EXPERIMENT 4

Measuring Length and Volume

Goals

Read and record length and volume measurements accurately.
Calculate experimental metric-American conversion factors for length and volume.
Determine the volume of a solid by direct measurement and by volume displacement.

Lab Questions

1. What is the base unit of length in the metric (SI) system?
2. What is the base unit of volume in the metric system?
3. What is a decimal system of measurement?
4. How are prefixes used in the metric (or SI) system?
5. What is an equality?
6. What is a conversion factor?

Concepts to Review

Metric prefixes
Significant figures
Metric conversion factors for length and volume
Measuring length and volume in the metric system
Metric-American conversion factors for length and volume

Discussion

Metric Units of Length

Scientists and allied health personnel carry out laboratory procedures, take measurements, read thermometers, and report results accurately and clearly. How well they do these things can mean life or death to a patient. The system of measurement used in science, hospitals and clinics, is the metric system, which is a *decimal system* (based on units of 10). The unit of length in the metric system is the ***meter (m)***. Using an appropriate prefix, you can indicate a length that is greater or less than a meter. A ***meterstick** is divided into 100 centimeters*. (See Figure 4.1.) Each centimeter is divided into ten millimeters. Table 4.1 lists some of the most commonly used metric units of length.

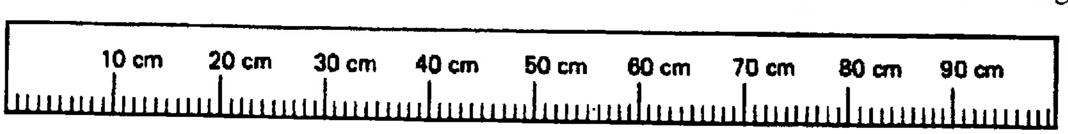


Figure 4.1 A meter stick

Table 4.1 Some Metric Units Used to Measure Length

Unit of Length		Equivalent in Meters	Equality
1 kilometer (km)	=	1000 meters (m)	1 km = 1000 m
1 decimeter (dm)	=	0.1 m (1/10 m)	1 m = 10 dm
1 centimeter (cm)	=	0.01 m (1/100 m)	1 m = 100 cm
1 millimeter (mm)	=	0.001 m (1/1000 m)	1 m = 1000 mm

Metric Units Of Volume

The volume of a substance measures the space it occupies. In the metric system, the unit for volume is the *liter (L)*. Prefixes are used to express smaller volumes such as deciliters (dL), or milliliters (mL). One cubic centimeter (cm^3 or cc) is equal to 1 mL. The terms are used interchangeably. (See Table 4.2.)

1 cubic centimeter (1 cm^3 or 1 cc) = 1 mL

Table 4.2 Some Metric Units Used to Measure Volume

Unit of Volume		Equivalent	Equality
1 kiloliter (kL)	=	1000 liters (L)	1 kL = 1000 L
1 deciliters (dL)	=	0.1 L (1/10 L)	1 L = 10 dL
1 milliliter (mL)	=	0.001 L (1/1000 L)	1 L = 1000 mL
1 milliliters (mL)	=	1 cm^3 = 1 cc	1 mL = 1 cm^3

Significant Figures in Measurements

When you use a meterstick or read the scale on a graduated cylinder, the measurement is reported as precisely as possible. Therefore, the number of significant figures you include depends on the markings on the measuring device you use. For example, on a 50-mL graduated cylinder, the smallest lines drawn represent 1 mL. When you read a volume in this cylinder, you can report the number of milliliters and also the tenths of a milliliter. This last digit is obtained by estimating between the 1-mL lines. If a liquid has a volume half-way between 21 mL and 22 mL, it would be reported as 21.5 mL. If the volume level lies exactly on the 21-mL line, a *significant zero* is used after the decimal point to give a measurement of 21.0 mL. A value of 21.0 mL indicates that you can read the volume more precisely than 21 mL.

On large cylinders, the volume lines represent larger volumes such as 5 mL or 10 mL. On a 250-mL cylinder, the marked volume lines usually represent 5 mL. On a 1000 mL cylinder, each volume line may be 10 mL. Then your precision on a measurement will be to the milliliter or mL.

In calculations with measured numbers, remember to report your answers with the correct number of significant figures (Review Experiment 3). In multiplication and division, the answer will have the same number of significant figures as the measurement with the fewest significant figures. In addition and subtraction, the answer is reported with the same number of decimal places as the least precise measurement.

Equalities and Conversion Factors

If we measure the same quantity in two different units, we have an ***equality***. For example, we learned that 1 meter (m) is equal to 100 cm. This relationship is called an ***equality***.

