the oil in some salad dressings rise to the top of the bottle?**

Section 2 Assessment

Target Reading Skill **Asking Questions** Use the answers you wrote in your graphic organizer about the headings to answer the questions below.

Reviewing Key Concepts

1. a. **Defining** What is mass?
   b. **Explaining** Why is mass more useful than weight for measuring matter?
2. a. **Identifying** What property of matter is measured in cubic centimeters?
   b. **Comparing and Contrasting** How are milliliters related to liters?
   c. **Calculating** A plastic box is 15.3 cm long, 9.0 cm wide, and 4.5 cm high. What is its volume? Include units in your answer.
3. a. **Listing** What measurements must you make to find the density of a sample of matter?
   b. **Explaining** How can you determine whether a solid substance is more dense or less dense than water?
   c. **Problem Solving** Propose a way to determine the density of air.

Math Practice

4. **Calculating Density** A piece of metal has a volume of 38 cm^3 and a mass of 277 g. Calculate the density of the metal, and identify it based on the information below.

Iron	7.9 g/cm^3	Tin	7.3 g/cm^3
Lead	11.3 g/cm^3	Zinc	7.1 g/cm^3

Math Practice

Math Skill Calculating density

Answer

4. 7.3 g/cm^3; The metal is tin.

Lab zone Chapter Project

Keep Students on Track Have students begin testing their balances for accuracy by determining the mass of a known weight. Suggest that students use masses less than 20 grams. Students can also choose containers for measuring volume. Suggest they choose a container that is heavier than the amount of error in the balance. Possible containers include small plastic or paper cups, yogurt containers, soda cans, margarine tubs, or milk cartons.

Lab zone Skills Lab

Making Sense of Density

Problem

Does the density of a material vary with volume?

Skills Focus

drawing conclusions, measuring, controlling variables

Materials

- balance
- water
- paper towels
- metric ruler
- graduated cylinder, 100-mL
- wooden stick, about 6 cm long
- ball of modeling clay, about 5 cm wide
- crayon with paper removed

Procedure

1. Use a balance to find the mass of the wooden stick. Record the mass in a data table like the one shown above right.
2. Add enough water to a graduated cylinder so that the stick can be completely submerged. Measure the initial volume of the water.
3. Place the stick in the graduated cylinder. Measure the new volume of the water.
4. The volume of the stick is the difference between the water levels in Steps 2 and 3. Calculate this volume and record it.
5. The density of the stick equals its mass divided by its volume. Calculate and record its density.
6. Thoroughly dry the stick with a paper towel. Then carefully break the stick into two pieces. Repeat Steps 1 through 5 with each of the two pieces.
7. Repeat Steps 1 through 6 using the clay rolled into a rope.
8. Repeat using the crayon.

Data Table

Object	Mass (g)	Volume Change (cm^3)	Density (g/cm^3)
Wooden stick			
Whole			
Piece 1			
Piece 2			
Modeling clay			
Whole			
Piece 1			
Piece 2			
Crayon			
Whole			
Piece 1			
Piece 2			

Analyze and Conclude

1. **Measuring** For each object you tested, compare the density of the whole object with the densities of the pieces of the object.
2. **Drawing Conclusions** Use your results to explain how density can be used to identify a substance.
3. **Controlling Variables** Why did you dry the objects in Step 6?
4. **Communicating** Write a paragraph explaining how you would change the procedure to obtain more data. Tell how having more data would affect your answers to Questions 1 and 2 above.

Design an Experiment

Design an experiment you could use to determine the density of olive oil. With your teacher's permission, carry out your plan.

Expected Outcome

Density values for all samples of each object should be equal.

Analyze and Conclude

1. The density of the whole object should equal the density of each piece.
2. Because every sample of a material has the same density, density is a characteristic of that material.
3. If the objects were wet, the mass and volume measurements would include water, introducing a source of error into the calculations.
4. Sample answer: Measure the mass and volume of each object several times. Then find the average mass and average volume in each case, and use these values to calculate density. Having more data would provide stronger evidence to support the answers to Questions 1 and 2.

Lab zone Skills Lab

Making Sense of Density

L2

Prepare for Inquiry

Key Concept

The density of a material is a characteristic property of that material.

Skills Objectives

After this lab, students will be able to

- measure mass using a balance
- measure volume using the water displacement method
- calculate density

Prep Time 10 minutes
Class Time 30 minutes

Advance Planning

Make sure the objects to be tested can be broken easily and will fit into graduated cylinders.

Safety

Caution students to handle graduated cylinders with care. Review the safety guidelines in Appendix A.

All in One Teaching Resources

- Lab Worksheet: *Making Sense of Density*

Guide Inquiry

Invitation

Ask: **What is the formula for calculating the volume of an object?** *(Volume = length × width × height.)* **How can you calculate the volume of an irregularly shaped object?** *(Measure the volume of water it displaces.)*

Introducing the Procedure

Have students develop a way to submerge objects that might float, such as wood or crayons, in order to measure their volumes without affecting the accuracy of the results.

Extend Inquiry

More to Explore Sample answer: Determine the mass of a graduated cylinder without the oil, then with the oil to determine its mass. Calculate the oil's density by dividing the mass by the volume.