Chapter 3
Observation and Measurement

Observations

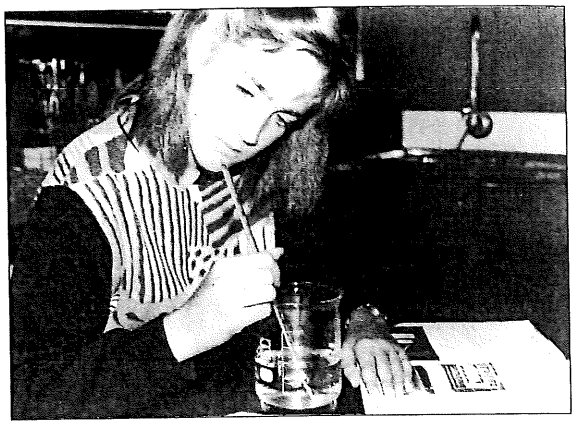


Figure 3.1 A student making an observation. Why is this an observation?

An **observation** is information gained from our senses. Our senses are sight, hearing, touch, taste and smell. We use our **eyes** to **see** other people and to read books. We use our **ears** to listen to music and to **hear** other people speak. Life would be pretty dull without our sense of **taste** which helps us to enjoy our food. Our sense of **smell** can help us to detect smoke from a fire or the pleasant aroma of lamb roasting.

Our sense of **touch** is a useful sense in science. With it we can detect hot and cold. We can feel the heaviness of things and we can also judge the size of objects by touching them with our hands.

Observation is a very important part of science because it provides most of the information we use. Being able to observe is an important skill for any science student or scientist.

Taking care with our senses

All of us know about using our senses of sight and hearing. Scientists use sight and hearing the same as everyone does. However, smell, taste and touch in science must be used carefully in science laboratories. It is not wise to taste unknown chemicals or even ones you know. There is always the chance that these may be **contaminated**. This means they may have been mixed with other chemicals which could be **poisonous**.

It is very important to be careful when touching things in the science laboratory. Some chemicals are poisonous. Many objects in science can be hot and burn. Others can give an electric shock.

When smelling things scientists use a special method. It is called **wafting**. The substance to be smelled is held about 30 centimetres or so away from the nose. Then a hand is waved towards and away from the nose to push the air from the object towards the nose as shown in Figure 3.2. In this way only a small amount of the substance is **inhaled**. If the substance was dangerous it would not do as much harm as taking a deep sniff of the chemical.

Extending our senses

In science we can use instruments to help extend our senses to make observations.

We can extend our **sight** with microscopes, telescopes, hand lenses and many other devices.

We can extend our sense of **hearing** with a **stethoscope**. Doctors use these to hear sounds such as a heartbeat.

Microphones and **amplifiers** can be used to detect sounds and make them louder.

Figure 3.2 Wafting is a safe way of smelling chemicals. Wearing safety glasses would also be advisable.

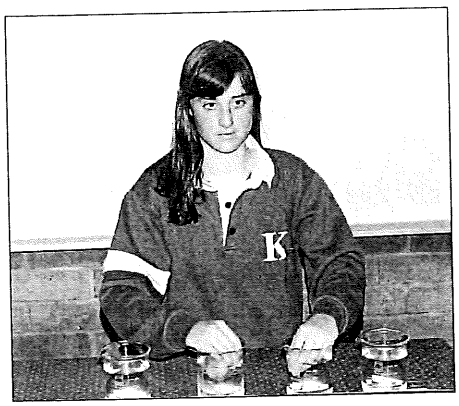
Measurement

A **measurement** is a number obtained by using an instrument for observation. Scientists make measurements because they are easy to understand and can provide more accurate information than general observations. For example, more accurate information is provided about the length of a plank if we can say that it is 2.5 metres long rather than just that it is a long plank. In addition our senses can sometimes be fooled because of the circumstances under which an observation is being made. For example, if a person has their right hand placed in iced water and their left hand in warm water for about 20 seconds and then both hands put into tap water then you will find that the person will report that the right hand feels warm and the left hand feels cold. But the water the hands are in is actually at the same temperature.

Figure 3.3 Using a hand lens to extend the sense of sight.

Figure 3.4 Using a stethoscope to extend our hearing.

Figure 3.5 An experiment to show how our senses can be unreliable. This is explained in the section on measurement.



(a) One hand in ice water and the other in hot water.

(b) Both hands in 20°C water.

