DABLING IN DENSITY

BACKGROUND INFORMATION

Introduction

Density, one of the physical properties of matter, describes the mass of a substance per unit volume. All matter has density. The volume of solids and liquids is typically measured differently, therefore density is usually measured as grams per cubic centimeter (g/cm^3) or grams per milliliter (g/mL), or some variation of these SI units. Temperature and pressure can affect the density of some substances, so in order to compare the densities of different substances, you must measure their mass and volume at the same temperature and pressure.

Density of Solids

The mass of a solid can be measured using a balance. The volume (amount of space an object takes up) of a solid can be measured using a ruler or a graduated cylinder. If the object is regularly-shaped, such as a cube or rectangular prism, the volume can be found by measuring the dimensions with a ruler and using the following equation: volume=length*width*height. The volume of a cylinder can be found by measuring the radius of the circular end and the height of the cylinder, and using the following equation: volume=Π*radius^2*height. There are equations for finding the volume of other regularly-shaped objects, but a graduated cylinder can also be used. The displacement of the water when the object is placed in the graduated cylinder is equal to that objects volume. Note that 1mL=1 cm^3, so volume (and therefore density) comparisons can be made, regardless of the method used to calculate the volume. The density of the objects can then be found by using the following equation: density=mass/volume.

Density of Liquids

The mass of a liquid can be measured using a balance and subtracting the mass of the container the liquid is in. The volume can be determined by reading the measurement at the meniscus (the curved bottom or top of the surface of the liquid). The density of the liquid can then be found by using the following equation: density=mass/volume. Matter will float in a fluid if the density of the matter is less than the density of the fluid. Matter will sink in a fluid if the density of the matter is greater than the density of the fluid. If the densities of the matter and the fluid are equal, the matter will remain at any depth to which it is submerged in the fluid.

Density of Gases

The density of gases depends upon the temperature. The higher the temperature, the more the molecules are spread out and the lower the density. The result is that warm gases rise and cool gases sink. The same concept helps to explain the weather resulting in high and low pressures. High pressure means high density, cooler, sinking air. Low pressure means low density, warmer, rising air.

Densities of Some Common Substances (in kg/m^3)		
Solids	*Liquids*	*Gases**
Aluminum 2.7 x 10^3	Alcohol (methyl) 0.82 x 10^3	Air 1.29
Brass 8.7 x 10^3	Blood, whole 1.05 x 10^3	Carbon dioxide 1.977
Copper 8.9 x 10^3	Blood plasma 1.03 x 10^3	Helium 0.18
Ice 0.92 x 10^3	Gasoline 0.68 x 10^3	Hydrogen 0.090
Iron 7.9 x 10^3	Mercury 13.6 x 10^3	Oxygen 1.43
Lead 11.4 x 10^3	Sea water (4°C) 1.03 x 10^3	Water vapor (100°C) 0.63
Steel 7.8 x 10^3	Fresh water(4°C) 1.00 x 10^3	

* at 0°C and 1 atm of pressure, unless otherwise specified

HOW MUCH SPACE?

Standards
IV.A.1.a

ENGAGEMENT Ask students to compare objects around the room based on how much room they take up. Demonstrate displacement of water as a means to measure how much space something takes up. Introduce the term meniscus at this point. Ask the students to consider ways displacement can be measured. Relate solid volume measurements to liquid volume measurements (see Background Information).

EXPLORATION Allow each group of students to use the materials provided (metric ruler, large graduated cylinder, water, and balance) to measure the dimensions and/or displacement, and mass of each of the objects provided. Have the students measure the dimensions *and* displacement of all regular-shaped objects so the relationship between the two can be observed. Ask the students to record all of their measurements in a table (sample provided below with sample objects) in their scientific notebooks- remind them to use SI units. Ask each student to calculate the volume of each regular-shaped object, based on the object's dimensions, in their scientific notebooks.

Sample Table:

Rachel's Measurements

object	displacement	length	width	height	mass
penny					
rubber eraser					
plastic cube					
wood block					
aluminum cube					

EXPLICATION Ask the reporter in each group to share the group's average volume for each object (both solid and liquid measurement, when applicable). Ask the students to rank the objects in order from the one that takes up the least amount of space to the one that has the greatest volume, in their scientific notebooks.

