LESSON 2

Determining Density

Inquiries 3
Periods 2–3

CONCEPTS

Matter has mass.

Mass is measured in grams, using a balance.

Matter has volume.

Volume is measured in cubic centimeters or milliliters.

Mass per unit volume is also called density. It is measured in grams per cubic centimeter.

Density is one characteristic property of matter.

STUDENT OBJECTIVES

Explain the difference between mass and volume.

Measure mass, in grams, using an electronic balance.

Measure the volume of a liquid, in cubic centimeters (or milliliters), using a graduated cylinder.

Calculate the mass of 1.0 cm^3 of a substance.

Recognize that the mass of a unit volume of a substance is also called its density.

Use exterior dimensions to calculate the volume of regular blocks.

Measure the volume of objects by using displacement of water.

Recognize that density is one characteristic property of matter.

OVERVIEW

This lesson is the first of four that examines the concept of density. In the first of three inquiries, students measure different masses and volumes of water with an electronic balance and a graduated cylinder, respectively. They use the information they collect to determine the mass of 1.0 cubic centimeter (cm^3) of water. The term "density" is introduced at this stage. By measuring the mass of different volumes of water, students discover that the density of a substance is independent of the quantity of the substance. Students then measure volume and mass of several substances, determining their densities. In Inquiry 2.2, they calculate volume by measuring regular blocks, and in Inquiry 2.3, they measure the volume of more complex objects through the displacement of water. They use the data they collect to discuss density as a characteristic property of matter. The results obtained from Inquiries 2.1, 2.2, and 2.3 are used to introduce Lesson 3, in which students predict the behavior of substances on the basis of their densities.

BACKGROUND

In physical science, the term **density** is defined as the mass per unit volume of a substance. It is calculated by measuring the mass of an object and dividing this mass by the object's volume. In this module, the gram is the unit of measure for mass, and the cubic centimeter or milliliter is the unit of measure for volume. The unit used to define the density of a substance is grams per cubic centimeter (g/cm^3). Density is a characteristic property of matter and, under defined conditions of temperature and pressure, can be

used to identify types of matter. A **characteristic property** is a property that is independent of mass, volume, and shape; thus, characteristic properties refer to substances, not objects. For example, the iron in a nail, a bolt, and a ship's hull has the same characteristic properties.

In Inquiry 2.1, students measure the mass of two different volumes of water and calculate the density of water from both sets of data. They should obtain a figure close to 1.0 g/cm^3 for both calculations, indicating that the density of water is independent of the volume measured, which is true for all substances. The density of water is 1.0 g/cm^3 at 4 °C; for the purposes of this lesson, 1.0 g/cm^3 can also be considered the density of water at room temperature. The density of water is often used as the measure to which other substances are compared. Water has a relative density of 1.0 compared with, for example, air at 0.0013 and gold at 19.3. Because in this module students measure mass and volume to determine density, grams per cubic centimeter, rather than relative density, is used, since this unit more clearly expresses density as a relationship between mass and volume.

In this module, no attempt has been made to relate density to "particle packing," because particulate theory is not mentioned in the National Science Education Standards until Grade 9. If your local curriculum requires discussing matter in terms of particles, refer to the suggestions about how to approach this topic in the Extensions at the end of this lesson.

An attempt has been made to simplify the math for this lesson. Students measure the volume of liquids with a graduated cylinder and measure the volume of regularly shaped blocks by making simple calculations based on ruler measurements. These types of calculations are not used in measuring irregularly shaped objects; instead irregularly shaped objects are measured by displacement (using Archimedes' principle). Students will only need to be able to read the scales on rulers and graduated cylinders and perform long division. If students are particularly weak at math, you may want to supply calculators.

