Teacher Guide: Determining Density via Water Displacement

Learning Objectives

Students will …

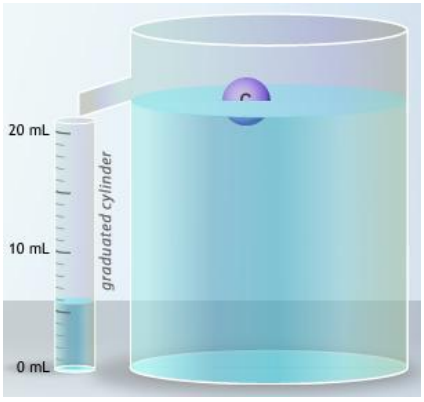
- Understand that a floating object will displace its own mass in liquid.
- Find the mass of an object that floats in water, based on the volume and density of the displaced water.
- Find the volume of an object that sinks in water or is pushed into water, based on the volume of the displaced water.
- Use this information to determine the density of a floating object.

Vocabulary

Archimedes' principle, density, displacement, mass, volume

Lesson Overview

By the time students try the *Determining Density via Water Displacement* Gizmo™, most will be familiar with calculating the density of an object by dividing its mass by its volume. But how can you find the density of an object if you don't have access to a balance?



As it turns out, if the object is floating in a liquid of known density, you don't need a balance at all! Using the Gizmo, students will see that the mass of a floating object is equal to the amount of water it displaces. Then they can measure the volume of another object of equal size and use these numbers to determine the density of the floating object.

The Student Exploration sheet contains one activity. In this activity, students use water displacement to find the mass, volume, and density of three objects.

Suggested Lesson Sequence

1. **Pre-Gizmo activity: Finding mass with no balance** (20 – 40 minutes)
   Bring in a block of wood and an overflow cup. (See the follow-up activity on the next page and the **Selected Web Resources** on page 3 of this document.) First, find the mass of the block with a balance and record this mass. Next, fill the overflow cup with water to the top, gently place the block into the water, and record the volume of displaced water.

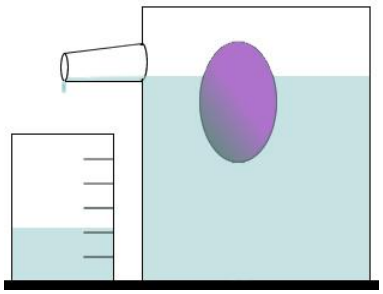
   Compare the water volume (in milliliters) to the mass (in grams). In theory, these numbers should be the same. If possible, repeat the experiment with a variety of other floating objects. When you have finished, ask students why they think that the volume of displaced water is equal to the mass of the object. (Hint: Archimedes' principle states that a floating object will displace its own weight in water.)

2. **Prior to using the Gizmo** (10 – 15 minutes)
Before students are at the computers, pass out the Student Exploration sheets and ask students to complete the Prior Knowledge Questions. Discuss student answers as a class, but do not provide correct answers at this point. Afterwards, if possible, use a projector to introduce the Gizmo and demonstrate its basic operations.

3. **Gizmo activities** (15 – 20 minutes per activity)
Assign students to computers. Students can work individually or in small groups. Ask students to work through the activities in the Student Exploration using the Gizmo. Alternatively, you can use a projector and do the Exploration as a teacher-led activity.

4. **Discussion questions** (15 – 30 minutes)
As students are working or just after they are done, discuss the following questions:
   - For a floating object, what is the relationship between the mass of the object and the amount of water it displaces?
   - What is the relationship between the density of an object and how low it floats in the water?
   - How can you use the Gizmo to compare the densities of the sinking objects?

5. **Follow-up activity** (45 – 60 minutes)
The experiment shown in the Gizmo can be easily reproduced in the classroom. You will need an overflow cup, a graduated cylinder, and a variety of floating objects such as plastic toys and blocks of wood.



