LESSON 2

Determining Density

CORBIS/DIGITAL STOCK

How can this diver remain at this depth? Why doesn't he float to the surface or sink to the bottom of the sea?

INTRODUCTION

In this lesson, you will start to investigate a property of matter called density. To do this, you will have to measure the mass and volume of several different objects made from different substances. You will then use the data you have collected to determine the mass of 1.0 cubic centimeter of the substance from which the objects are made.

OBJECTIVES FOR THIS LESSON

Discuss the terms "mass" and "volume."

Find the mass of a known volume of water.

Calculate the mass of 1.0 cubic centimeter of water.

Measure the mass and volume of some regular and irregular objects.

Calculate the density of these objects.

Getting Started

1. In your notebook, write what you think the difference is between mass and volume. After a few minutes, your teacher will lead a class discussion on mass and volume. Be prepared to contribute your ideas to this discussion.

2. After the discussion, write your own definitions for mass and volume in your science notebook. Include the units you would use for measuring each of them.

3. Read "Useful Calculations" on page 16.

MATERIALS FOR LESSON 2

For you

- 1 copy of Student Sheet 2.1: Measuring the Mass and Volume of Water
- 1 copy of Student Sheet 2.2: Comparing the Densities of Different Substances
- 1 copy of Student Sheet 2.3: Measuring the Densities of Irregular Objects

For your group

- 2 100-milliliter (mL) graduated cylinders
- 1 aluminum block
- 1 transparent plastic block
- 1 wax block
- 1 white plastic block
- Metric rulers
- 1 copper cylinder
- 1 nylon spacer
- 1 steel bolt
- Paper towels or newspaper
- Access to an electronic balance
- Calculators, if available

USEFUL CALCULATIONS

Volume is a measure of space taken up by some matter. In this module, the units cubic centimeters or milliliters are used when measuring volume. Because 1 milliliter equals 1 cubic centimeter, these units are interchangeable.

The volume that something takes up can be measured in several different ways. A graduated cylinder can be used to measure the volume of liquids. The exterior dimensions of regular solid objects can be measured to calculate their volume. For example, the volume (measured in cubic centimeters) of a block can be calculated by measuring the block's length (l), height (h), and width (w) in centimeters and then multiplying these together, as shown in the following equation:

Volume of a block =
l (centimeter) × h (centimeter) ×
w (centimeter) = volume in cubic centimeters

Different formulas can be used to calculate the volume of other regular objects (such as cylinders or spheres). Volumes of solids can also be measured indirectly by using a graduated cylinder. This method is done by the displacement of water. You used this method in Inquiry 1.2.

Mass is a measure of the amount of matter in an object. In this module, gram is used as the unit for measuring mass. Mass can be measured using a balance.

The density of a substance is the mass of a known volume of a substance. It is usually measured in grams per cubic centimeter.

Inquiry 2.1
Measuring the Mass and Volume of Water

PROCEDURE

1. Collect the plastic box of materials for your group. Check its contents against the materials list. During this lesson, you will also use an electronic balance. Other groups will be sharing the balance with you. Your teacher will assign an electronic balance to your group.

2. Work with your partner. Take one of the graduated cylinders out of the plastic box. Examine it carefully. Discuss the answers to the following questions with your partner:

   A. What is the unit of measure for the graduated cylinder?

   B. What is the maximum volume it can measure?

   C. What is the minimum volume it can measure?

   D. What is the number of units measured by the smallest division on its scale?

3. In this experiment, you will investigate the mass of different volumes of a substance. The substance you will use is water. Discuss with your partner how you could find the mass of 50 mL of water by using the graduated cylinder and the electronic balance. Consider the measurements and the calculations you need to make. Write your ideas in your notebook. You will be expected to contribute your ideas to a short class discussion.

4. Record the steps of the agreed-upon class procedure on Student Sheet 2.1.

5. Make sure that before you place anything on the balance it reads 0.0 gram (g) (see Figure 2.1). If the balance does not read 0.0 g, press the button marked ZERO. Wait for 0.0 g to appear before continuing. Once you place an object on the balance, wait a few seconds for the reading to stabilize before recording your measurement.

