SECTION 2

Measuring Matter

DISCOVER ACTIVITY

Which Has More Mass?

1. Your teacher will provide you with some small objects, such as a rock, a plastic drinking cup, an aluminum can, and a pencil. 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 your results, list the objects from lightest to heaviest.

Think It Over

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

GUIDE FOR READING

- What is the difference between weight and mass?
- How is density calculated?

Reading Tip Before you read, define mass, volume, and density in your own words. Then revise your definitions as you read.

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

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

Mass

A veterinarian wants an updated weight for a dog at its annual check-up. To find the weight, the owner steps on the scale in the vet's office, holding the dog. Their combined body weight presses down on springs inside the scale. The more the girl or her dog weighs, the more the springs compress and the higher the reading. Subtract the owner's weight from the total, and the vet has his answer.

However, a scale would not indicate the same weight if you were on the moon. Step on a scale on the moon, and the springs inside it wouldn't compress as much as they did on Earth. You would weigh less on the moon.

Figure 7 If a dog won't stand on the scale by itself, you can step on the scale with it.

Weight or Mass? Why does your weight change when you travel away from Earth? The reason is that your **weight** is a measure of the force of gravity on you. On Earth, all objects are attracted downward by Earth's gravity. On other planets, the force of gravity may be more or less. On the moon, the force of gravity is much weaker than on Earth. You weigh less.

In everyday life, weight is a useful measurement of how much matter an object contains. But scientists rely on a property that is constant wherever the object may be. This property is called mass. The **mass** of an object is the measurement of how much matter it contains. **An object's weight will change if you move it from Earth to the moon or to other planets, but its mass will stay the same.**

Units of Mass To measure the properties of matter, scientists use a system of units called the **International System of Units.** The system is abbreviated "SI," after its French name, Système International. For mass, the SI unit is the kilogram (kg). If you weigh 90 pounds on Earth, then your mass is approximately 40 kilograms.

Although you sometimes 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 about 5 grams, the mass of a baseball is about 150 grams, and the water in a medium-sized glass has a mass of about 200 grams.

Checkpoint *What is the SI unit for mass?*

Volume

The amount of space that matter occupies is called its **volume.** It's easy to see the volume that solid and liquid objects take up. But gases have volume, too. Watch a balloon as you blow into it. You're actually increasing its volume with your breath.

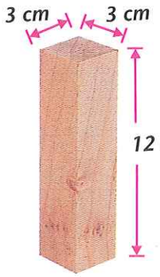


Figure 8 Volume is measured in several units. Usually, liquids are measured in liters (L) or milliliters (mL), and solids are measured in cubic centimeters (cm^3).

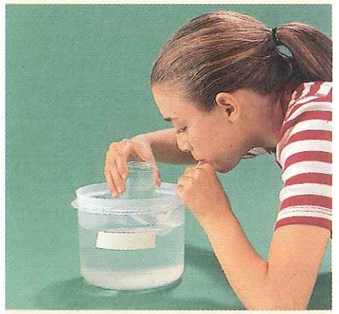
TRY THIS

Bubble Time

ACTIVITY

Do gases have volume?

1. Fill a large container with water. Completely submerge a clear plastic cup, right side up, in the container.
2. Mark the water level with a piece of tape on the outside of the container.
3. Turn the cup upside down underwater, without letting any air bubbles enter the cup.
4. Insert the short end of the straw into the water and up into the cup. Then blow into the straw.



Inferring Did blowing air into the cup change the water level in the container? Explain your observations.

INTEGRATING MATHEMATICS For rectangular objects such as a block of wood, the volume is found by multiplying the measurements of length, width, and height.

$$Volume = Length \times Width \times Height$$

When you multiply the three measurements, you must multiply the units as well as the numbers. So, just as $2 \times 2 \times 2 = 2^3$, $cm \times cm \times cm = cm^3$. If a block of wood has a length of 3 centimeters, a width of 3 centimeters, and a height of 12 centimeters, then the volume would equal the product of those values.

$$Volume = 3\ cm \times 3\ cm \times 12\ cm = 108\ cm^3$$

The name for cm^3 is the cubic centimeter, and it is a common unit of volume. Other units of volume include the liter (L) and the milliliter (mL), both of which are often used to measure liquids. A milliliter is exactly 1 cubic centimeter. There are 1,000 milliliters in one liter.

How can you measure the volume of an object with an irregular shape, such as a piece of fruit or a rock? One way is to put the object in a graduated cylinder containing water and measure the change in the volume of the water.

Checkpoint *How can you calculate the volume of a rectangular object like a shoebox?*

In Your Journal

Although scientists rely on SI units, people use other measurement units for many different purposes. Research the units used in diamond cutting, horse breeding, sailing, or other activities that interest you. Write a brief essay to present your findings.

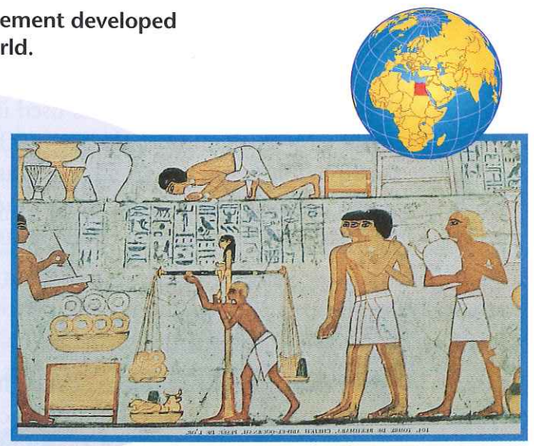
SCIENCE & History

Measurement Systems

Like so much else in science, systems of measurement developed gradually over time in different parts of the world.

