MiSP DENSITY TEACHER'S GUIDE
Teacher Guide

Introduction

In this unit students will learn about the constant relationship between the mass of a substance and its volume. This constant relationship is known as **density**.

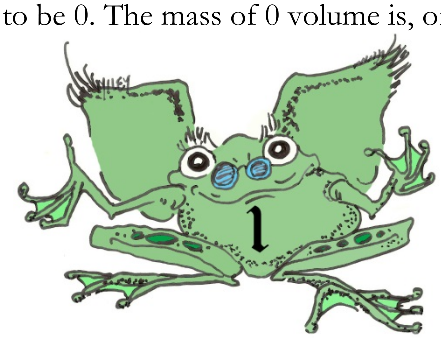
Students should be familiar with the concepts of mass and volume and be experienced in their measurement.

Standards

ILST Core Curriculum — Skills:
Standard 4 Physical Setting 10
ILST Core Curriculum — Major Understandings:
Standard 4 Physical Setting 3.1a, 3.1h
Earth Science Core Curriculum — Major Understandings:
Standard 1 Mathematical Analysis Key Idea 1
Earth Science Core Curriculum — Major Understandings:
Standard 4 Physical Setting 3.1a

This unit begins with a demonstration of the difference in the densities of three common liquids: water, syrup, and corn oil. The liquids are layered on top of each other to show that water floats on syrup and corn oil floats on water. The students are then given a table showing the masses of four volumes of water, oil, and syrup. They write responses to a series of math questions, and this helps them see that as you increase the volume of these homogeneous substances, the masses increase proportionally. This understanding leads directly to the definition of density as the mass per unit of volume. The mathematics questions vary in the different levels of this unit to accommodate different levels of math proficiency.

On day 2 the students plot the coordinate values in the table and draw a line connecting the data points. This activity allows the students to represent graphically the unit rate of change in mass as volume changes and to visualize density as the unit rate of change (slope) of the line connecting the data points for a particular substance. In addition, students at math levels 2 and 3 calculate the unit rate of change (slopes) of the lines. The difference in slopes represents the difference in densities of the different solutions. Once the unit rate of change (slope) of the line has been determined, the equation for the line is easily derived because the *y*-intercept has to be 0. The mass of 0 volume is, of course, 0.



In the laboratory component of this unit, students will determine the mass of three different volumes of water and the same three volumes of a salt solution. They will plot the mass-to-volume relationship to determine the density of each solution. Because the student-generated data is likely to contain error, connecting the data points may not result in a straight line. This problem will simply be pointed out to the students at math level 1; students at levels 2 and 3 will use a ruler to draw a best-fit line through the points and will discuss the meaning of the best-fit line.

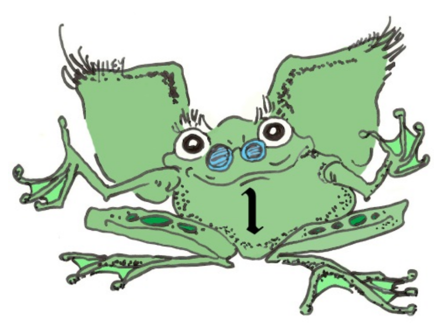
Science Background for Teachers:

Adapted from *Floaters and Sinkers: Mass, Volume, and Density.* 2004 AIMS Education Foundation. Density is a measure of the "compactness" of a material. It is the ratio of the mass of any material to its volume. Therefore, it never changes for a material that is uniform in consistency. A large amount (volume) of a material has the exact same density as a small amount (volume). For example, a steel pin has the same density as a steel beam. The steel beam is thousands of times more massive than the pin, but it also takes up thousands of times more space, so the ratio of mass to volume (the density) remains the same for both. On the other hand, the density of a small pebble is greater than the density of a redwood tree even though the tree is much larger.

The density of materials is determined by the masses of the atoms in the material and the amount of space between the atoms. Gases have low density not only because the atoms making up the gases have small masses, but also because the amount of space between the atoms is large. Heavy metals like gold, lead, and uranium are very dense because the atoms they are composed of are massive and spaced closer together. Materials that are nonhomogeneous (most biological materials fall in this category) have varying densities because the exact composition can change from sample to sample. For example, the density of wood from different trees varies considerably; bamboo wood ranges in density from 660 to 830 kg/m^3, oak ranges from 590 to 930 kg/m^3, and red pine ranges from 370 to 660 kg/m^3. Most of this variability is due to differences in the water content of individual samples of the wood.

Water has a density of one gram per cubic centimeter (ml) at 4˚C and is the standard for comparing the densities of different materials. Materials with a density greater than 1 g/ml are denser than water and will sink in water; materials with a density less than 1 g/ml will float in water.

Density is a concept that has traditionally been difficult for middle school students to understand, perhaps because density is usually introduced to students in the form of an equation, density = mass/volume. While this formula accurately describes how to calculate density, it does not necessarily help students understand the concept of density. A better way to develop student understanding of density is to begin with concrete examples such as those contained in this unit.