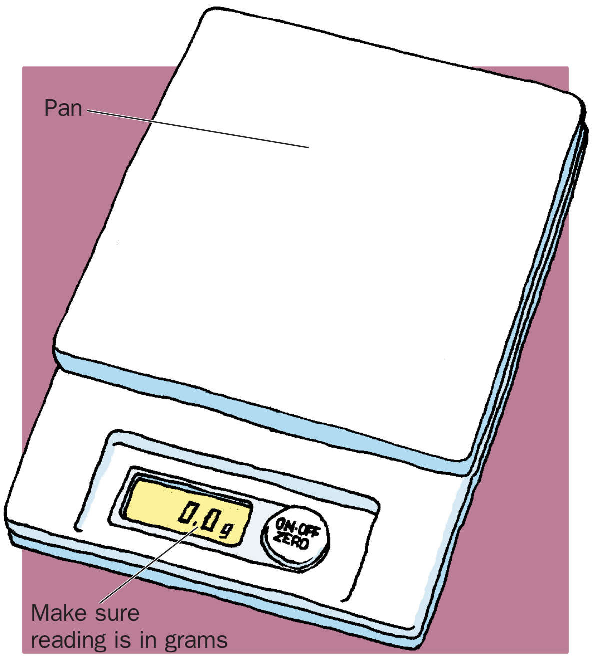


Figure 2.1 *Make sure the balance reads 0.0 g before placing an object on it.*

6. Look at Figure 2.2 to review how to accurately measure volume with a graduated cylinder.

7. Follow the class procedure to find the mass of 50 mL of water. Record your measurements in Table 1 on the student sheet.

8. Complete the last column of Table 1. You can calculate the mass of 1 cm^3 of water by dividing the mass of the water by the volume of the water.

9. Repeat the experiment using 25 mL of water. Remember, you already know the mass of the graduated cylinder.

10. Use your results to answer the following questions on Student Sheet 2.1: Does changing the volume of water change the mass of 1 cm^3 of water? Does changing the mass of water change the mass of 1 cm^3 of water? What is the density of water in grams per cubic centimeter (g/cm^3)? Does changing the mass or volume of water change its density?

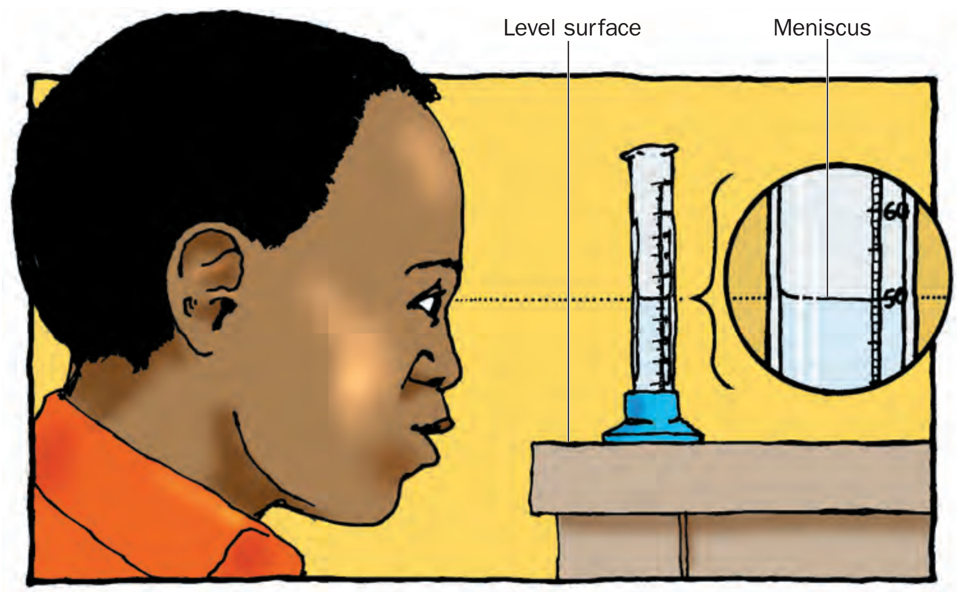


Figure 2.2 *Make sure the graduated cylinder is on a level surface. When you take a reading, make sure your eye is level with the bottom of the meniscus. The "meniscus" is the curved upper surface of the water in the cylinder.*

Inquiry 2.2
Comparing the Densities of Different Substances

PROCEDURE

1. Take the blocks of wax, transparent plastic, white plastic, and aluminum (the silver-colored metal) out of the plastic box.