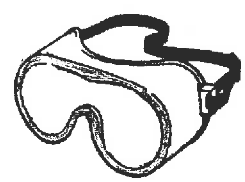
An Equality: 1 m = 100 cm

When an equality is written in the form of a fraction, the relationship is called a ***conversion factor***. Two fractions are possible and both are conversion factors for the equality.

Conversion Factors for 1 m = 100 cm

$\frac{100\text{ cm}}{1\text{ m}}$ and $\frac{1\text{ m}}{100\text{ cm}}$

Laboratory Activities



BE SURE TO PUT ON YOUR SAFETY GOGGLES BEFORE YOU BEGIN THIS EXPERIMENT!

A. Using A Meterstick

Materials needed: Meterstick, string

A.1 ***Meterstick markings*** *Obtain* a meterstick and observe the markings. The smallest markings are the millimeters (mm) or one-tenth of a centimeter (0.1 cm). Answer the questions for Section A in the laboratory record.

A.2 ***Measuring length*** Use the meter stick to measure some lengths in centimeters (cm). Measure the width of your little fingernail, the distance around your wrist, the length of your shoe and your height. (String may be used to obtain the distance around your wrist.) Report each measurement to the millimeter (0.1 cm). Remember to report the precision of the measurement as 32.0 cm if the end lines up with the cm mark. ***Note: Do not round off any numbers obtained from measurement. Keep all significant figures.***

A.3 Determine the length and width of the sides of the rectangle drawn in the report page. Have a second person repeat the measurements. Record. Calculate the area of the rectangle using the formula: Area = L x W. Compare the calculated areas from both sets of measurements.

B. Comparing Metric and American Units of Length

Materials needed: Meterstick and ruler or yardstick

B.1 ***Metric-American factor for length*** Using a ruler or yard stick and a meterstick, determine the number of centimeters (to 0.1 cm) that correspond to a distance of 12.0 inches. Place your values in a ratio with the number of centimeters in the *numerator*, and the number of inches (12.0 in.) in the *denominator*. Divide and round off your answer to the correct number of significant figures. The result is your *experimental* value for the number of centimeters in 1 inch. It should be close to the conversion factor of 2.54 cm/in. (See Figure 4.2.)

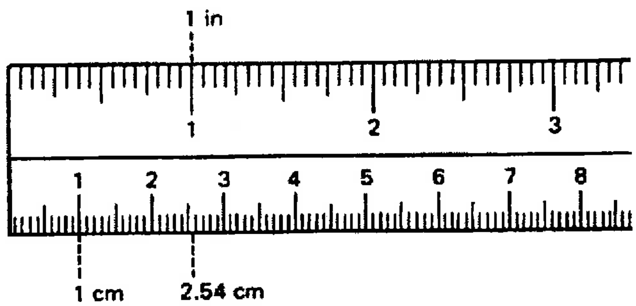


Figure 4.2 Comparing centimeters and inches

B.2 ***Calculating your height in centimeters and meters*** Record your height in inches. Or use a yardstick to measure. Using the conversion factor (2.54 cm/in.), **calculate** your height in centimeters. Show your setup for the calculation in the space provided for calculations. Compare the calculated value with the height in cm in measured in part A.2.

$$\text{your measured height (in.)} \times \frac{2.54 \text{ cm}}{1 \text{ in.}} = \text{your height (cm)}$$

B.3 Convert your height in centimeters to meters using the metric conversion factor in the following setup:

$$\text{your height (cm)} \times \frac{1 \text{ m}}{100 \text{ cm}} = \text{your height in meters}$$

C. Measuring the Volume of Liquids

Materials needed: Display of graduated cylinders with liquids, 250-mL (or larger) graduated cylinder, and a 1-cup measure

In the laboratory, the volume of a liquid is measured in a graduated cylinder. (See Figure 4.3) To read the volume of water properly, set the cylinder on a level surface and bring your eyes even with the liquid level. You will notice that the water level is not a straight line, but curves downward in the center. This curve, called a *meniscus*, is read at its lowest point (center) to obtain the volume measurement for the liquid. In this graduated cylinder, the volume of the liquid is 42.0 mL.

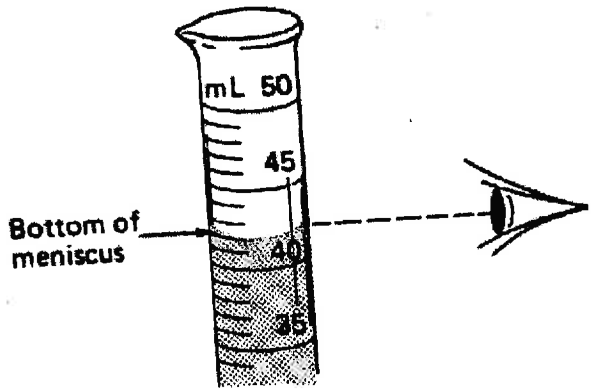


Figure 4.3 Reading a volume of 42.0 mL in a graduated cylinder

C.1 ***Reading the volume on a graduated cylinder*** Determine the volume of each of the liquids in a display of graduated cylinders. (See the discussion for reporting significant figures.) On a 50-mL graduated cylinder, each line measures 1 mL. By estimating the volume ***between*** the 1-mL markings, you can report the volume to the tenths (0.1) of a milliliter.