1400 B.C.
Egypt

The ancient Egyptians developed the first known weighing instrument, a simple balance with a pointer. Earlier, they had been the first to standardize a measure of length. The length, called a cubit, was originally defined as the distance between the elbow and the tip of the middle finger.



640 B.C
Lydia

Merchants in the Middle East and Mediterranean used units of weight to be sure that they received the correct amount of gold and silver and to check the purity of the metal. A *talent* was about 25 kilograms and a *mina* about 500 grams. The Lydians minted the first true coins to have standard weight and value.

200 B.C
China

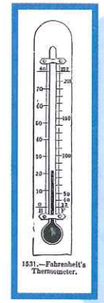
Shih Huang Ti, the first emperor of China, set standards for weight, length, and volume. Even earlier, the Chinese were the first to use decimal notation, the number system based on 10 digits. This is the system most people use today.

A.D. 789
Central Europe

The foot of Charlemagne, emperor of most of central Europe, was set as the standard unit of length. The standard unit of weight was the *Karlspfund,* translated as "Charlemagne's pound."

A.D. 1714
Germany

Gabriel Fahrenheit invented the thermometer, a temperature-measuring device that relies on the expansion of mercury with heat. His name later came to be used as the name for a unit of temperature.



A.D. 700
England

During the reign of Ethelbert II in England, the term *acre* was in common use as a measurement of area. An acre was defined as the amount of land that two oxen could plow in one day.

A.D. 1983
France

The International Bureau of Weights and Measures defines a single set of units that is the same everywhere. In 1983, the meter was defined as the distance light travels in a fraction of a second.

1500 B.C. | 1000 B.C. | 500 B.C. | A.D. 1 | A.D. 500 | A.D. 1000 | A.D. 1500 | A.D. 2000

Figure 9 This table lists commonly-used units of mass, volume, and distance. *Making Generalizations Which units measure the amount of space an object occupies? Which units measure the amount of matter in an object?*

Common Units and Conversions

Quantity	SI/Metric Units	Other Units	Conversions
Mass	Kilogram (kg) Gram (g)		1 kilogram = 1,000 grams
Volume	Cubic meter (m^3) Liter (L) Milliliter (mL) Cubic centimeter (cm^3)	Quart Gallon	1 milliliter = 1 cm^3
Distance	Meter (m) Kilometer (km) Centimeter (cm)	Foot Mile Inch	1 kilometer = 1,000 meters 1 centimeter = 0.01 meter

Density

Different substances may have the same mass, but they don't necessarily fill the same volume. Remember the riddle about the bricks and the feathers? A kilogram of bricks takes up a much smaller volume than the same mass of feathers. This is because bricks and feathers have different densities—a very important characteristic property of matter. **Density** is the measurement of how much mass is contained in a given volume. **To calculate the density of an object, divide its mass by its volume.**

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

A unit of density is always a unit of mass, such as grams, divided by a unit of volume, such as cubic centimeters. One typical unit of density is written as "g/cm^3," which is read as "grams per cubic centimeter." The word *per* means "for each," which in mathematics is the same as "divided by." For liquids, density is often stated in grams per milliliter, or g/mL. The density of water is 1.0 g/mL, which is the same as 1.0 g/cm^3.

Sometimes you can compare the densities of substances just by observing them. For example, suppose you have a solid block of wood and a solid block of gold. When you drop each block into a tub of water, the wood floats and the gold sinks. You know the density of water is 1.0 g/cm^3. You can conclude that the wood has a density lower than 1.0 g/cm^3. In contrast, the density of the gold is greater than 1.0 g/cm^3.

Figure 10 An object sinks or floats depending, in part, on its density. These ducks are made of many different substances, but overall, a duck's body has a density less than that of water.

Sample Problem

A small block of wood floats on water. It has a volume of 25 cubic centimeters and a mass of 20 grams. What is the density of the wood?

Analyze. You know the mass and the volume. You want to find the density.

Write the formula. $\text{Density} = \frac{\text{Mass}}{\text{Volume}}$

Substitute and solve. $\text{Density} = \frac{20\ g}{25\ cm^3}$

$\text{Density} = 0.8\ g/cm^3$

Think about it. The answer shows mass per unit volume. The correct unit is g/cm^3.

Practice Problems

1. A sample of liquid has a mass of 24 grams and a volume of 16 milliliters. What is the density of the liquid?
2. A metal sample has a mass of 43.5 grams and a volume of 15 cubic centimeters. What is its density?

Watch a bottle of oil-and-vinegar salad dressing after it's been shaken. You will see oil droplets rise toward the top of the bottle. Eventually, the oil forms a separate layer above the other ingredients. What can you conclude? You're right if you said the oil is less dense than the rest of the liquid dressing.

The density of a substance is the same for all samples of that substance. For example, all samples of pure gold have a density of 19.3 g/cm^3. Therefore, density is another example of a characteristic property.

Section 2 Review

1. Why are mass and weight different measurements?
2. What two quantities do you need to know in order to calculate density?
3. Describe how you could measure the volume of an object with an irregular shape.
4. **Thinking Critically** **Problem Solving** The density of aluminum is 2.7 g/cm^3. A metal sample has a mass of 52.0 grams and a volume of 17.1 cubic centimeters. Could the sample be aluminum? Explain your answer.

Science at Home

You can demonstrate differences in density to your family. Label two cups A and B and place a cup of water in each. Stir 3 teaspoons of salt and several drops of food coloring into Cup B. Dip a clear straw into Cup A to a depth of about 2 cm. Place your finger on the end of the straw and dip it into Cup B to a depth of about 4 cm. Remove your finger from the straw and then replace it. Remove the straw from the cup. Explain to your family what densities have to do with the results.