Lesson Objectives:

After completing this lesson, the students will be able to

- define density as the mass of a substance divided by the volume
- demonstrate that the density of a substance is constant using a graph, a table, and calculations
- explain why liquids of different densities form layers.

Day 1 — Defining Density

Begin the lesson by using the students' practical understanding of density. For example, ask the students what weighs more: steel or wood? The immediate response will probably be that steel weighs more. Now give groups of students a steel paper clip and a large wooden ruler and ask them to guess which weighs more. The response will probably be the ruler. Weigh one paper clip and one ruler on a balance to show the students that they are right. In the discussion that follows, the students should be able to recognize that the weight of an object depends on its size, so to compare materials, it is necessary to start with the same amount (volume). This discussion prepares the students for the formal definition of density.

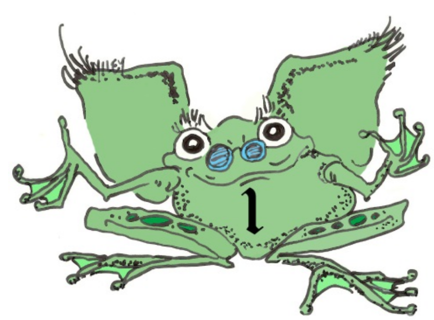
To demonstrate the difference in densities of liquids, <u>slowly</u> pour syrup, then water, and then oil into a large graduated cylinder. Use volumes and a cylinder that are large enough for all of the students to see. You may want to add food coloring to the water and oil to increase visibility. The liquids will layer according to their densities, with syrup on the bottom, water in the middle, and oil on top. Instruct the students to label the drawing on Density Worksheet #1 and to answer the question, why do you suppose these layers formed? The students will most likely respond that the syrup is the "heaviest." Some students may ask why volume is not important in this case. You can say, "Good question! We are getting there!" Continue with the table and related calculations in Worksheet #1. Note that the masses in the table are approximate for the purpose of convenience. If students do not finish the math, have them do this for homework.

Level 1 — Question of the Day:

The density of a substance is determined by dividing the mass in grams (g) by the volume in milliliters (ml) of that substance. From your responses in question #2, complete the following sentence:

The density for a given substance ________________ (does, does not) remain constant for different volumes of that substance.

Levels 2-3 — Question of the Day:



The density of gasoline is 0.7 g/ml.

a) Write a sentence that explains the meaning of the statement above.
b) How does the density of gasoline compare to the densities of water, oil, and corn syrup?
c) If we added gasoline to the beaker with the water, oil, and corn syrup, what would we see?

Day 2 — Graphing the Relationship between Mass and Volume

On the first day of this unit, the students used a table to demonstrate the relationship between various volumes of three different liquids and their corresponding masses. Today they will use the data found in the table on water, oil, and corn syrup to graph the relationship between the volume and the mass of these substances. Use Density Worksheet #2 to guide the students through this process. Level 1 students will need help setting up their graphs and plotting the data. Students at levels 2 and 3 should be able to do this independently and can then move on to an exploration of unit rate of change (levels 2 and 3) and linear equations (level 3).

Level 1 — Question of the Day:

1. Complete the sentence below so that it states the relationship between the layering of corn syrup, water, and oil and the densities of these liquids.

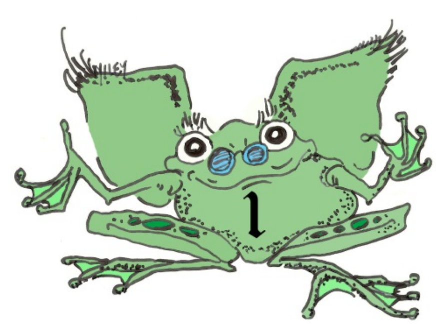
   The greater the density, the _______________ the position of the substance in the beaker.

2. The line representing the greatest density on your graph has the greatest steepness / the least steepness (circle one).

Level 2 — Question of the Day:

The unit rate of change (slope) of a line represents the constant rate of change in the linear relationship represented by the line.

a) The unit rate of change (slope) of the line for water is __________.
b) The unit rate of change (slope) of the line for oil is _____________.
c) The unit rate of change (slope) of the line for corn syrup is ___________.
d) These unit rate(s) of change (slopes) represent the ________________of the liquids.
e) If your graph had no key, how could you use the unit rates of change (slopes) of the three lines to identify which line represents water, which represents oil, and which represents corn syrup?



Level 3 — Question of the Day:

Using the linear equation you wrote for **corn syrup**, complete the table of values:

x (volume in ml)	y (mass in g)
0	0
2	
4	
6	
8	
10	

The unit rate of change (slope) of this line will be ___________

and the y-intercept will be (_____ ____).

Days 3 and 4 — Laboratory: The Density of Water and Salt Solutions

Students should follow the instructions provided in “Density Lab — Levels 1, 2, or 3.”