2. Discuss the following questions with the other members of your group:

   A. Do you think all of these blocks have the same density?

   B. What evidence do you have to support your answer?

   C. What measurements will you need to make to test your hypothesis?

3. Work with your partner to determine the density of each of the blocks (see Figure 2.3). You will need to share the blocks with the other members of your group. Record your results in Table 1 on Student Sheet 2.2.

4. Check your results and calculations against those of the other pair in your group. If your calculated densities do not match (to within 0.1 g/cm^3), repeat your calculations.

5. Answer the following questions on the student sheet: Are the densities of the different substances the same or different? How could this information be used to identify the substance from which an object is made?

Figure 2.3 *Use the ruler to measure the blocks. Calculate the volume of each block in cubic centimeters. Use the balance to measure the mass of the blocks.*

Inquiry 2.3
Measuring the Densities of Irregular Objects

PROCEDURE

1. In this inquiry, you will determine the density of some objects with complex shapes. Remove the three objects (steel bolt, copper cylinder, and nylon spacer) from the plastic box.

2. Discuss with other members of your group how you could find the density of each of these objects. Refer to Inquiry 1.2 for help in finding the volume of objects. You will discuss your ideas with the rest of the class before proceeding with the inquiry.

3. Draw a series of simple diagrams in the boxes on Student Sheet 2.3, showing how you are going to find out the mass and volume of the objects. You may not need to use all the boxes.

4. Work with your partner to devise a table in which to record your data. You may need to make some rough layouts in your notebook. Make sure you include space in the table for all your measurements, your calculations, and the density of the objects. Use the correct units of measure when labeling columns. When you have decided on a good layout, use a ruler to draw your table in the space provided on Student Sheet 2.3.

5. Find the mass, volume, and density for each of the objects. Both pairs in your group should find the mass of each of the objects *before* immersing them in water. Check your results with the other pair in your group. You can ignore small differences in the densities you have obtained.

6. Complete your data table.

7. Answer the following questions on Student Sheet 2.3: Are any of the blocks from Inquiry 2.2 or objects from this inquiry made from the same substance? How did you reach your conclusion? How do the densities of the objects compare with the density of water?

REFLECTING ON WHAT YOU'VE DONE

1. During the lesson, you measured the mass and volume and calculated the density of a liquid and some solids. All the substances had different densities. Your teacher will lead a discussion about the results from all three inquiries. To help you participate in the discussion, write your answers to the following questions in your notebook:

   A. What is the difference between mass and volume?

   B. What units did you use to measure mass and volume?

   C. How did you calculate the density of an object?

   D. What units did you use to measure density?

   E. Does changing the amount of a substance change its density?

   F. If two objects are made from the same substance, will they have the same density?

2. Read "Density as a Characteristic Property."

DENSITY AS A CHARACTERISTIC PROPERTY

The density of a substance is a characteristic of that substance. Therefore, density is a property that can be used to help identify a substance. Properties used to help identify substances are called characteristic properties.

Characteristic properties are not affected by the amount or shape of a substance: A bolt made from iron will have the same characteristic properties as the hull of an iron ship or a piece of iron railing. You will encounter more characteristic properties later in the module. Perhaps you can think of some now.

Knowing the density of a substance can be useful. For example, substances with low densities can be used to make objects that fly. Based on the results you obtained in Lesson 2, do you think steel or aluminum would be better for building an airplane? Would you want to make a bike out of lead? Why or why not?

Mass or Weight?

What is the weight of the sugar inside the bag in the picture? If you answer the question by saying 1 kilogram, you would be wrong! You see, kilograms and grams are units of mass, not weight. Weight is measured in units called newtons. Confused by the difference between mass and weight? Why do we need different units?