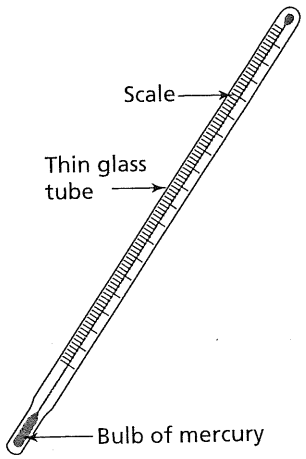


Figure 3.6 A thermometer is used to measure temperature.

Figure 3.7 A clinical thermometer is used to check a person's body temperature.

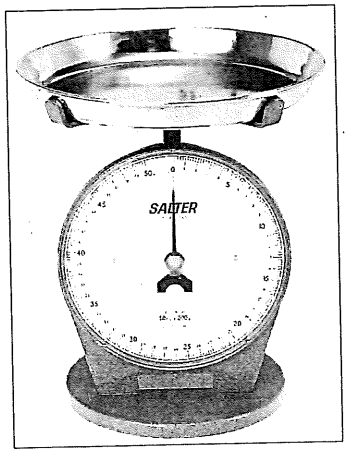


Figure 3.8 Scales are used to measure mass.

This is why measurement is more reliable than an observation without instruments.

Measuring instruments

In science the commonly used measuring instruments are thermometers, scales or balances, rulers, measuring cylinders and timers. These are used to measure temperature, mass, length, volume and time.

Temperature

A **thermometer** is used to measure **temperature**. There are several types of thermometer. The main type used in science consists of a glass tube filled with mercury or coloured alcohol. It has a scale divided into sections called **degrees Celsius**. The degree Celsius is called the unit of temperature. The symbol for it is **°C**. Water boils at 100°C and freezes at 0°C.

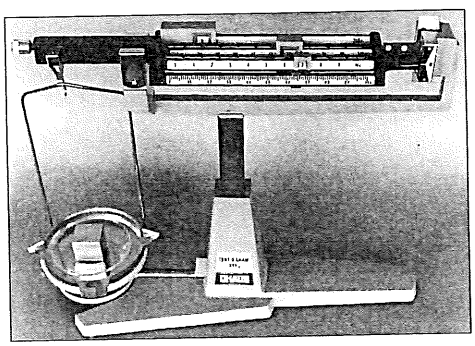
Most thermometers have a scale between −10°C and 110°C. There is another type of thermometer called a **clinical thermometer**. This has a scale between about 35°C and 42°C. A clinical thermometer is used to check a person's body temperature. It should be about 37°C.

Mass

Our sense of touch helps us to detect the mass or heaviness of different objects. A cricket ball is obviously heavier than a tennis ball. It has a greater mass.

Our sense of touch is not, however, very accurate when it comes to measuring the mass of very small objects. To help us, we use **scales** or **balances**.

There are many different types of scales and balances. With some scales you simply put the object to be weighed on a pan and read the dial to find out the mass. With others you have to slide weights along a



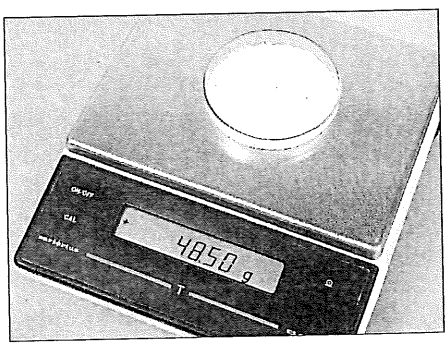


Figure 3.9 Balances used in science laboratories.

scale until you find the balance point. You then read off the mass from the scale.

The unit of mass is **grams** or **kilograms**. A five cent coin has a mass of about 3 grams.

One kilogram is the same thing as a thousand grams, while one tonne is the same thing as a thousand kilograms. A large car has the mass of about one tonne.

The abbreviation for gram is **g** and for kilogram is **kg**. For example, five grams is written as 5 g and five kilograms as 5 kg.

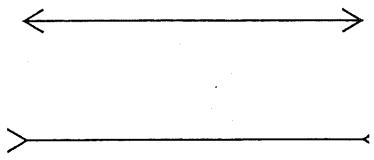


Figure 3.10 An optical illusion of length.

Length

Optical illusions are a good example of why we need an instrument to measure **length**. For example, which of the lines in Figure 3.10 is the longer? Use a ruler to check your choice.

To make the measurement of length more accurate we use a **rule**. A metre-rule is a rule that is one metre long and divided up into millimetres and centimetres. There are a thousand millimetres in one metre.

Large distances are measured in kilometres. There are a thousand metres in one kilometre. A kilometre is about twice around your school oval.

The symbols for the commonly used units of length are millimetre (**mm**), centimetre (**cm**), metre (**m**) and kilometre (**km**).

