Module 2

Targets/Objectives

At the end of the lesson, students should be able to:

- Explain the properties of mass and volume.
- Identify the apparatus used in measuring mass and volume.
- Calculate the volume of regular and irregularly shaped objects.
- Calculate the density of an unknown liquid and irregularly shaped solids.

Lecture Guide

Measurement of Mass

Mass is a measure of the amount of matter in a substance or an object. The basic SI unit for mass is the kilogram (kg), but smaller masses may be measured in grams (g).

To measure mass, you would use a balance. In the laboratories, mass may be measured with a triple beam balance or an electronic balance as shown below.

Fig 1. Triple Beam Balance

The triple beam balance (fig. 1) is used to measure masses very precisely; the reading error is ±0.05 gram.

Steps in using the triple beam balance from
https://www.physics.smu.edu/~scalise/apparatus/triplebeam/

1. With the pan empty, move the three sliders on the three beams to their leftmost positions, so that the balance reads zero. If the indicator on the far right is not aligned with the fixed mark, then calibrate the balance by turning the set screw on the left under the pan.
2. Once the balance has been calibrated, place the object to be measured on the pan.

3. Move the 100-gram slider along the beam to the right until the indicator drops below the fixed mark. The notched position immediately to the left of this point indicates the number of hundreds of grams.
4. Now move the 10-gram slider along the beam to the right until the indicator drops below the fixed mark. The notched position immediately to the left of this point indicates the number of tens of grams.
5. The beam in front is not notched; the slider can move anywhere along the beam. The boldface numbers on this beam are grams and the tick marks between the boldface numbers indicate tenths of grams.
6. To find the mass of the object on the pan, simply add the numbers from the three beams.
7. As with a ruler, it is possible to read the front scale to the nearest half tick mark.

Electronic balances (fig. 2) have become a popular standard equipment in many school laboratories due to its extreme ease of use for any skill level. It allows the user to accurately measure the mass of a substance to a level of accuracy impossible for traditional balances. This is importance in experiments that require precise amounts of the substance to achieve the desired results.

Fig 2. Electronic Balance

Steps in using the electronic balance from https://sciencing.com/use-electronicbalance-7860190.html

1. Place the electronic balance on a flat, stable surface indoors. The precision of the balance relies on factors such as wind, shaky surfaces, or similar forces will cause the readings to be inaccurate.
2. Press the "ON" button and wait for the balance to show zeroes on the digital screen.
3. Press the "Tare" or "Zero" button to automatically deduct the weight of the container from future calculations. The digital display will show zero again, indicating that the container's mass is stored in the balance's memory.

4. Carefully add the substance to the container. Ideally this is done with the container still on the platform, but it may be removed if necessary. Avoid placing the container on surfaces that may have substances which will add mass to the container such as powders or grease.

5. Place the container with the substance back on the balance platform if necessary and record the mass as indicated by the digital display.

Measurement of Volume

Volume is a measure of the amount of space that a substance or an object takes up. The basic SI unit for volume is the cubic meter (m^3), but smaller volumes may be measured in cm^3, and liquids may be measured in liters (L) or milliliters (mL).

Volumes are measured depending on its state:

- The volume of a liquid is measured with a measuring container, such as a measuring cup or graduated cylinder.
- The volume of a gas depends on the volume of its container: gases expand to fill the entire container.
- The volume of a regularly shaped solid can be calculated from its dimensions. For example, the volume of a rectangular solid is the product of its length, width, and height.
- The volume of an irregularly shaped solid can be measured by water displacement method.

Tools in measuring volume of liquids

1. Measuring cups. A common tool used in measuring the volumes of liquids. Measuring cups expresses liquid volumes in SI units of milliliters and English system of cups and fluid ounces (fig 3).

Fig 3. Measuring cup

2. Volumetric Glassware. These includes beaker, graduated cylinder, Erlenmeyer flask, volumetric flask, pipets and burets. Each of these containers are used in the laboratory for different purposes.

Fig 4. Beaker, Erlenmeyer flask, graduated cylinder and volumetric flask

Measuring Volumes of Regular Solids

The volume of a solid object with a regular geometric shape (rectangular box, cube, cylinder, sphere) can be determined using the volume formula for the shape.

Cube : $V = s^3$

Rectangle : $V = L\ x\ w\ x\ h$

Sphere : $V = \frac{4}{3}\pi r^3$

Cylinder : $V = \pi r^2 h$ where:

V= volume

s = length of a side

L= length w= width

h= height r= radius

Measuring Volumes of Irregularly Shaped Solids

The volumes of irregularly shaped objects cannot be determined using the volume formula. The volume of this objects can be determined using the water displacement method, where the object is submerged in water and the difference in volume before and after the object is submerged will be the volume of the object.

