Measuring the Density of Water

Overview

Students will (1) measure the *density* of water, (2) measure and compare the density of salt water, (3) demonstrate changes in density by adding marbles to a floating plastic container until it sinks, and (4) compare their result with calculated predictions.

Concepts

- A useful definition of a *gram* is the mass of one milliliter of pure water.
- Whether an object will float depends on the amount of water that object displaces.

Materials

- Clear plastic containers about 15 cm (6 in) square and 4 cm (1.6 in) deep (for example those used for take-home food such as salads). One per group.
- Graduated cylinders, 50 ml or 100 ml
- Scales, 0 to 200 grams
- Glass marbles, 125 per group (pennies will also work and are less likely to roll around)
- Glass or plastic bowls, large enough to hold one of the clear plastic containers listed above
- Table salt, about 4 gm per group
- Paper towels

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, however, you can try similar 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 liquid capacity (*volume*). They 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. Students will need this value for Part II of the activity. Alternatively, before Part II each group of students can weigh 10 or 20 marbles, and calculate the mass per marble themselves, rather than having the teacher provide them with this number.

Procedure

Engagement

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) (d=m/v). 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 one will float, while objects with a specific gravity of more than one 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 known density of water.

The human body is about 70% water and has about the same average density as water.

Activity

Part I

Determining the density of tap water:

1. Measure the mass of the empty graduated cylinder. Record the weight.
2. Fill the cylinder with water to the 100 ml line. This is the volume.
3. Measure the mass of the cylinder with water.
4. Subtract the mass of the empty cylinder from the mass of the filled cylinder.
5. Divide the mass of the water by its volume. This will yield the density of the tap water. Record your result.

Determining the density of tap water with salt:

6. Use an eyedropper to remove 2 g (2 ml) of water from the cylinder.
7. While the cylinder is on the scales, add 2 g of salt.
8. Read the new water level inside the cylinder. This is the new volume.
9. Divide the mass of the water inside the cylinder by its new volume. This is the density of the salt water. Record your result.
10. Compare the densities of the salt water and the fresh water.

Part II

1. 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. On the last cylinder of water, any water left over in the graduated cylinder must be subtracted from the 100 ml originally in the cylinder. Multiply the number of times you refilled your cylinder by 100, then subtract the amount of water left over in the last cylinder. This is the total volume, TOTAL(ml). Record your answer.
2. 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(g).
3. Calculate the number of marbles your boat will hold. Divide your TOTAL(g) by the mass of the marble (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.
4. 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.
5. Carefully place the boat, with the number of marbles calculated in step 4 inside the boat, into the bowl of water.
6. 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.
7. 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?

8. To repeat the experiment, be sure to first dry the marbles and the inside of your boat.
9. Optional: Add a significant amount (e.g., 20 grams or more) of salt to the water, then repeat the experiment. Do you find a difference? Why?

Explanation

Part I

A useful definition of a gram is the mass of one cubic centimeter (cm^3), 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 (Archimede's Principle). A plastic boat which 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.

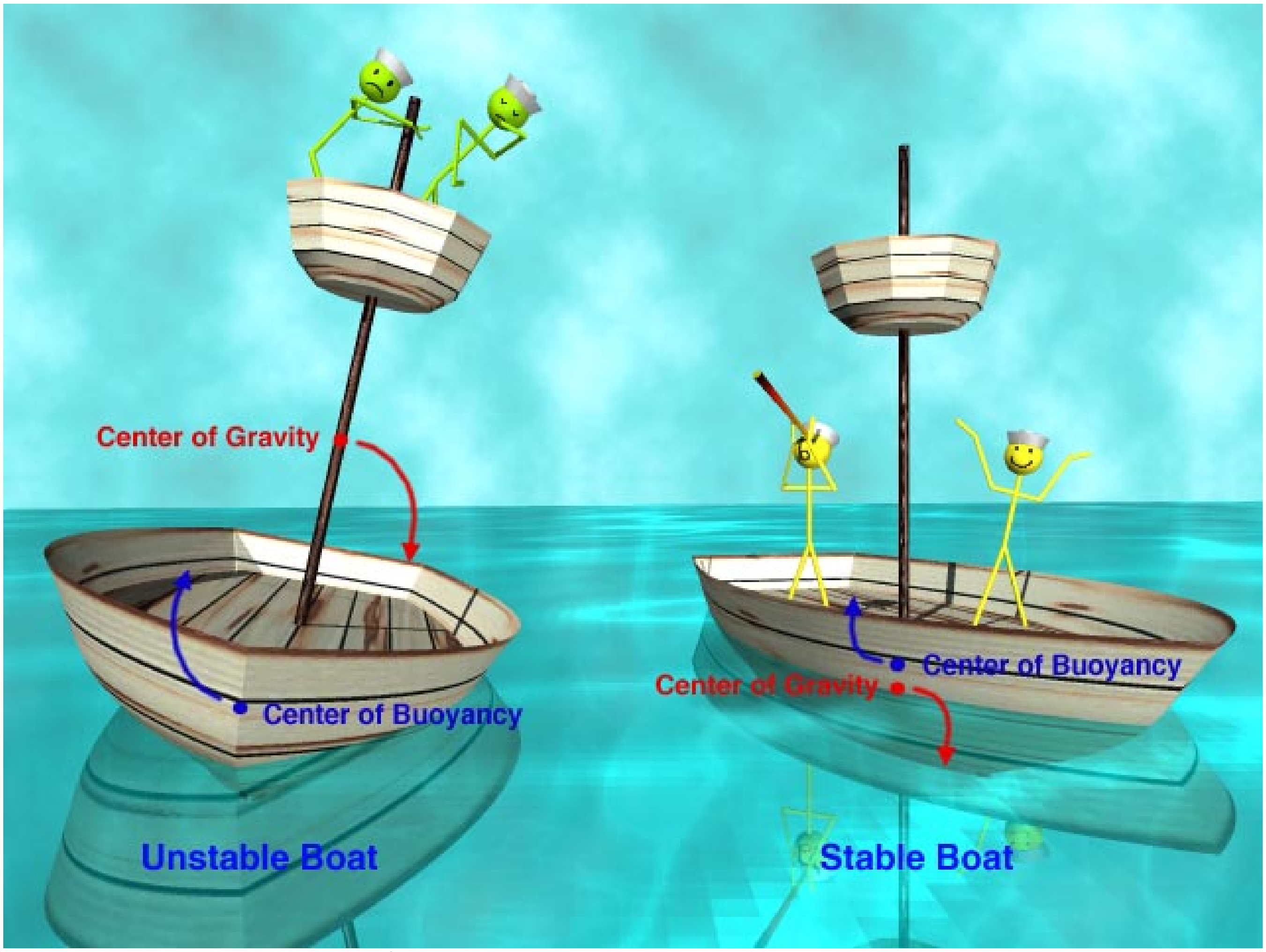

Figure 1. **An unstable boat** (left) **and a stable boat** (right).

Extension

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?

Links to Related CD Activities, Images, and Movies

Activity *Salinity and Deep Ocean Currents*

Activity *Cartesian Diver*

Vocabulary

density *buoyant (buoyancy)* *gram*
specific gravity *volume*

Source

San Juan Institute Activity Series.