To measure very small sizes we can use instruments such as the **vernier callipers** or the **micrometer screw gauge**.

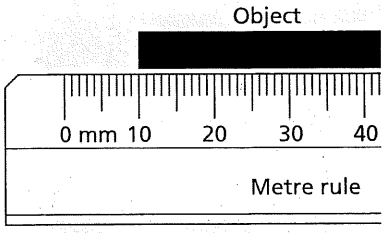


Figure 3.11 Measuring the length of an object with a rule. This object is 3.3 cm long.

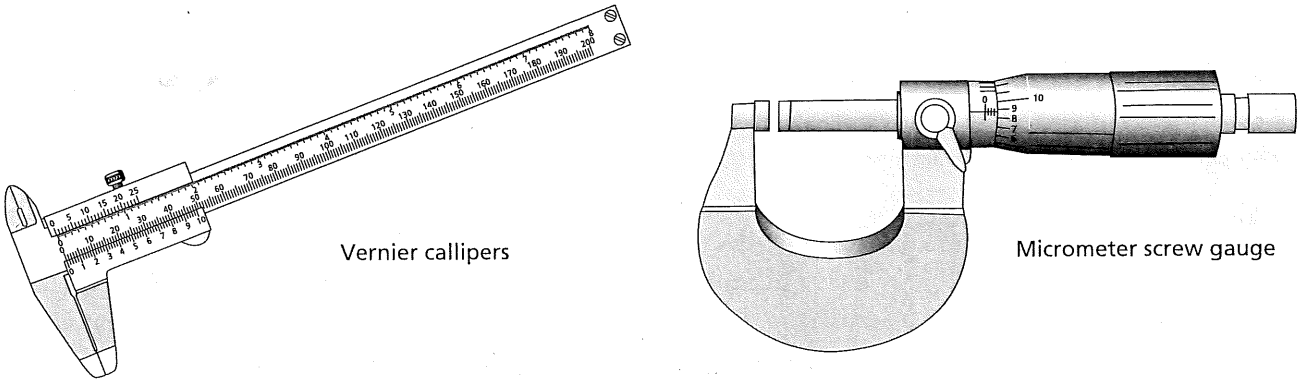


Figure 3.12 Instruments for measuring very small lengths accurately.

Area

Area refers to the amount of surface of an object. An object with a large surface has a large area. The area of a 20 cent coin is bigger than the area of a 5 cent coin.

However, sometimes it is difficult for us to judge the area using our senses alone. For example, which has the bigger area, a dinner plate or a page of this book? It is difficult to compare areas when they are different shapes.

With many objects we can measure some lengths and then use a **formula** to calculate the area. For example, to find the area of one page of this book, we measure the length and the width. Then multiply the two together to find the area. So the formula is:

$$\text{Area} = \text{length} \times \text{width}$$

For a triangle we can use the formula:

$$\text{Area} = 1/2 \text{ base} \times \text{height}$$

For a circle we can use the formula:

$$\text{Area} = \pi \times (\text{radius})^2$$

The unit for area will depend on the unit used to measure length. If the length was measured in centimetres, then the area is in **square centimetres**. This is written as **cm^2**.

Volume of solids

Volume is the amount of space taken up by an object. Sometimes we use instruments to measure this, or we can use a formula and calculate volume.

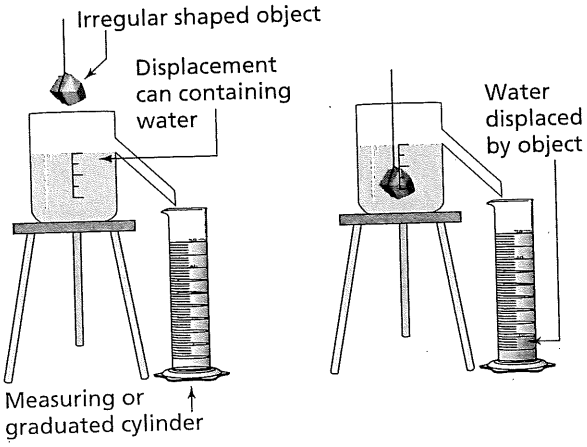


Figure 3.13 A displacement can is used to measure the volume of an object which is irregular.

Volume of regular-shaped solids

The volume of some solids can easily be calculated from a few measurements and a formula. The volume of a solid rectangular prism like a box can be calculated using:

$$\text{Volume} = \text{length} \times \text{width} \times \text{depth}$$

The units of volume will depend on the unit of length chosen. If length is in centimetres, then volume is in **cubic centimetres**. This is written as **cm^3**.

Volume of irregular-shaped solids

The volume of solids which have an unusual or irregular shape can be measured with a **displacement can** as shown in Figure 3.13.