Many students at this age find the concepts of mass and volume very difficult to grasp. Because density is derived through the measurement of both of these, you may find that students still use the terms "weight" and "heaviness" instead of "density." In fact, adults commonly use the term "lightweight" when referring to low density. Density can be considered "heaviness for its size" or, better still, "heaviness for its volume." If students discuss the density of substances in these terms, they have an excellent grasp of the concept. By Lesson 6, most students should be able to measure mass and volume, calculate mass per unit volume and call it density, and use density as a characteristic property.

In this module, the term "weight" is avoided. You may wish to address the difference between mass and weight, which is particularly confusing to students because, outside science, weight is *incorrectly* measured in grams. The reader "Mass or Weight?" on Student Guide (SG) page 21 explains in simple terms the difference between mass and weight.

Some may object to the use of electronic balances, provided with the kit, to measure mass. The term "balance" is now widely applied to any device that measures in units of mass; it is not applicable only to "beam balances." Also, it is preferable to use the term "balance" instead of "scale" because the latter term is also used in several other contexts in this module. At this level, you should treat the internal workings of the balance as a "black box."

Student Misconceptions

There are many misconceptions that relate to mass, volume, density, and floating and sinking. Some common student misconceptions include the following:

- Students incorrectly think that mass alone is the determining factor in floating and sinking; that is, heavy objects sink, and light objects float. (Mass per unit volume, or density, is the determining factor in floating and sinking.)
- Students incorrectly think that because mass and volume are both used to measure "quantities," the terms are interchangeable. (Mass is a measure of the quantity of matter in an object, and volume is a measure of the space it occupies.)
- Students incorrectly assume that mass is affected by changes in shape. (Mass is not affected by shape. For example, because it floats, students may think that a flat piece of aluminum foil has less mass than an identical piece rolled into a ball. In actuality, it floats as a result of the surface tension and buoyancy force of water.)
- Students incorrectly believe that density and weight are the same. (**Weight** is a measure of the force of gravity acting on an object and is measured in newtons. It is *not* the same as density and is *not* used when calculating density.)
- Students incorrectly believe that mass and weight are the same. (**Mass** is a measure of the inertia of an object. For practical purposes, it is measured in the same way as weight.)

MATERIALS FOR LESSON 2

For each student

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*

*Needed, but not supplied

For each group of 4 students

1 plastic box with lid
Block Set:
  1 aluminum block
  1 transparent plastic block
  1 wax block
  1 white plastic block
Irregular Objects Set:
  1 copper cylinder
  1 nylon spacer
  1 steel bolt
2 graduated cylinders, 100 mL
1 metric ruler (with millimeter and centimeter scales)

For the class

4 electronic balances
Paper towels or newspaper to dry apparatus*
Calculators, if available*

PREPARATION

1. Make one copy of each of the student sheets for each student.
2. Make sure the balances are working and that batteries are installed.
3. Measure the length, mass, and volume of the objects for each group of students. These measurements will be used in the assessment to determine students' ability to make accurate measurements.
4. Find out whether students are proficient at accurately measuring length using rulers, mass using balances, and volume using graduated cylinders. Also find out their familiarity with the units of measure for length, mass, and volume.
5. Students should have read "What Is Matter?" (Lesson 1) and answered the questions at the end of the reader.

Getting Started

1. Hand out the student sheets.
2. Ask students what they think the difference is between mass and volume. Have them write their ideas in their science notebooks. Write several of their ideas on the board or on a transparency.
3. Have students read "Useful Calculations," on SG page 16. Review the concepts of mass and volume by referring to "Useful Calculations" and/or to the questions from the reader in Lesson 1, "What Is Matter?" Initiate a discussion that focuses on the difference between mass and volume and the units used when measuring each.
4. After the discussion, have students write their own definitions of mass and volume in their notebooks. They should include the units they would use when measuring each of them. Ask three or four students for their definitions.

Inquiry 2.1
Measuring the Mass and Volume of Water

PROCEDURE

1. Have one member from each group collect a plastic box containing the materials. Students will work in groups of four and in pairs. Pairs within groups compare results to check the precision of measurements they make.