ELABORATION Next, ask them to think about this hypothesis statement: *If an object has a greater volume, then it has a greater mass.* Remind the students that in order for a hypothesis to be widely accepted in science, there must be no substantial, realistic evidence that the hypothesis does not hold true. Ask them to disprove the hypothesis by sharing some objects or instances for which the stated hypothesis does not hold true.

EVALUATION Display a numbered 'equal mass set' in view of the students. In the 'Assesment' section of their scientific notebooks, ask the students to predict the rank of the objects in order from greatest to least volume. Under their response, ask them to use what they have learned to predict the order of the objects from greatest to least amount of mass in their scientific notebooks. Remind the students that a prediction means making an educated guess by using knowledge and stating that there is not enough information to make an educated guess (since they have convinced themselves that mass is not determined by size/volume) is acceptable. Do not reveal the masses of the objects, which will be used in the following activity.

MASS AND VOLUME: A LOVING RELATIONSHIP TO DENSITY

Standards
IV.A.1.c.

PREDICTION Fill a large, clear tub with water to about 30cm deep. Ask each student to predict what will happen when you place unopened, room-temperature Coke and Diet Coke cans into the tub of water. Ask them to record their predictions in their scientific notebooks. Place the cans in the water, on their side.

DISCUSSION Ask the students to discuss their observations with their group members. Remind the students of the previous lab and discuss the fact that volume does not determine mass (and vice versa). Introduce the idea that the Coke demonstration is a way to show that volume and mass *are* related. Introduce the loving relationship:

D =

or

$$D = m / V$$

Discuss the units of density in relation to the layout of the formula [some mass measurement divided by (per) some solid or liquid volume measurement].

OBSERVATION Ask each group to spend 6-7 minutes at each of four stations. For large classes, set up eight stations with two each of the four described. Laminate and post the instructions at each station, if time is an issue. Remind the students that the reporter must read the directions to their attentive group members before anyone may handle the lab equipment. The set-up for the four suggested stations:

Station One

Set-up:

- numbered equal mass set (cylinders made of different materials, in different lengths, all with the same mass), used in first activity
- balance
- metric ruler
- calculator

Laminated Card at Station One:

Directions

1. Share your predictions from the previous lab about the mass of the objects BEFORE handling them. If you determined that you did not have enough information to make a useful prediction, discuss what information would you need to make a prediction.
2. Measure and record the mass of all of the cylinders in your scientific notebooks.
3. The *diameter* is the distance straight across the middle of a circle. The *radius* is half of the diameter. Each group member/pair should calculate the *radius* of the circle at the end of one of the cylinders by measuring its diameter and dividing it by 2.
4. Next each group member/pair should determine the volume of the cylinder by using the following equation:

   $$\textbf{volume} = \Pi \times \textbf{radius}^2 \times \textbf{height}$$

   The Π symbol represents a number. The calculator has a button for the symbol. The ^{2} means you multiply the radius by itself. Ask the teacher to check the group's answer before continuing.
5. Determine the density of each of the cylinders and record them in your scientific notebooks- remember units! Measure as many objects as time allows.

Station One Results

object	**mass** /	**volume** =	**density**
cylinder 1			
cylinder 2			
cylinder 3			
cylinder 4			
cylinder 5			

Station Two

Set-up:

- density blocks (cubes made of different materials, all with the same volume)
- balance
- metric ruler
- calculator

Laminated Card at Station Two:

Directions

1. Discuss the similarities between the objects BEFORE handling them. Use new vocabulary when appropriate.
2. Discuss the characteristics of a cube. What do you notice about the dimensions (the length, width, and height)?
3. As a group, determine the volume of one of the cubes- remember units! Check your group's answer with the teacher before continuing.
4. Determine the density of the cubes and record all of the measurements in your scientific notebooks- remember units! Measure as many objects as time allows.

