Will it sink or float?

ISBN 979-8-3851-1777-2

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Densities of Liquids and Solids

Safety Concerns:

There are no particular hazards associated with this experiment. You should wear goggles when making solutions in Part 3 if your instructor requires it.

The density (d) of a substance is a physical property characteristic of each substance defined as the mass per unit of volume. For example, the density of water at 4°C is 1.00 g/cm^3 or 1.00 g/mL. (By definition, 1 cubic centimeter = 1 cm^3 = 1 cc = 1 mL).

$$density = \frac{mass}{volume} \quad \text{or} \quad d = \frac{m}{V} \qquad (1)$$

Nails and corks are both solids, but if you place a nail in a glass of water, it will sink to the bottom, while a cork will float. Similarly, gasoline and mercury are both liquids immiscible with water, but if you pour mercury into water, it will sink to the bottom, while gasoline will float.

Experimental Questions

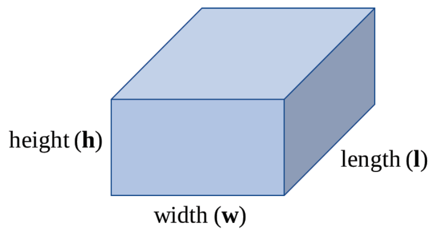
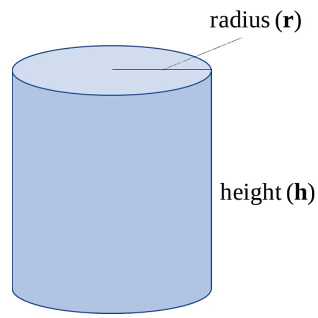
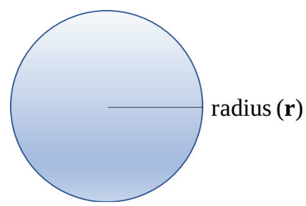
- How can we predict in advance whether a particular substance will float or sink in water?
- What physical properties can we measure that will allow us to make a prediction?
- How can we verify that we are measuring accurately?

Pre-Experiment Question

1. A 16-penny steel nail weighing 9.79 g is placed into 7.72 cm^3 of water in a graduated cylinder, and it sinks to the bottom. The water level increases to 8.92 cm^3.
   a. What is the mass of the nail?
   b. What is the volume of the nail?
   c. Describe in a sentence how you determined the volume of the nail.

   d. What is the density of the steel nail? Show all work, including units.

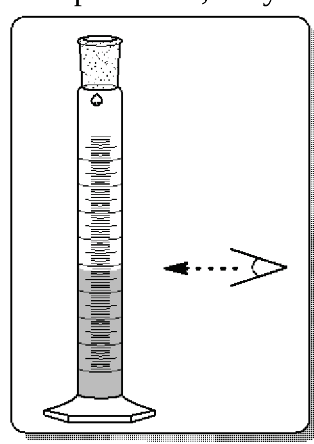
Table 1: Equations to calculate volume of some solid objects

Object	Diagram	Volume, cm^3
Rectangular prism		$l \times w \times h$
Cylinder		$\pi \times r^2 \times h$
Sphere		$4/3 \times \pi \times r^3$

Part 1: Density of known solids

Each pair of students will be given two objects composed of a known substance, and should complete the following steps.

A. Record the identity of the two objects in your notebook or on your report form, as your instructor directs.



B. Determine the mass of each of the two objects using a laboratory balance. Record your measurements (report form or notebook) using the correct number of significant digits.

C. Using only a **centimeter ruler** and the information in Table 1, determine the volume of each of the two objects, reporting your answer to the correct number of significant digits.

D. Using only a **graduated cylinder**, determine the volume of each of the two objects, reporting your answer to the correct number of significant digits. Remember to view the volume at eye level, as shown in the picture at the right.

Record your results in your notebook or on your report form in a table such as this:

Object ID (plastic or aluminum)	Mass, g	Volume, cm^3 (using ruler)	Density, g/cm^3 (using ruler)	Volume, mL (using cylinder)	Density, g/cm^3 (using cylinder)

Thinking About the Data

2. Before proceeding, form a team with another pair of students, and engage in a discussion about which of the two instruments for measuring volume (ruler or graduated cylinder) is likely to have given a more accurate answer, and which is likely to have given a more precise answer. You may choose the same method as likely to be both more accurate and more precise, or you may choose different methods for each. Write down your predictions in your notebook or on your report form, as instructed.
3. Calculate the density of each of the two objects using each of the two volume measurements (ruler or cylinder) using equation (1).
4. Post your results into the class pool (*e.g.*, whiteboard, computer) as directed by your instructor.
5. Using the class data, report the mean value and the standard deviation of the density of the two solids from Part 1 using each method for measuring volume (ruler or cylinder).
6. Considering the class data, which method gave the more precise result? Discuss as a team or class and hypothesize a reason for this.
7. Look up or obtain from your instructor the accepted value of the density for the two objects from Part 1. Calculate the percentage measurement error between each class result and the accepted value.