2. Explain to students that in addition to these materials they will also be using an electronic balance. Assign an electronic balance to each group.

3. Allow students 2–3 minutes to discuss the questions in Step 2 of the Student Guide. These questions, which follow, are designed to familiarize students with the scale on the graduated cylinder:

A. What is the unit of measure for the graduated cylinder? (milliliter, mL)

B. What is the maximum volume it can measure? (100 mL)

C. What is the minimum volume it can measure? (10 mL)

D. What is the number of units measured by the smallest division on its scale? (1 mL)

NOTE Remind students that 1 mL is the same as 1 cm^3.

4. Discuss students' answers to the questions.

5. Allow students 3–4 minutes to do Step 3 in the Student Guide with their partners. In a class discussion, ask students to give their ideas about the procedure.

6. From their answers, construct a procedure on the board or on a transparency with the following components:

A. Measure the mass of the graduated cylinder (avoid the term "weigh").

B. Put exactly 50 mL of water into the graduated cylinder.

C. Find the mass of the graduated cylinder plus water.

D. Subtract the mass of the graduated cylinder from the mass of the graduated cylinder plus water.

7. Have students record this procedure on Student Sheet 2.1.

8. Work through Steps 5 and 6 in the Student Guide with students. If your students are unfamiliar with the use of electronic balances and graduated cylinders, you may need to spend considerable time on these steps.

9. Have students follow the agreed-upon procedure for finding the mass of 50 mL of water and complete Steps 7 through 10 in the Student Guide.

10. Discuss students' answers for the questions in Steps 3 through 6 on the student sheet. Emphasize the following points:

- The mass of 1 cm^3 of water remains the same regardless of the volume of water measured.
- The mass of 1 cm^3 of water remains the same regardless of the mass of water measured.
- Mass per unit volume is called density and can be measured in grams per cubic centimeter.
- Changing the mass or volume of water does not change its density.
- The density of water is a characteristic property of water.

NOTE This is a good point to break the lesson. If Inquiry 2.2 is conducted on another day, you may wish to review these questions again before beginning the inquiry.

Inquiry 2.2
Comparing the Densities of Different Substances

PROCEDURE

1. Ask students to read Steps 1 through 4 in the Student Guide.

2. Discuss Steps 2 and 3. You may need to review the procedure for finding the volume of a block.

3. Have students conduct the inquiry, record their results in Table 1 on Student Sheet 2.2, and answer questions 2 and 3 on the student sheet.

4. Discuss students' results and their answers to the questions on the student sheet. Focus on the fact that each substance has a different density, which is a characteristic of the substance, and that density can be described as one characteristic property of a substance. Discuss the idea that, given a list of known densities, students could identify the substance from which an object is made by measuring its density.

Inquiry 2.3
Measuring the Densities of Irregular Objects

PROCEDURE

1. Have students read Steps 1 and 2 in the Student Guide. Allow 2–3 minutes for students, working in their groups, to discuss Step 2.

2. Ask students from a few groups to give their ideas about the steps of their procedures. As students work out the correct sequence for the procedure, write the procedure on the board or on a transparency so that the whole class can follow it. Ask students why they should find the mass of their objects *before* immersing them in water. (Answer: If the objects are wet, measurements of mass will be incorrect.) You may ask students to demonstrate the procedure for measuring the volume of the objects by using the displacement of water. Students should use this procedure as the basis for their drawings in Step 3.

3. Have students complete Steps 4 through 7 of the procedure. You may wish to discuss the components of their data table. Avoid providing the table. Students should be reminded to include units, but they should select the units they are going to use.

4. Ask some students to write their results on the board or overhead. These answers can be used as the basis for a discussion on the ways students have laid out their data tables. Review the questions in Steps 3 and 4 on the student sheet. How can students tell whether any of the objects and blocks are made from the same substance? Are they? (Answer: They are not.) How do the densities of the objects compare with the density of water? Look for answers that suggest that the density of the objects is greater than that of water, but do not proceed farther. In the next lesson, students will use these answers to predict floating and sinking.