Procedure:

1. Place water to a measuring container such as a graduated cylinder and record the volume. This reading will be the initial volume (V_i).
2. Submerge the object in the water, as observed, the water level will rise as the object is being submerged. Record the new volume of water. This will be the final reading (V_f)
3. Compute the volume of the object using the formula $V_{object} = V_f - V_i$

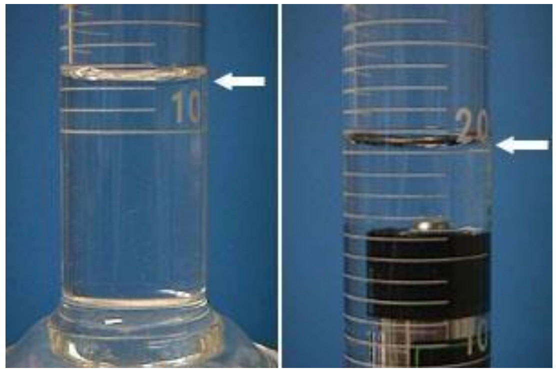

Fig 5. A battery submerged in water

In figure 5, the initial volume of water (on the left) is 12.4 ml. After the battery has been submerged, the volume reading is 20.5 ml. The volume of the battery is $V_{battery} = 20.5 - 12.4 = 8.1 ml$

The following video shows how the volume of an irregular shaped objects can be measured by the displacement method.

https://www.youtube.com/watch?time_continue=17&v=e0geXKxeTn4&feature=emb_log o

Example 1. Calculate the volume (in cubic centimeters) of a prism that is 5 m long, 40 cm wide and 2,500 mm high.

Solution:

Volume of the prism = L x w x h

Convert each parameter in centimeters (cm)

$$L = 5m x \frac{100cm}{1m} = 500cm$$

$$h = 2{,}500mm x \frac{1cm}{10mm} = 250cm$$

$$Volume\ of\ prism = 500cm\ x 40cm\ x\ 250\ cm$$
$$= 5{,}000{,}000\ cm^3\ or\ 5.0x10^6 cm^3$$

Example 2. Calculate the volume of a metal sphere with radius of 3.5 cm. Solution:

Volume of sphere $= \frac{4}{3}\pi r^3$

$$V = \frac{4}{3}\pi(3.5)^3$$

$$V = 179.594\ cm^3$$

Example 3. A graduated cylinder is filled to an initial volume of 25.0 ml. A small pebble is dropped into the graduated cylinder. The final volume of the graduated cylinder is 29.3 ml. What is the rock's volume in both ml and cm^3?

Solution:

Initial volume of water (V_i) = 25.0 ml

Final volume of water (V_f) = 29.3 ml

Volume of pebble = $V_f - V_i$

$= 29.3 - 25.0$

$= 4.3\ ml$

Volume of pebble in cm^3 = $4.3\ ml \times \frac{1 cm^3}{1\ ml} = 4.3\ cm^3$

Density

Densities are widely used to identify pure substances and to characterize and estimate the composition of many kinds of mixtures. Some definitions of densities are:

- is a mass per unit volume of a material substance.
- is commonly expressed in grams per cubic centimeter.
- indicates how much of a substance occupies a specific volume at a defined temperature and pressure.

Density Formula:

$$\boldsymbol{D = \frac{M}{V}}$$

where: M = mass of the substance V= volume of the substance D= density of the substance

Units: $\frac{g}{cm^3}$, $\frac{kg}{m^3}$, $\frac{lb}{in^3}$, $\frac{lb}{ft^3}$

Using Water as a Density Comparison

When an object is placed in water, the object's relative density determines whether it will float or sink in water. If the object has a lower density than water, it will float to the surface of the water. If an object has a higher density than water, it will sink. Density of water at 4°C is 1.0000 $\frac{g}{cm^3}$

Example: Cork has a density of 240 $\frac{kg}{m^3}$, so it will float in water, while lead has a density of 11,340 $\frac{kg}{m^3}$ will sink.

Liquids tend to form layers when added to water. Ethyl alcohol (789 $\frac{kg}{m^3}$) will float on water and form a separate layer until it is thoroughly mixed. Glycerin (1259 $\frac{kg}{m^3}$) will sink into the water and form layer at the bottom no matter how vigorously it is mixed. Mixing liquids with different densities tend to form layers or "density column" as shown un Figure 6.

Fig 6. Density Column

Example 1. A metal ball has a mass of 2kg and a volume of 6 m^3**.** What is its density?

Solution:

Given: M=2 kg, V= 6 m^3

$$\boldsymbol{D} = \frac{\boldsymbol{M}}{\boldsymbol{V}}$$

Substitute the given values

$$\boldsymbol{D} = \frac{\boldsymbol{M}}{\boldsymbol{V}} = \frac{2\,kg}{6\,m^3}$$

$$= 0.333\ \frac{kg}{m^3}$$ (round off to three decimal places)

Example 2. What is the volume of a marble that has a mass of 3 g and density of 2.7 g/ml? **Solution:**

$$\boldsymbol{D} = \frac{\boldsymbol{M}}{\boldsymbol{V}}\ ;\ \boldsymbol{V} = \frac{\boldsymbol{M}}{\boldsymbol{D}}$$

Substitute the given values

$$\boldsymbol{V} = \frac{\boldsymbol{M}}{\boldsymbol{D}} = \frac{3\,g}{2.7\ \frac{g}{ml}}$$

$$= 1.111\ ml$$ (round off to three decimal places)

Example 3. If the density of a diamond is 3.5 g/cm^3, what would be the mass of diamond whose volume is 0.5 cm^3? **Solution:**

$$\boldsymbol{D = \frac{M}{V}} \quad ; \quad \boldsymbol{M = D \ x \ V}$$

Substitute the given values $\boldsymbol{M = D \ x \ V}$

$$= 3.5 \ \frac{g}{cm^3} \ x \ 0.5 \ cm^3$$

$$= 1.75 \ g$$