2.6

Measuring Matter: Mass, Weight, and Volume

Using fluids—both liquids and gases—requires an understanding of their behaviour. You need to know how they behave when they are still, when they are moving, when something is moving in them, when they are pushed, or when they are pulled. Learning about these things requires the ability to measure matter.

Mass and Weight

"How much does it weigh?" "Let's check the weight of the candy." You hear expressions like these almost daily. Usually, when people use the term weight, they are referring to the measurement of mass. Mass and weight are not the same thing.

Mass is the amount of matter in an object and is used to measure many things, from food to mail. An object's mass stays constant everywhere in the universe. Mass is measured in grams (g), or units derived from grams, such as milligrams (mg) and kilograms (kg).

An object's **weight** is a measurement of the force of gravity pulling on the object. It is measured in newtons (N), named after Sir Isaac Newton. Because gravity is not the same everywhere in the universe, an object's weight varies according to where that object is in the universe. (See **Figure 1**.)

Because gravity is approximately the same everywhere on Earth's surface, people often use the words mass and weight interchangeably. Remember that mass and weight are different.

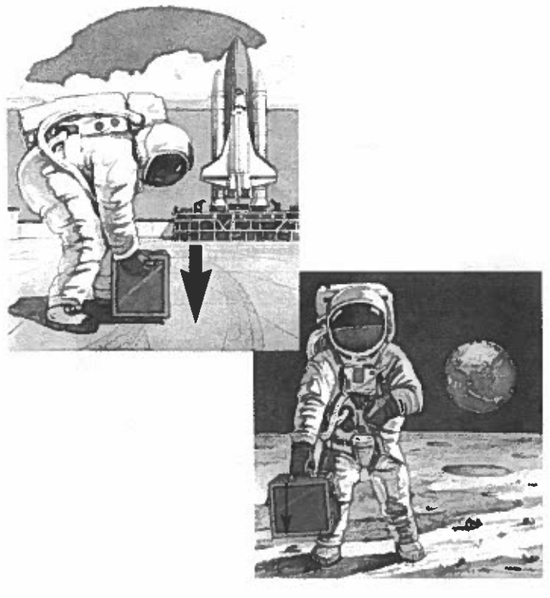

Figure 1

The downward pull (force of gravity) on an object on the surface of Earth is approximately 6 times as large as on the Moon. Because of this difference in gravity, objects on the Moon weigh 1/6 what they do on Earth. The *weight* of the object changes, but the mass is the same in both locations.

Volume

In addition to having mass and weight, matter occupies space. **Volume** is a measure of the amount of space occupied by matter. It is measured in cubic metres (m^3), litres (L), cubic centimetres (cm^3), or millilitres (mL).

Capacity is related to volume. It is a measure of the amount of space available inside something. People measure the volume or capacity of things such as fish aquariums, medical syringes, and ships' cargo holds.

Different types and quantities of matter are measured in different ways. Here are some techniques that you might use in your class.

Measuring Liquids

Liquids are measured by observing how much of a container they fill. A tall, narrow container (such as a graduated cylinder) gives the most accurate measurement. Look at the container from the side, with your eye level with the surface of the liquid. You might notice a slight curve at the edges of the surface where the liquid touches the container. This "curved" surface is called the meniscus. Read the volume at the lowest place on the meniscus. Liquids are generally measured in litres (L) or millilitres (mL).

Measuring Volume of Solids — Rectangular Solids

Rectangular solids may be measured with a ruler, and their volume calculated using the formula

$$\text{volume} = \text{length} \times \text{width} \times \text{height}$$

Solids are usually measured in cubic metres (m^3) or cubic centimetres (cm^3), but may sometimes be given in litres (L) or millilitres (mL). Interestingly, 1 cm^3 is the same as 1 mL, so 1000 cm^3 equals 1 L.

Measuring Volume of Solids — Small Irregular Solids

The volume of a small irregular solid must be measured by **displacement**. In this technique, you choose a container (such as a graduated cylinder) that your small object will fit inside. Then pour water into the empty container until it is about half full. Record the volume of water in the container, then carefully add the object. Record the volume of the water plus the object. Calculate the volume of the object using the formula:

volume of object = (volume of water + object) – (volume of water)

Measuring Volume of Solids — Large Irregular Solids

To measure the volume of a large irregular solid, you will need an overflow can and a graduated cylinder (**Figure 2**). This measurement is best done over a sink. Fill the overflow can with water until water starts to run out of the spout. Wait until the water stops dripping, then place the graduated cylinder under the spout. Carefully lower the object into the water and observe what happens.

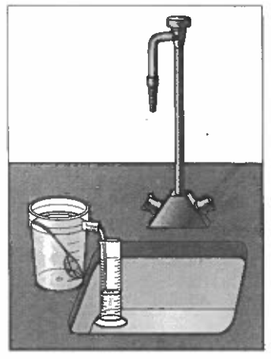

Figure 2

A volume of water equal to the volume of the solid will pour out of the spout and into the measuring cylinder.

Try This — Measuring Volume

Your teacher will provide you with several samples of matter and equipment to measure volume. Estimate the volume of each sample.

1. Record your estimates in a chart.
   - Select the appropriate equipment for measuring the volume of one of the samples.
   - Following the guidelines given above, find the volume of your sample.
   - Share your results with the rest of your class.
2. Record the volumes of all the samples in your chart.
3. Which samples were you able to estimate quite accurately? Which were harder to estimate?

Understanding Concepts

1. Describe the relationship between mass and weight. Give an example of this relationship.
2. Imagine you have travelled to a planet that has twice the force of gravity of Earth. You have taken a solid with a mass of 1 kg with you. Describe its mass, weight, and volume on this planet, compared with that on Earth.

Design Challenge

What measurements will you need to make of the fluid in your Design Challenge?