REFLECTIONS

1. Have students answer the questions in Step 1 of "Reflecting" in the Student Guide in their notebooks and read "Density as a Characteristic Property," on SG page 20.

2. Briefly discuss the answers to the questions in Step 1 and those on the use of metals at the end of "Density as a Characteristic Property."

HOMEWORK

Period 1

Students should read "Archimedes' Crowning Moment" at the end of Lesson 2 and answer the accompanying question. You may use this reader as an introduction to Inquiry 2.3.

Periods 2 and 3

After Inquiry 2.3, have students explain how they would determine the density of an irregularly shaped cork. Suggest that students outline their procedure as a series of labeled diagrams.

EXTENSIONS

Science

1. Have students read "Mass or Weight?" on SG page 21 and answer the accompanying question.

Science

2. If particulate theory is on your local curriculum, you may wish to discuss it in relation to density. To explain density, you will need to discuss *both* the mass of the particles and how closely they are packed together.

Science **Mathematics**

3. Have students write a table of all the metric units that relate to mass and volume.

Mathematics

4. Have students find out how to calculate the volume of other regular objects, such as a sphere, a cylinder, and a tetrahedron. Students should practice using the formulas for finding the volumes of these objects.

Language Arts

5. The term "density" has a very specific meaning in physical science. Have students investigate other meanings and use each in a sentence.

ASSESSMENT

1. Assess individual student measuring skills for length, mass, and volume by directly observing students and comparing student data tables with actual dimensions, masses, and volumes of objects.
2. Assess students' ability to calculate density on the basis of the data *they* obtained on densities.
3. Assess students' comprehension of terminology by their use of the terms "mass," "volume," and "density" in the correct context and by their answer to question A in "Reflecting."
4. Use questions B through D in "Reflecting" and the data table students constructed in Inquiry 2.3 to assess their correct use of the above terms and the units of measure.
5. Step 7 in Inquiry 2.3 and questions E and F in "Reflecting" may provide information on student comprehension of density as a characteristic property of matter.

Name: _____

Class: _____ Date: _____

Student Sheet 2.1
Measuring the Mass and Volume of Water

Write down the procedure for finding the mass of 50 mL of water.

2. Use Table 1 to record your data and calculations.

Table 1 Calculating Mass

Volume of Water (cm^3)	Mass of Graduated Cylinder (g)	Mass of Graduated Cylinder and Water (g)	Mass of Water (g)	Mass of 1 cm^3 of Water (density in g/cm^3)
25				
50				

3. Does changing the volume of water change the mass of 1 cm^3 of water?

4. Does changing the mass of water change the mass of 1 cm^3 of water?

5. What is the density of water in grams per cubic centimeter?

6. Does changing the mass or volume of water change its density?

Name:_____

Class:_____ Date:_____

Student Sheet 2.2
Comparing the Densities of Different Substances

Use the data you collect to complete Table 1.

Table 1 Comparing Different Objects

Substance	Length (l) (cm)	Width (w) (cm)	Height (h) (cm)	Volume (v) (cm^3) ($v = l \times w \times h$)	Mass (m) (g)	Mass of 1 cm^3 (density in g/cm^3) (m/v)

2. Are the densities of the different substances the same or different?

3. How could this information be used to identify the substance from which an object is made?

Name: _____

Class: _____ Date: _____

Student Sheet 2.3
Measuring the Densities of Irregular Objects

1. Draw the procedure below.

1

2

3

4

(continued)

Student Sheet 2.3 (continued)

2. Draw your data table.

3. Are any of the blocks from Inquiry 2.2 or objects from this inquiry made out of the same substance? How did you reach your conclusion?

4. How do the densities of the objects compare with the density of water?