Activity #1: Determining Densities

The concept of density has many useful applications. This image is an electron density map, used by biochemists to help understand the structure of a protein.

Summary

Students will use two different methods to determine the densities of a variety of materials and objects.

The first method involves direct measurement of the volumes of objects that have simple geometric shapes, while the second uses the water displacement method to determine the volumes of irregularly-shaped objects. After the densities are determined, students will create x-y scatter graphs of mass versus volume, and these graphs will reveal that objects with densities less than water (floaters) lie above the graph’s diagonal, and those with densities greater than water (sinkers) lie below the diagonal.

Grade Level: 8 (7-9)    Group Size: 4

Time Required: 2 hours

Activity Dependency: Floaters and Sinkers

Expendable Cost Per Group: $ 2.00

Keywords: density, displacement, x-y scatter graph
Pre-Requisite Knowledge

• Students should be able to use rulers to measure lengths to the nearest millimetre, triple beam balances to measure masses to at least the nearest 0.1 gram, and graduated cylinders to measure liquids to at least the nearest 1 millilitre.

• Students should be able to calculate the volumes of rectangular, cylindrical, and spherical solids.

• Students should be able to graph points on an x-y coordinate grid.

Learning Objectives

• Students will be able to describe a method for determining the density of an object or material that has a simple geometric shape (rectangular prism, sphere, or cylinder).

• Students will be able to describe a method for determining the density of an object or material that has a complex geometric shape.

Materials List

• An assortment of small objects for which students will determine densities by first measuring dimensions and then calculating volumes. This assortment should consist of objects whose shapes are regular (rectangular prisms, spheres, or cylinders) such as metal bars, brass weights, blocks of wood, marbles, Fire Balls™ candy, wine corks, candles, art gum erasers, large crayons with their pointed ends cut off, Styrofoam™ spheres (available from craft supply shops) and modelling plasticine that has been moulded into cubes or spheres. Be sure to include some objects that float in the assortment.

• A second assortment of objects that have irregular shapes; their volumes will be determined by the displacement of water. This group can include rocks; small figurines (e.g., plastic soldiers or animals, metal or ceramic figures, but note, they should not have any hollow portions and should be made of only one material); large nails, nuts, or bolts; short lengths of metal chain; pieces of broken brick, pottery, plastic, or Styrofoam™ (if spheres are not being used in the first assortment of materials); rubber test tube or flask stoppers; and chunks of vegetables such as carrots or potatoes.

• rulers, at least one per team

• calculators, one per team

• balances accurate to at least 0.1 g (e.g., standard triple beam balances), one per team

• 25, 50, and 100 mL graduated cylinders, at least one per team (ideally one small one plus one of the larger ones per team)

• 250 and/or 500 mL beakers, one or both per team

• pans or trays to catch water that overflows from the beakers, one per team
• funnels to fit into the tops of the graduated cylinders (optional, but they help limit the amount of spilled water), one per team

• sponges and/or dishrags (for wiping up drips and spills), at least one per team

• thread

Introduction/Motivation

The lesson Introduction, in which students determine the density of a rectangular box filled with an unknown substance, should provide adequate introduction to the activity. To further motivate students, explain that you have a variety of materials for which they can try to determine the densities. Mention that some of the materials have known densities, meaning that scientists have determined their densities to a high degree of accuracy, using sophisticated measuring devices. Tell the students that after they have determined the densities of the objects available, they can compare their results to the known densities. The challenge is for them to measure and weigh their objects very carefully, so they will be able to get results that are very close to the known densities.

Vocabulary/Definitions

density: the mass per unit volume of a substance at a given pressure and temperature

Procedure

Part 1:

With students working in teams, ask them to determine the densities of the objects in the first assortment listed in the Materials section. Create a large data table on the board with room for each team to enter its results for each object, rounding densities to the nearest one-hundredth. Different teams should get slightly different densities for the same objects, and it would be good to have students discuss why these differences occur. (See Investigating Questions and Trouble Shooting Tips). If two teams get very different densities, however, it is likely that a measurement error was made, and the students involved should repeat their measurements and calculations.

Part 2:

Next, present the class with the second assortment of objects, whose shapes are not regular. Ask students to work within their groups to figure out a way to determine the densities of these oddly-shaped objects. Give them plenty of time to explore this problem (5-10 minutes, perhaps). If they can’t come up with the water-displacement method on their own, ask them to imagine filling a bathtub all the way to the top.

Then ask what would happen if they took a litre jug of juice and lowered it into the water. How much water would spill over the edge of the tub? What if they lowered themselves into the filled tub of water until they were completely submerged -- how much water would spill out? Would it be possible to catch and measure the amount of water that spilled out?
Note: You will need to point out that liquid volumes are measured in litres or millilitres, but solid volumes are measured in meters or centimetres cubed. By a fortunate coincidence, however, 1 millilitre of water equals 1 cubic centimetre of water. (Students could also determine this for themselves.) This means that using standard laboratory graduated cylinders to measure displaced water allows for a very easy conversion of the volume of displaced water to the volume of the object. The volume in millilitres is simply the same as the volume in cubic centimetres, with the latter being the proper unit for density.