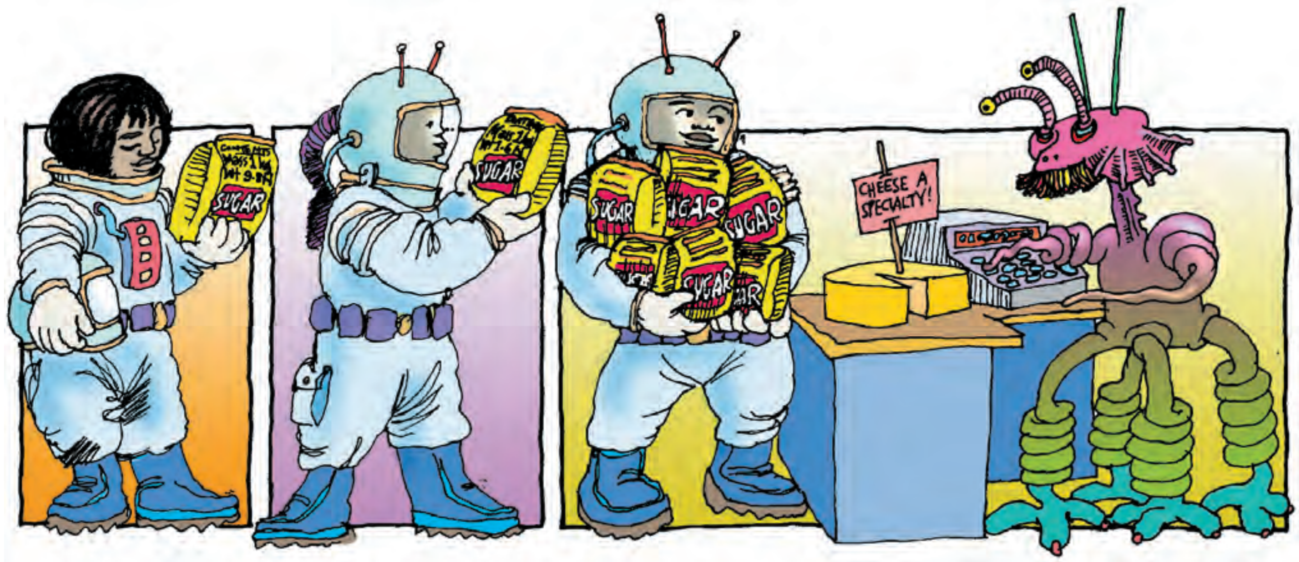
We have already discussed that mass is a measure of the amount of matter in an object. The bag contains sugar with a mass of 1 kilogram. Weight is quite different from mass. It is a measure of the force of gravity. Gravity is the force of attraction between two objects. Earth and the sugar are attracted to each other. This attraction varies with the size of the two objects and their distance apart. The force of attraction between a mass of 1 kilogram and Earth is about 9.8 newtons. So the answer to the question "How much does the sugar in this bag weigh?" is 9.8 newtons.

How much does this bag of sugar weigh?

If an astronaut took the bag of sugar to the moon, what would be its mass? Would it contain the same amount of matter? The answer is yes. Provided the astronaut hasn't eaten or dropped any of the sugar, the bag would still contain sugar with a mass of 1 kilogram. What is the weight of the bag of sugar on the moon? The moon is much smaller than Earth, so the force of attraction between the sugar and the moon is less. Gravity on the moon is about one-sixth of that on Earth. So what is the weight of sugar on the moon? Divide 9.8 newtons by 6 and you'll get an approximate answer. ☐

QUESTION

How would the weight of the same bag of sugar on Mars and Jupiter differ from that on Earth? Explain your answer.



When it comes to mass, it doesn't matter where you are because the mass of an object is always the same. But if you are buying something by weight, you will get a lot more for the same cost if you buy it on the moon!

Archimedes' Crowning Moment

Archimedes, one of the most famous mathematicians and scientists of ancient Greece, had a problem. The king had a new crown. It looked like pure gold. But the king was suspicious. How could he be sure that the jeweler hadn't cheated him by adding another, less valuable metal to the molten gold? The king asked Archimedes to find out whether the crown was made from pure gold.

