# Density

## Goals

- The purpose of this experiment is to investigate the topic of density by determining the densities of some materials.

## Introduction

There is a lesson in the old bromide: "Which is heavier, a pound of feathers or a bound of lead?" Neither is heavier since a pound of anything is still a pound. It is not possible to compare masses of objects unless it is done on the basis of the same portion of each object. For instance, it is possible to say that one person is heavier than another person since the comparison is on a pound per person basis. Since all materials have mass and occupy space, it is possible to compare materials by stating the amount of mass contained in a specific volume of each material. Density is defined as the mass per unit volume of a material, where mass is usually expressed in grams and volume in cubic centimeters or milliliters. Density is determined by measuring the mass and volume of a sample of a material and then dividing the mass by the volume:

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} \qquad \text{or} \qquad D = \frac{m}{V}$$

The density of any material is a characteristic property of the material and can help identify the material. Furthermore, density is used to relate the mass of a sample of the material to the volume or the volume to the mass. That is, the density is used as a property conversion factor to find the volume given the mass,

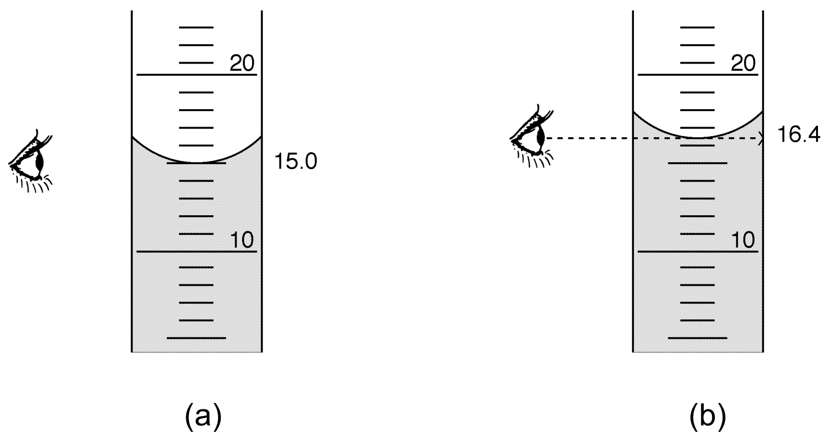
$$V = \frac{m}{D}$$

or to find the mass given the volume,

$$m = V \times D$$

In this experiment, the densities of several materials are determined and densities are used as conversion factors.

The volumes of liquids are often determined in the laboratory by use of graduated cylinders. These cylinders are calibrated in the factory so that they will contain certain specific volumes. Lines are etched on the outside surface of the cylinder to indicate the positions corresponding to various volumes. Distances between subsequent lines on the cylinder correspond to specific volumes. Volumes of liquids are measured by pouring a liquid sample into the cylinder and observing the position of the surface of the liquid. Some liquids, such as water, do not form a flat surface called a meniscus. Consequently, glass graduated cylinders are calibrated so that the volumes are read by observing the lowest portion of the curved meniscus. In other words, read the bottom of the meniscus. The volume of the liquid is measured by observing the position of the meniscus with respect to the calibration lines on the cylinder. Consider an example of the reading of the volume of a liquid in a graduated cylinder. In Fig. 2-1b, the position of meniscus coincides with the 15-mL mark and the volume of the liquid would be read as line but falls between lines. The estimation of




the position of the meniscus illustrates a very important method involved in the measurement called interpolation. See the discussion at the beginning of Appendix 1. Interpolation is accomplished by visually splitting the distance between two lines into equal parts and then approximating the position at which the meniscus lies between the two lines. In the figure, if the distance between lines is split into 10 parts then the meniscus appears to lie at the 16.4-mL position. The interpolation method is very important in volume measurements. The number of digits to be read by interpolation depends on how the volume measuring device is calibrated. When in doubt about how to read a cylinder, consult you instructor.

## Safety

Act in accordance with the laboratory safety rules of Cabrillo College.
Wear safety glasses at all times.
Avoid contact* with all chemical reagents and dispose of reactions using appropriate waste container.

## Materials:

Reagent Central solutions include:
Unknown solution

Equipment: Graduated cylinder pennies aluminum foil paper samples

## Experimental Procedure

Measure all masses to the nearest 0.01 g. Be careful to use the balances correctly. Your instructor will demonstrate the proper use of the laboratory balances. Balances are delicate instruments, so use them with care and respect. It is a good idea to use the same balance for subsequent weighings. The volumes of liquids are measured using graduated cylinders or a calibrated syringe. Since the number of significant digits in the volumes will dictate the number of digits in your calculated densities, be sure to read the volumes carefully.

### 1. DENSITY OF WATER

Dry your 10-mL graduated cylinder and find its mass to the nearest 0.01 g. Pour about 9 mL of water into the cylinder and carefully read the volume to the nearest 0.1 mL. Now weigh the cylinder plus the water to the nearest 0.01 g. Be sure to record your data in your notebook. Repeat the experiment three times.

### 2. DENSITY OF AN UNKNOWN LIQUID

Obtain a sample of unknown liquid and find its density using the same method you used for water.