$$\%\text{ measurement error} = \frac{(measured\ value - accepted\ value)}{accepted\ value} \times 100$$

8. Which method gives the more accurate result? Discuss as a team or class and propose a reason for this.

Part 2: Density of unknown solids

Each team of students will be given three or four objects composed of one or more unknown substances.

Using a laboratory balance and a graduated cylinder, determine the mass, volume and density of each of the four objects. Record in the table below or in your notebook.

Object	Mass, g	Volume, mL	Density, g/mL
1			
2			
3			
4			

Thinking About the Data

9. Post your four results into the class pool (*e.g.*, whiteboard, computer) as directed by your instructor.
10. Individually or as a team (as directed), using **all** the class data, make a scatterplot (on paper or using a computer, as directed) with mass on one axis and volume on the other. Before you do this, think carefully about the equation of a line (y = mx + b). The slope, m, is a ratio of

"rise/run," calculated as $\Delta y/\Delta x$, and will have the units of (units of y-axis)/(units of x-axis). Considering the ratio in equation (1), choose which variable you want on which axis.

11. As a team, consider whether the data exhibits one or more linear relationships between the graphed variables. If so, a best-fit line ("trendline") will represent the average of the ratio of the y values to the x values. **Do not draw any trendlines yet.**

Best-Fit Line

A trendline (or best-fit line) is a line within a scatter plot that shows the linear relationship of data. A best-fit line allows data points that were not collected during an experiment to be predicted. Since measurements have some random error, it is unlikely that the best-fit line will pass *exactly* through any of the points. A best-fit line helps average out these random errors to get a more accurate result than any individual measurement can provide. Most spreadsheet applications, such as Microsoft Excel®, are able to perform linear regression, using statistical analysis to determine the best-fit line.

12. As a team, consider whether any best-fit lines of the class data on this graph should necessarily pass through the point (0,0). Give an explanation for your choice. After checking with your instructor, you may proceed to add or draw trendline(s) onto the graph.

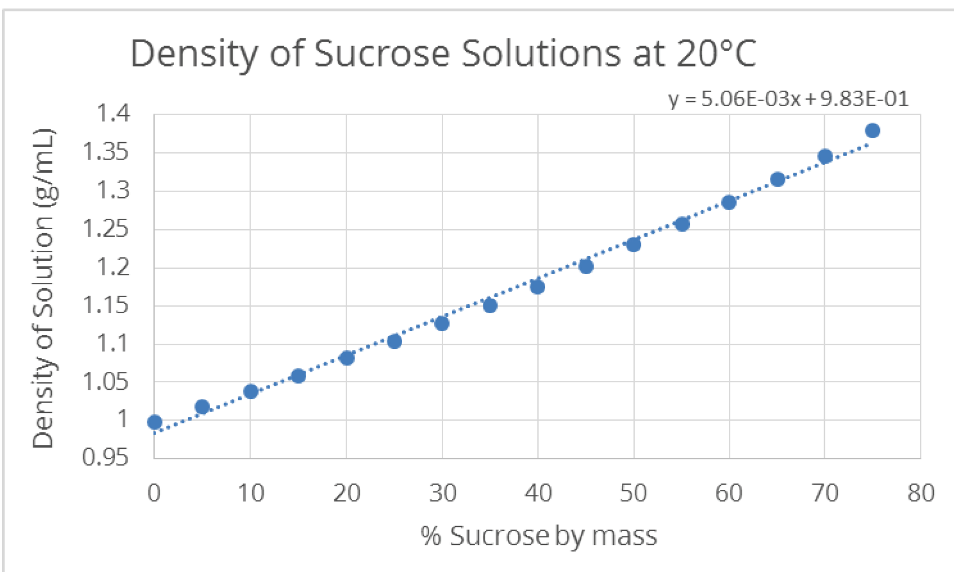
13. Determine the slope of your line(s) using the formula in equation (2). Be sure to use points **on the trendline**, not data points, for the y and x values.

$$m = slope = \frac{(y_2 - y_1)}{(x_2 - x_1)} \tag{2}$$

14. Report the average density of any solid using the correct units.

Figure 1: Density of sucrose solutions at 20°C in tabular and graphical forms*

% Sucrose by mass	Density, g/mL
0	0.998
5	1.018
10	1.038
15	1.059
20	1.081
25	1.104
30	1.127
35	1.151
40	1.176
45	1.203
50	1.23
55	1.258
60	1.286
65	1.316
70	1.347
75	1.379



* Data from Hofmann, G. *ISCOTABLES: a handbook of data for biological and physical scientists*, 7th ed.; Instrumentation Specialties Co.: Lincoln, Neb., 1977.