Station Two Results

object	**mass** /	**volume** =	**density**
plastic cube			
copper cube			
wood cube			
iron cube			
aluminum cube			

Station Three

Set-up:

- numbered specific gravity set (objects made of different materials all with different masses and volumes)
- balance
- large graduated cylinder
- water
- metric ruler
- calculator

Laminated Card at Station Three:

Directions

1. Share similarities and differences between the objects BEFORE handling them. Predict the densities of the objects based on visual clues only. If you determine that you do not have enough information to make a useful prediction, discuss what information would you need to make a prediction.
2. Determine the density of the objects and record all of the measurements in your scientific notebooks- remember units (for some objects you may choose to use a liquid volume measurement and others will have a solid volume measurement)! Measure as many objects as time allows.

Station Three Results

object	**shape / description**	**mass** /	**volume** =	**density**

Station Four

Set-up:

- cylindrical specific gravity set (cylinders made of different metals all with the same volume, but different masses)
- balance
- metric ruler
- calculator

Laminated Card at Station Four:

Directions

1. Share your predictions about the mass of the cylinders BEFORE handling them.
2. Measure and record the mass of each of the cylinders in your scientific notebooks.
3. The *diameter* is the distance straight across the middle of a circle. The *radius* is half of the diameter. As a group, calculate the *radius* of the circle at the end of one of the cylinders by measuring its diameter and dividing it by 2.
4. As a group, determine the volume of the cylinder by using the following equation:

$$\textbf{volume} = \Pi \times \textbf{radius}^2 \times \textbf{height}$$

   The Π symbol represents a number. The calculator has a button for the symbol. The ^{2} means you multiply the radius two times. Ask the teacher to check the group's answer before continuing.
5. The volume of all of the cylinders is the same. Determine the density of the cylinders and record all of the measurements in your scientific notebooks- remember units! Measure as many objects as time allows.

Station Four Results

object	**mass** /	**volume** =	**density**
aluminum cylinder			
brass cylinder			
steel cylinder			
copper cylinder			

RELATION Ask the students to answer the following questions in their scientific notebooks, based on their findings during the lab:

- If two objects have the same mass, but one has a greater volume (takes up more space), what can be said about the density of the larger object? Remind them to think of Station One.
- If two objects have the same volume, but one has a greater mass, what can be said about the density if the object with the greater mass? Remind them to think of Station Four.

EXTENTION Discuss this inverse relationship with the students. Ask them to share any other instances when they have noticed this kind of relationship.

EXPANSION Ask the students to think about density of liquids. Ask them if they can think of any examples that demonstrate the different densities of liquids. Prompt them by discussing the fact that liquids with different densities do not readily combine- they stay separated.

THE RAINBOW CONNECTION: A COLORFUL WAY TO SEE DENSITY

Standards
IV.A.1.b.

ENGAGEMENT Tape two Styrofoam cups, both with holes poked in the bottom, in opposite sides of a large, clear tub. Fill the tub with room-temperature water to just shy of the top of the cups. Immediately pour hot, red-colored water into one cup, and cold, blue-colored water with blue-colored ice cubes into the other. Explain that the water is only colored so that the layering can be seen (it affects nothing else, but visibility). Ask students to discuss the reasons why the layering may take place. Introduce the density rod as a way to determine relative density of a water solution. Explain that dissolving things into water can also change its density.

EXPLORATION Ask the students to determine the densities of several beakers of water solutions (fresh water and water with varying degrees of salinity) based on observing their density rods. Ask each student to rank the solutions from least to greatest density, based on their observations using the density rods, and record their findings in their scientific notebooks.

EXPLICATION Ask the groups to share their findings and discuss why they came up with their predicted order. What have they determined about the density of salt water?

ELABORATION Ask the students if there are any other tests or comparisons they would like to perform. Ask the students to consider the implications of these findings. How could this affect their trip to the beach or lake, or their fishing trip?

EVALUATION Ask the students to describe the method for making a rainbow with the most colors in their scientific notebooks under ‘Assesment’ (which color/salinity would they pour in first, second…). After they have considered this individually, ask them to discuss their ideas and work as a group to create their rainbow.