An overflow cup is shown at right. These are available in many science catalogs, or you can make your own—see the **Selected Web Resources** on page 3 of this document. Fill the overflow cup until the water starts to overflow. Place a beaker under the spigot of the cup.

Gently place an object into the overflow cup, and record the volume of the water that spills from the cup. This volume (in milliliters) is equal to the mass of the object (in grams). Then, push the object down until it is completely submerged. (Try not to get too much of your hand into the water.) Record the new water volume: this is the volume of the object. Divide the mass by the volume to find the density of each object.

Finally, place each object into a pail of water and compare how high or low each object floats in the water. The denser the object, the lower it will float in the water. In fact, the percentage of the object that is underwater will be equal to the density of the object! (For example, an object with a density of 0.4 g/cm^3 will be 40% submerged.)

Scientific Background

Density is a measure of the mass in a given volume of a substance. To calculate the density of an object, divide the mass by the volume:

$D = m \div V$ or, more formally: $\rho = \frac{m}{V}$

To find the volume of an irregular object, the only practical method is to submerge the object in liquid. As the object moves into the liquid, an equal volume of liquid is pushed out of the way. This will cause the water level to rise, or, if the container is full, the water will overflow. By collecting this water, the volume of the object can be measured.

In most cases it is simple enough to find the mass of an object using a balance or scale. However, Archimedes' principle gives another method for finding the mass of a floating object. Archimedes' principle states that an object in liquid is buoyed up by a force that is equal to the weight of the displaced liquid. In the case of a floating object, the force of gravity pulling the object down is exactly balanced by the buoyant force pushing up. Therefore, the weight of the object is equal to the weight of displaced liquid, which means that the mass of the object is equal to the mass of displaced liquid.

Since water has a density of 1 g/mL, its mass (in grams) is equal to its volume (in milliliters). Therefore, the mass of the object is equal to the volume of displaced water. To find the density of a floating object in the Gizmo, first find its mass by placing it in the overflow container of water, and then find its volume either by pushing it into the water or by measuring the volume of an equally-sized sinking object.

Technology Connection: Submarines, divers, and fish

The net force on an object submerged in water is equal to the difference between the object's weight and the buoyant force pushing it up. The buoyant force is equal to the weight of displaced water, so the greater the volume of the object, the greater the buoyant force. Submarines, scuba divers, and fish control their buoyancy by adjusting their weight or volume.

A submarine has an inner hull and an outer hull. The space between the hulls, called the *ballast tank*, can be filled with seawater to help the submarine gain weight and sink below the surface. When the submarine needs to rise again, compressed air is blown into the ballast tank to expel the seawater. This lightens the submarine and allows it to rise.

Scuba divers and fish control their buoyancy by changing their volume. Scuba divers wear a weight belt and a buoyancy control device (BCD), which is a vest that can be inflated with compressed air from the air tank. When the vest is inflated the volume of the diver increases, causing her to displace more water and increase her buoyancy. Many fishes utilize a *gas bladder* in the same way. A gas bladder is inflated with oxygen released from the fish's blood.

Selected Web Resources

Water displacement (includes overflow cup instructions): http://www.iit.edu/~smile/ph9504.html
Buoyancy: http://hyperphysics.phy-astr.gsu.edu/Hbase/pbuoy.html
"Why does a ship float? http://www.brighthub.com/engineering/marine/articles/19774.aspx
How submarines work: http://www.onr.navy.mil/focus/blowballast/sub/work2.htm
Fish gas bladders: http://www.lookd.com/fish/gasbladder.html

Related Gizmos:
Density: http://www.explorelearning.com/gizmo/id?629
Density Laboratory: http://www.explorelearning.com/gizmo/id?362
Density via Comparison: http://www.explorelearning.com/gizmo/id?396
Density Experiment: Slice and Dice: http://www.explorelearning.com/gizmo/id?434
Archimedes' Principle: http://www.explorelearning.com/gizmo/id?603