Part 3: Preparing a solution of a particular density

Your team goal for Part 3 is to prepare a sucrose solution in which one of the two solids from Part 2 will float, and one will sink. Each team will be given 20 g of sucrose. You may refer to Figure 1 to help you make a plan.

A. Engage in a team discussion to **decide upon the concentration of sucrose** you will make, and devise a procedure to make the solution. For example, to prepare a 10% (w/w) solution, you might accurately measure 10 g sucrose into a container, add exactly 90 g water (so that the total mass would be 100 g), and stir to mix. Note that sucrose solutions greater than about 40% are very slow to dissolve in water that is at room temperature.
B. Have your instructor or lab assistant check and approve your team's procedure before continuing.
C. After your instructor approves your team's procedure, carry out the experiment.
D. Using the two solids from Part 2, test the solution to see if your team was successful (one object floats and one sinks).

Thinking About the Data

15. Describe the results of Part 3 (success or failure) in your notebook or on your report form.

Part 4 (optional): Determining the actual density of the sucrose solution

A. Engage in a team discussion to **design a procedure to determine the density of your solution** using a laboratory balance and a graduated cylinder. The procedure should be designed to minimize the effects of random error on the final determination of density. Record your proposed procedures in your notebook or on your report form.
B. Have your instructor or lab assistant check and approve your team's procedure before continuing.
C. After your instructor approves your team's procedure, carry out the experiment.
D. If your team's procedure includes making a graph, you may use Excel or other computer software to produce the graph. If your experiment is designed to produce data representing a line that should pass through (0,0), be sure to set the option in the software that forces the y-intercept to be 0.

Thinking About the Data

16. Report the density of the sucrose solution prepared in Part 3. Summarize how your team determined the density of this solution.

17. Determine the percent error between the **density your team determined** for the solution that you determined in Part 4 and the **density predicted** in Figure 1 for that percent of sucrose.

18. Describe how you might be able to reduce this percent error if you were going to repeat the experiment.

19. Suppose you are given one of the unknown objects from Part 2, a ruler, and a laboratory balance. Describe a procedure by which you would be able to tell which one you have, using only the materials provided.

CLEAN UP:

- Return unknown solids to the appropriate location.
- Pour your sucrose solution down the drain.
- Wash your unknown solids, graduated cylinders and any other glassware that you used with soap, water and a brush (if necessary), and rinse clean.
- Wipe your bench area clean with a sponge or damp paper towel.

Post-Experiment Questions

20. How might we predict in advance whether a particular plastic object will float or sink in water? What physical properties can we measure that will allow us to answer the question: ***Will it sink or float***?

21. Considering the procedures carried out during this experiment by individuals, teams, and the whole class, what can we do to verify that we are measuring something accurately?

22. The density of brine (saturated aqueous sodium chloride solution) is 1.2 g/mL. Suppose that you have one of the unknown objects from Part II, a juice glass, and some brine. Describe a procedure by which you would be able to tell which one you have, using only the materials provided.

23. The density of steel is reported to be 8.05 g/mL. Using this as the accepted value, calculate the percent measurement error for the density of steel that you calculated in Pre-Experiment Question #1.

Table 2: Density and solubility of two common alcohols

Substance	*Density, g/mL*	*Water solubility, g per 100 mL water*
n-propyl alcohol	0.803	∞
n-butyl alcohol	0.810	7.3

24. n-Propyl alcohol is miscible with water, meaning that it dissolves completely in water in all proportions. However, n-butyl alcohol has a solubility of 0.73 g per 100 mL water at 25°C. Given only the liquid, water, and a test tube or beaker, propose a method for distinguishing whether a liquid is n-propyl alcohol or n-butyl alcohol.

25. Mineral oil has a density of 0.830 g/mL. It is immiscible with water, and so if water and mineral oil are placed into the same container, two layers will form. Propose a method to distinguish whether an unknown liquid is mineral oil or 1-propyl alcohol without making any measurements of mass or volume.

26. Suppose you do not have access to any water. Propose a method to distinguish whether an unknown liquid is mineral oil or 1-propyl alcohol, using only the liquid, a graduated cylinder, and a laboratory balance.