# Measurement and Density

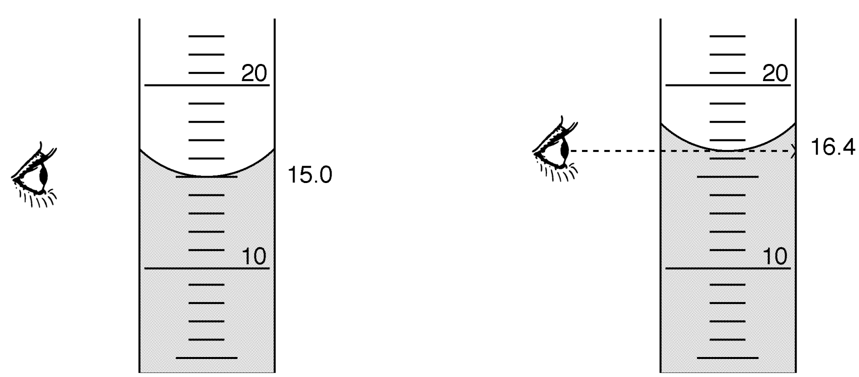
## Goals

- Learn to record accurate measurements from a variety of devices.
- Measure the density of solids and solutions.
- Use the property of density and measurement to calculate dimensions of irregular objects.

## Introduction

Measurement is the foundation of everything that we do in the laboratory. Learning to take accurate measurements is an important skill that takes practice. There are many types of measurements that are taken in the laboratory, such as length, volume, mass, temperature to name a few. Each type of measurement, when taken with a physical scale with graduated marks, is taken in the same way, reporting all of the known digits and one final estimated (interpolated is the fancy word) digit that represents the uncertainty in the measurement. For rulers and other types of scales this is rather straight forward, but liquids present an additional challenge.

Many liquids, like water, adhere to the surface of glass and form a curved surface when placed in a glass tube. The surface is called a meniscus. Glassware made for the measurement of liquids is generally calibrated to give the correct volume reading when evaluated at the bottom of the meniscus. The correct procedure for using such glassware is to align your eye level with the bottom of the meniscus. Report of all the know digits, and the interpolated digit. The reported measurement should always contain one interpolated digit beyond the calibration marks. If the device has calibrations of 10 mL, the measurement reported would be to the one's place. If the device has calibrations of 1 mL, the measurement reported would be to the tenth's place, and so on. For example, in figure (a) below, the meniscus falls exactly on the 15-mL mark. The calibrations are in one mL increments. the reported measurement must be to the tenth's place. Thus the measured volume is reported as 15.0 mL. In figure (b) the meniscus falls between the 16 and 17 mL calibration lines, but slightly closer to the 16. The measurement is reported as 16.4 mL.




(a) (b)

Density is an intensive property of matter, a property that is independent of the amount of a sample measured. The density of a material is found by measuring its mass and volume, and then calculating mass to volume ratio.

The mass is most often measured using a balance. To protect the balance, measurements of mass are usually done through weighing by difference. A container is first weighed. The mass of the container is recorded. The sample, solid or liquid, is then placed in the container and the system weighed. The mass of the container is then subtracted from the mass of the system, giving the mass of the sample.

The volume of the sample can be obtained in a number of ways depending on the type of sample. The volume of regular solids such as cubes or cylinders can be calculated from their dimensions as measured by a ruler. The volume of a cube is the length x width x height. The volume of a cylinder is $\pi r^2$ x height. For irregular solids, and regular solids, displacement is also an option. To measure a volume by displacement, a graduated cylinder is used. The cylinder is partially filled with water and the volume recorded. The object is then carefully placed into the cylinder with the water. The new water level is recorded. The volume of the object is found by the difference of the two measurements.