### 3. THE VOLUME OF A DROP OF WATER

You need a small container and a disposable pipet, and a measuring syringe or an eye dropper. To make a convenient pipet, cut off half of the tip of a disposable pipet to leave a tip about 5 cm long. Weigh the container to the nearest 0.01 g.

Draw some water into the pipet, syringe, or dropper and practice dispensing drops until you make drops of the same size. Add 30 drops of water to the container and weigh it. You may add a few more or less than 30 drops but keep an accurate count on the number of drops you add. Repeat the exercise using another 30 drop sample.

### 4. DENSITY OF PENNIES

You need 15 post 1983 pennies, a small container, a balance, and a plastic metric rule. You are going to determine the density of the penny sample by measuring the mass of the sample and finding the volume by stacking the pennies to make a cylinder.
Assuming that the stack of pennies is a cylinder, the volume is calculated by the formula

$$V = \pi (d/2)^2 h$$

where V is the volume, $\pi$ is 3.142, d is the diameter, and h is the height.

Weigh an empty container to the nearest 0.01 g. Place the 15 pennies into the container and weigh it again to the nearest 0.01 g.

Use the metric rule to measure the diameter of a penny to the nearest 1 mm. Stack the pennies into a cylinder and devise a way to measure the height of the cylinder to the nearest 1 mm.

### 5. THICKNESS OF METAL FOIL

To directly measure the thickness of a sample of aluminum foil a special instrument is needed. However, the thickness can be simulated indirectly by viewing a sheet of foil as a thin rectangular solid having a length, width, and height. The height is the thickness. Since density relates mass to volume, the volume of a rectangular sample can be found from its mass. If we know the length, width, and volume of a rectangular solid it is possible to calculate the height.

Obtain a sheet of aluminum foil having a regular shape. Smooth the sheet on your laboratory book and, using a metric ruler, carefully measure the length of the edge of the sheet to the nearest 0.01 cm. If the sheet is not square, measure the length of adjacent edges. Use the balance to find the mass of the sheet. Do not crease or crumple the sheet. Record your data.

## Data Organization Suggestions

Create tables for your numerical data as shown below. When taking numerical data be sure to record the value and the unit. Every number should have a unit written after it! Separate these small experiments 1 per page, allowing enough room for calculations below your data.

| 1. Density of Water | Trial 1 | Trial 2 |
|---|---|---|
| Mass of cylinder + water | ____________ | ____________ |
| Mass of cylinder | ____________ | ____________ |
| Mass of water | ____________ | ____________ |
| Volume of water | ____________ | ____________ |

## Data Analysis

1. Density of water

Calculate the mass of the water sample and use the mass and volume to find the density of the water for each of the three trials. Report the average density.

2. Density of unknown liquid

Calculate the mass of the liquid sample and use the data to find the density of the liquid for eachof the three trials. Report the average density.

3. Volume of a drop of water

Use your data to find the mass of the 30 drops and calculate the mass per drop. Using a density for water of 1.00 g/mL, calculate the average volume of one of your drops of water.

Calculate the average volume of a drop that you dispense from your pipet, syringe, or dropper. Also, calculate the number of your drops per 1.0 mL of water.

4. Density of pennies

Calculate the mass of the sample and the volume of the cylinder. Calculate the density of the pennies by dividing the mass of the sample by the volume. A table of the densities of some common metals, in grams per cubic centimeter, is given below. Which metal has a density comparable to your calculated density?

| | | | | |
|---|---|---|---|---|
| Aluminum 2.7 | Magnesium 1.7 | Copper 8.9 | Nickel 8.9 | Silver 10.5 |
| iron 7.9 | Zinc 7.1 | Titanium 4.5 | Gold 19.3 | Tungsten 19.1 |

5. Thickness of aluminum foil

Calculate the area, A, of the sheet from the length of the edge or edges. The area is the product of the length, $l$, and the width, w, or the square of the length of the edge if the sheet is a square:

$$A = l \times w \text{ or } A = l^2$$

Calculate the approximate thickness of the foil as follows. Assuming that the foil is a rectangular solid, the volume is given by the area of the face times the height (thickness). This can be expressed as:

$$V = At$$

Where V is the volume, A is the area, and t is the thickness. If the density of aluminum is 2.70 $g/cm^3$, the volume of the foil sample is determined from the mass and the density. Once the volume is known, it is used along with the area to find the thickness of the foil.

$$t = V/A$$

Calculate the thickness of the aluminum foil in centimeters. Express the thickness in terms of millimeters.

## Questions for Analysis

Answer the following questions in your laboratory notebook:

1. Mercury is a liquid metal having a density of 13.6 g/mL. What is the volume of 5.00 lb of mercury metal? (453.6 g/1 lb)

2. A sample of aluminum has a mass of 14.24 g and a volume of 5.27 $cm^3$. What is the mass of a 49.7 $cm^3$ sample of aluminum?

3. A piece of magnesium is in the shape of a cylinder with a height of 7.13 cm and a diameter of 1.63 cm. If the magnesium sample has a mass of 26.4 g, what is the density of the sample? (See part 4 of the experiment)

4. A sample of aluminum foil has the dimensions of 12.1 cm × 16.2 cm. If the mass of this sample is measured to be 0.12 g and the density is known to be 2.70 $g/cm^3$, what is the thickness of the foil in millimeters to the correct number of significant figures?