Make the beakers, graduated cylinders, trays, and funnels available to students so that they can devise their own water-displacement methods to determine the volumes of the oddly-shaped objects. If students have trouble devising an accurate method, offer suggestions, but let them do some problem solving on their own before stepping in. The idea is for students to place a beaker on the tray, and then use one of the other containers to fill the beaker with water to the point where it just begins to overflow. Students should then wait for any last overflow dripping to stop before placing an empty container at the beaker’s spout to catch the soon-to-be displaced water. Students will likely discover that they need to lower the object into the beaker gently to avoid splashing, since splashed water will affect the amount of displaced water collected.

For the smaller objects, students may be able to simply submerge the object into a partially filled graduated cylinder. The change in water level will equal the volume of the submerged object. This method is more accurate than measuring water that has spilled out an overflowing beaker.

You may need to remind students of the need for accuracy, not only in the weighing of the objects, but also in measuring the volume of displaced water. Using the smallest graduated cylinder possible will allow for a more accurate measurement. Students should try to estimate the volume of water that will be displaced, and match the size of the graduated cylinder to the estimate.

You might also need to ask students which they should do first: find the mass of the object or find its volume. They should be able to reason that the objects will be weighed more accurately if they are weighed first, since that way they will be completely dry and no water will be added to the mass.

For any of the objects that float, students will have another problem to solve. They may try using a pencil point to hold the object just below the surface of the water. They could also use thread to tie the object to another, heavier object that will sink, such as a rock or piece of metal. They will then need to subtract the volume of the rock or metal from the displaced volume of water in order to obtain the volume of the otherwise floating object.

As in Part 1, create a large data table on the board with room for all teams to enter their results, rounding their densities to the nearest one-hundredth. Have any teams with widely disparate results repeat their measurements and calculations.

Use the table below to compare the student results to the known densities of the common materials shown. If the materials from which some of the objects were made are known, students can compare the accuracy of their determinations to the known values. If the materials the objects are comprised of are not known, students may be able to speculate about their composition based on the values in the table.
Part 3:

After students have determined the densities of the objects, ask them to find one more density, that of water. They may be puzzled at first, but give them time to realize that, just like the solid objects, they only need to find the mass of a known volume of water. (You may need to remind them to subtract the mass of the container for the water.) Check their results to make sure they get a density close to 1.00.

Next, have each student create a scatter graph for the objects, in which mass in grams is on the x-axis, and volume in cubic centimetres is on the y-axis. Their graphs should look something like the one below.

![Graph of mass vs. volume for objects and water](image)

**Figure 1**

Have students add the dashed line that forms the diagonal to their graphs. Explain that this represents the density of water, since for pure water; the mass in grams is equal to its volume in cubic centimetres. Put another way, the ratio of mass to volume is approximately 1 g/cm³ at room temperature and pressure, as long as the units are grams and cubic centimetres (cm³).

Have students examine their completed graphs. Ask students what the points that lie above the dashed line have in common. Although there may only be a few of them, students should note that these are the least dense of the objects and in fact, they are the objects that float. The points for all the other objects, the ones that sink, lie below the line. In other words, they are denser than water. Make sure students understand that, ordinarily, anything less dense than water floats and anything denser than water sinks. If students argue that ships are made of metal but float nevertheless, ask them why they think that is so. (This topic is explored in the lesson What Floats Your Boat?)
Troubleshooting Tips

• If students are not rounding their measurements correctly, or if they are "over-rounding" their measurements, their results may vary widely from those of their classmates and/or the known values for some of the materials. Watch students as they make their measurements to make sure they are rounding lengths to the nearest 0.5 or 1 millimetre, masses to the nearest 0.05 or 0.1 g, and water volumes to the best accuracy available for the graduated cylinders being used. Also, some students tend to always round measurements up. For example, for an actual measurement of 25.72 grams, such a student will round to 25.8 grams, rather than the correct rounding of 25.7 grams.

Investigating Questions

• Why do different teams often get slightly different densities for same objects?
• How might the ways measurements are rounded affect the densities that are calculated?
• Are there any ways that more accurate density determinations could be made?
• If an object has a density greater than 1.0, will it float in water or sink?
• If salt is added to water, will the water become denser or less dense?

Assessment

• Provide students with a table of densities of common materials. Ask them to identify the material with the highest density, and the material with the lowest density. Ask them to give an example of a material that will float in water, and a material that will sink in water. Also, ask them what the density of water is.

• Provide students with a list of several objects, their masses, and their volumes. Ask students to calculate the density for each object, and check that they include units in their answers.

Activity Extensions

• Provide students with ice cubes (as large and rectangular as possible) and ask them to determine the density of ice. See Lesson Extension Activities section for further information and discussion ideas.

• Provide each team of students with a can of Coca-Cola and a can of Diet Coca-Cola. Ask them to determine the density of each. They may be surprised to find that the diet drink is less dense than the regular drink. An alternate way to demonstrate this is by simply placing each can in an aquarium of water: the diet cola will float while the regular cola will sink. Ask students to read the list of ingredients on each can and try to determine what is responsible for the density difference. Most
likely it is due to the density differences in the sweeteners used, with the synthetic sweetener aspartame being less dense than the natural sugars used in ordinary soft drinks.