C.2 Using a measuring cup, measure 1 cup of water. Using a 250-ml or 500-mL graduated cylinder, determine the volume (mL) of water. Record. Calculate the number of milliliters in 1 quart (1 qt = 4 cups). How close is your measured value to the conversion factor 946 mL per quart?

D. Measuring the Volume of A Solid

Materials needed: Metal solid with a regular shape, string or thread, meterstick, graduated cylinder large enough to hold metal solid

D.1 ***Volume of a Solid By Direct Measurement*** Obtain a metal solid that has a regular shape such as a cube, rectangular solid, or cylinder. Record its shape. Use a meterstick to determine the dimensions of the solid in centimeters (cm). (See Table 4.3.) ***Keep this object for section D.3.***

Table 4.3 Formulas for Calculating the Volume of a Solid

Shape	Dimensions	Volume
cube	length (L)	$V = L^3$
rectangular solid	length (L), width (W), height (H)	$V = L \times W \times H$
cylinder	diameter (D), height (H)	$V = \frac{\pi D^2 H}{4} = \frac{3.14\ D^2 H}{4}$

D.2 Using the proper formula from Table 4.3, calculate the volume of the solid (cm^3). Include the units and round off to give an answer with the correct number of significant figures.

D.3 ***Volume of a Solid By Volume Displacement*** When an object is submerged under water, it displaces its own volume of water which causes the water level to rise. The difference in the water level before and after the object is submerged is due to the volume of the object. (See Figure 4.4.) By measuring the water level before and after the object is added, the volume of the object can be calculated.

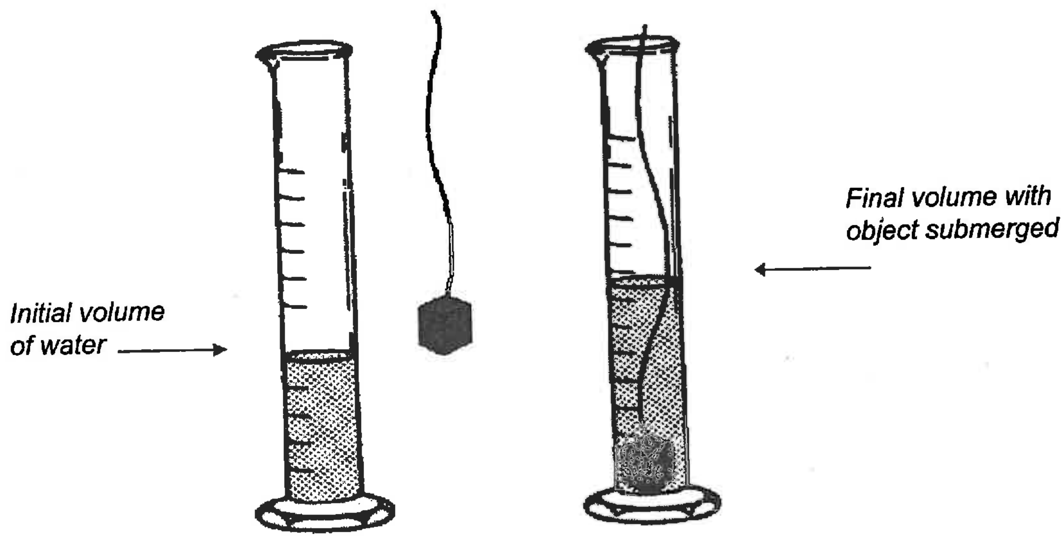


Figure 4.4 Measuring the volume of a solid by volume displacement

Obtain a graduated cylinder that can hold the solid you used in D.1. Place water in the graduated cylinder until it is about half-full. Record the volume of water. Slowly submerge the solid under the water. Tie a piece of thread around heavy solids. Record the new volume of the water. Calculate the volume (mL) displaced by the solid.

$$V_{\text{water + object}} - V_{\text{water initially}} = V_{\text{object}}$$

D.4 Convert the volume of the solid from milliliters to cubic centimeters(1 mL = 1 cm^3).

$$\text{volume of solid (mL)} \times \frac{1\ \text{cm}^3}{1\ \text{mL}} = \text{volume of solid (cm}^3\text{)}$$