MEASURING THE DENSITY OF WATER

Unit: Salinity Patterns & the Water Cycle  
Grade Level: Middle to High  
Time Required: 45 min.

Content Standard: Physical Science  
Principles: Properties of matter: Substances have characteristic properties (e.g., density) that are independent of sample amount.

Student Learning Objectives
- Measure the density of water (and discover that the definition of a gram is the mass of one milliliter of pure water)
- Compare the density of salt water with fresh water
- Demonstrate changes in density by adding marbles to a floating plastic container until it sinks
- Compare their result with calculated predictions
- Discover that the whether or not an object will float depends on the amount of water that it displaces

BACKGROUND: One of the most important molecules on Earth is water. Water is commonly used as a reference for physical properties. One such physical property, density, is defined as the measure of a material’s mass (e.g., in grams) divided by its volume (e.g., in milliliters). The density of water, 1 g/ml, is also used as a means of comparison called specific gravity. Water is defined to have a specific gravity of 1 (no units). Objects with a specific gravity of less than 1 will float in pure water, while objects with a specific gravity of more than 1 will sink. Seawater has an average specific gravity of 1.028 with 3.5 g of dissolved salts for every 100 g of pure water. Ship designs and carrying capacity are based upon the density of seawater.

Materials: Per student group – clear plastic container (15 X 15 X 4 cm; 6 X 6 X 1.6 in; e.g., those used for take-home salads), 125 glass marbles or pennies, glass or plastic bowls (large enough to hold one of the clear plastic containers described above), graduated cylinders (50 or 100 ml), 4 gm table salt. For sharing among groups – paper towels, eyedropper, scale (0 – 200 gm).

Preparation: Clear plastic containers made with thin plastic will give the best results because the thin plastic will have little effect on volumes and densities. If you cannot find these, you can use containers such as Tupperware, but results may not be as accurate. Separate lids and bottoms of the plastic containers. Each group should have 1 lid or 1 bottom. Use the graduated cylinders to pour water into the lid or bottom to find its volume (should be in the 500 to 700 ml range). These containers will be the boats used in Part II. Measure the mass of 10 or 20 marbles together, and then calculate the mass per marble: AVERAGE MARBLE MASS (g). Students will need this value for Part II of the activity. (Alternatively, each group of students can calculate the mass per marble themselves.)

Activity – Part I
- Determine the density of tap water:
  - Measure the mass of the empty graduated cylinder. Record the weight.
  - Fill the cylinder with water to the 100 ml line. This is the volume.
  - Measure the mass of the cylinder with water.
  - Subtract the mass of the empty cylinder from the mass of the filled cylinder.
  - Divide the mass of the water by its volume. This will yield the density of the tap water. Record your result.
- Determine the density of tap water with salt:
  - Use an eyedropper to remove 2 g (2 ml) of water from the cylinder.
  - While the cylinder is on the scale, add 2 g of salt.
  - Read the new water level inside the cylinder. This is the new volume.
  - Divide the mass of the water inside the cylinder by its new volume. This is the density of the
salt water. Record your result.

- Compare the densities of the salt water and the fresh water.

**Activity – Part II**

- Measure the volume of the plastic container (boat). Fill a graduated cylinder with 100 ml of water and pour it into the hull of your boat. Do this as many times as necessary until the boat is full. Be sure to keep track of how many times you re-filled the cylinder. When your boat is full, record the amount of water remaining in the graduated cylinder (if any). Find the total volume of water in your boat: Multiply the number of times you refilled your cylinder by 100. Subtract the amount of water left over in the last cylinder. Record the total volume: TOTAL VOLUME (ml).

- Find the mass your boat will carry. Since one milliliter of water is equal to one gram, the volume in ml of your boat also equals the mass it can carry in grams. Write your total mass: TOTAL MASS (g).

- Calculate the number of marbles your boat will hold. Divide your TOTAL (g) by the AVERAGE MARBLE MASS (g) from “Preparation” section. This equals the number of marbles your boat should be able to carry. Record this number. Calculate 90% of that number by multiplying by 0.9.

- Count out 90% of the calculated number of marbles and place them into your boat. Be sure the marbles are distributed evenly to avoid tipping of the boat.

- Carefully place the boat, with the number of marbles calculated in step 4 inside the boat, into the bowl of water.

- Add more marbles to your boat, one at a time, counting and adding these to the previous number of marbles. Continue this until the boat sinks. Remember to place the marbles carefully to maintain a level boat. Record the number of marbles it took to sink the boat.

- Compare the calculated number of marbles to the actual number of marbles held afloat by your boat before it sank. If the numbers are different, what factors may have contributed to that difference?

- To repeat the experiment, be sure to first dry the marbles and the inside of your boat.

- OPTIONAL: Add a significant amount (e.g., 20 grams or more) of salt to the water and repeat the experiment. Do you find a difference? Why?

**Assessment / Questions**

- **Part I –** A useful definition of a gram is the mass of one cubic centimeter (cm³), also called a milliliter (ml), of pure water. The density of pure water varies with temperature: water contracts until almost freezing and expands into a gas when boiling. The density of pure water is 1 g/ml at 4°C (39°F); however this changes by less than 0.2% at room temperature. Adding salt increases the density of the water.

- **Part II –** For any floating object, the buoyant force equals the weight of the liquid displaced (Archimedes’ Principle). A plastic boat that holds 500 ml of water will support 500 g of any denser material. A less dense load of the same mass will have a higher center of gravity and will cause the boat to tip. (See Figure 1 below.)

- Discuss whether it will be easier for a person to float in salt water or fresh water. Why? Have any of the students noticed this difference?

- For stability, the center of gravity of a boat must be below the center of buoyancy as in Figure 1 (right). The boat in Figure 1 (left) will tip over. Standing up in a canoe shifts the center of gravity and can cause it to flip over. What other types of boats are designed to be more stable than canoes? What are the advantages of the canoe design over more stable boats?

**Vocabulary**

- **buoyancy:** In physics, an upward force on an object immersed in a fluid (i.e. a liquid or gas), enabling it to float or at least to appear to become lighter. If the buoyancy exceeds the weight, then the object floats; if the weight exceeds the buoyancy, the object sinks.

- **density:** Mass per given unit of volume.

- **mass:** The property of a body that causes it to have weight in a gravitational field.

- **specific gravity:** The ratio of density of a given substance to that of pure water at 4°C and at a pressure of one atmosphere.

- **volume:** The measure of three-dimensional space occupied by an object.

**Original source:** San Juan Institute Activity Series and NASA’s “Visit to an Ocean Planet” CD-ROM

Aquarius Education & Public Outreach URL: [http://www.bigelow.org/aquarius](http://www.bigelow.org/aquarius)
Figure 1. An unstable boat (left) and a stable boat (right).