## 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.

## 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. GENERAL MEASUREMENTS

Spread throughout the room are various samples and measuring devices. Complete the table below by recording each sample, property measured, measuring device and observed measurement. Be sure to include the proper units with your measurement. There should be twelve measurements in all.

| Sample | Property Measured | Measuring Device | Measurement |
|---|---|---|---|
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## 2. DENSITY OF WATER

Dry a 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.

| | |
|---|---|
| Mass of cylinder and water | |
| Mass of cylinder | |
| Mass of water | |
| Volume of water | |
| **Calculated Density of water** | |

## 3. DENSITY OF AN UNKNOWN LIQUID

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

| | |
|---|---|
| Mass of graduated cylinder and unknown | |
| Mass of empty graduated cylinder | |
| Mass of unknown | |
| Volume of unknown | |
| **Calculated Density of unknown** | |

## 4. DENSITY OF A METAL CYLINDER

You need an unknown metal cylinder, a balance, and a plastic metric rule, and a 25-mL graduated cylinder. You are going to determine the density of the metal cylinder sample by measuring the mass of the sample and finding the volume by two methods, linear measurement with a ruler and displacement.

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 the cylinder directly on the balance to the nearest 0.01 g.

Use the metric rule to measure the diameter of the cylinder to the nearest 0.01 cm. Measure the height of the cylinder to the nearest 0.01 cm.

Make a second determination of the cylinders volume by displacement using the graduated cylinder and water. Carefully dry the cylinder after the measurement.

Density from calculated volume from linear measurements

| | |
|---|---|
| Mass of metal cylinder | |
| Diameter of metal cylinder | |
| Height of metal cylinder | |
| Calculated volume of metal cylinder | |
| **Density of metal cylinder** | |

Density from volume by displacement

| | |
|---|---|
| Mass of metal cylinder | |
| Final volume of water and cylinder | |
| Initial volume of water | |
| Volume of metal cylinder | |
| **Density of metal cylinder** | |

**Question:** Which density determination is more accurate, contains less uncertainty? Explain.

### 3. DENSITY OF METAL SHOT

You need a quantity of metal shot, a small 25-mL beaker, a balance, and a 25-mL graduated cylinder. First determine the mass of the sample of metal shot. Weigh the 25-mL beaker. Place the shot in the beaker and re-weigh. Find the mass of the shot by difference. Place about 10 mL of water into the 25-mL graduated cylinder. Carefully record the volume. Carefully poor the metal shot into the graduated cylinder and record the new volume. Recover the shot by using the provided strainer, and return the shot to the drying area over the paper towels.

| | |
|---|---|
| Mass of 25-mL beaker and metal shot | |
| Mass of 25-mL beaker | |
| Mass of metal shot | |
| Final volume of water and metal shot | |
| Initial volume of water | |
| Volume of metal shot | |
| **Density of metal shot** | |

## 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 found 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 the density is known. 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.

| | |
|---|---|
| Mass of foil | |
| Length of one side | |
| Length of adjacent side | |
| Area of foil in $cm^2$ | |
| Density of aluminum | 2.704 $g/cm^3$ |
| **Thickness of foil in cm** | |

**Provide your calculations below:**

## 6. AREA OF IRREGULAR SHAPE

Just as the thickness of aluminum foil could be calculated in the preceding experiment, the area of irregular shapes can be calculated as well as long as the object has a uniform thickness. The trick here is to determine an area to mass ratio, similar to density, but with area instead of volume. As long as the object is of uniform thickness, the ratio of the area to mass should remain constant. Here we will measure the area of an irregular sheet of paper.

Start by measuring the dimensions of a regular rectangular piece of paper. Measure the length and width to the nearest 0.01 cm. Now use the balance to determine the mass of the regular sheet of paper to the nearest 0.01 g. Determine the ration of the area to mass for the rectangular sheet of paper. Finally weigh the irregularly shaped piece of paper to the nearest 0.01 g. Use your area to mass ratio to determine the area of the irregular sheet.

| | |
|---|---|
| Mass of rectangular sheet | |
| Length of one side of rectangular sheet | |
| Length of adjacent side or rectangular sheet | |
| Area of rectangular sheet in $cm^2$ | |
| Area to mass ratio of rectangular sheet $g/cm^2$ | |
| Mass of irregular sheet | |
| **Area of irregular sheet in $cm^2$** | |