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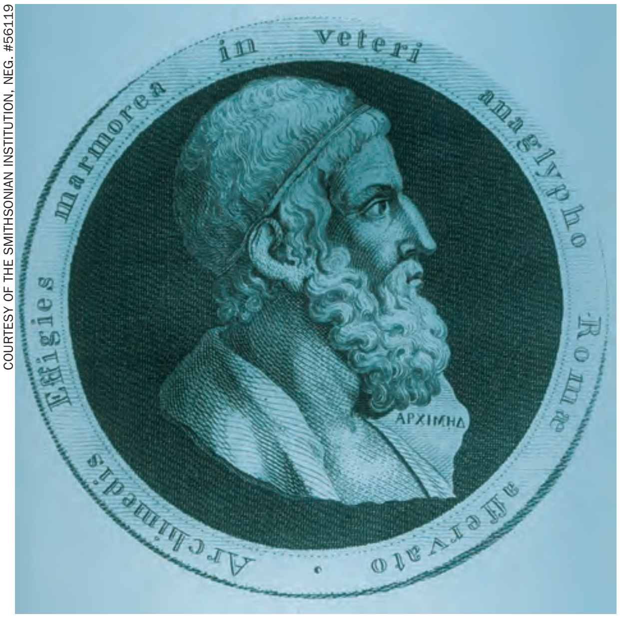


Archimedes was an expert on mass, volume, and density.

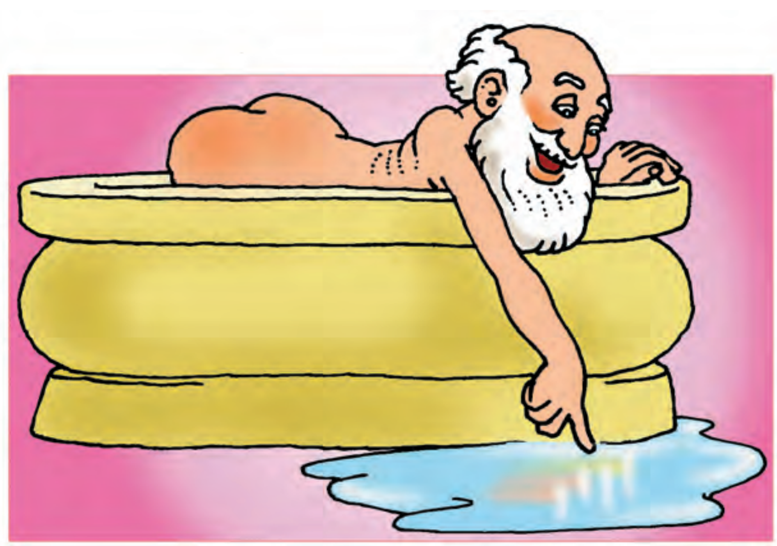
Archimedes knew his reputation was on the line. He could have taken the problem down to the public marketplace, where he often went to discuss scientific questions with other scholars. But instead, he decided to relax in a bath. The tub was filled to the brim. Still concentrating on his problem, Archimedes immersed himself in the water.

Splash! Water spilled over the sides of the tub and onto the floor. He had made a real mess. But that mess triggered an idea—an idea that would help solve the king's dilemma.

"When I got into the tub," Archimedes reasoned, "my body displaced a lot of water. Now, there must be a relationship between my volume and the volume of water that my body displaced—because if I weren't so big, less water would have spilled on my floor."

This observation brought Archimedes back to the problem of the gold crown. What if he put it in water? How much water would it displace? And could he apply this observation to prove that the crown was made of pure gold?

Archimedes knew about the importance of controls, so he began by finding a piece of gold and a piece of silver with



"Hmmm . . . the volume of my body equals the volume of water on the bathroom floor."

exactly the same mass. He dropped the gold into a bowl filled to the brim with water and measured the volume of water that spilled out. Then he did the same thing with the piece of silver.

Although both metals had the same mass, the silver had a larger volume; therefore, it displaced more water than did the gold. That's because the silver was less dense than gold.

Now it was time to check out the crown. Archimedes found a piece of pure gold that had the same mass as the crown. He placed the pure gold chunk and the crown in water, one at a time.

The crown displaced more water than the piece of gold. Therefore, its density was less than pure gold. The king had been cheated! Although this was just one of Archimedes' many contributions to science, there's no doubt that it was his "crowning moment"! □

QUESTION

Pretend you are Archimedes. What instructions would you give for comparing the density of a crown with the density of gold?