Volume of liquids

The volume of a liquid cannot be measured using a formula since the shape of a liquid can change. It is easier to measure the volume of a liquid by placing it into a measuring vessel.

Cups, jugs and medicine glasses can all be used to measure the volume of a liquid. In the laboratory we use **measuring cylinders** or **beakers** to measure the volume of a liquid. Measuring cylinders are used when accurate volumes are required. The volume of a liquid is measured in **litres** or **millilitres**. The abbreviation for litre is **L**. The abbreviation for millilitres is **mL**. Milk comes in cartons which hold 600 mL or one litre.

One millilitre is equal to one cubic centimetre.

Measuring cylinders come in many sizes. Small ones measure up to 10 mL. Large ones can measure up to a litre. The scale on the side of the cylinder is used to tell how much liquid is in the vessel. However, the shape of the top surface of the liquid is not flat. It is always slightly curved. Always use the bottom curved surface when measuring the volume of the liquid. This curved surface of the liquid is called the **meniscus**.

One exception to the downward meniscus curve occurs with the liquid metal mercury. The reason for its upward curving meniscus will be examined later.

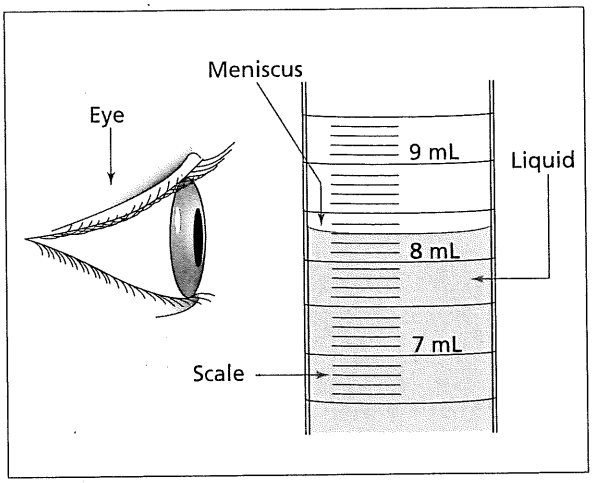


Figure 3.14 Reading a measuring cylinder with a curved meniscus. The volume of liquid here is 8.3 mL.

Time

Our sense of time is basically gained from the events that are occurring around us, such as the Sun rising and setting, mealtimes and school bells. These events indicate that it is a certain time in the day or that a certain time has elapsed since previous events occurred.

However, this is a very approximate measure of time which is dependent on the event occurring at approximately the same time-interval.

To measure time more accurately we use a **clock**, a **watch** or a **timer**. The basic unit of time is the **second**. As the second is an extremely small unit of time, larger units such as **minutes**, **hours** and **days** are used. There are sixty seconds in a minute and three thousand six hundred seconds in an hour.

Older-style clocks have second, minute and hour hands which circle around the face of the clock. These instruments work on a complex system of springs, spindles and cogged wheels. Newer timing devices are electronic and present the time as a digital read out.

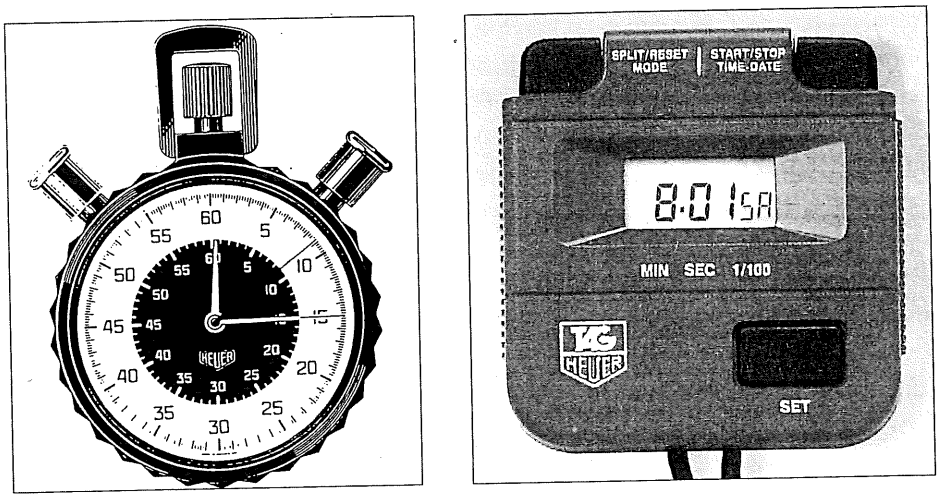


Figure 3.15 Mechanical and electronic timers are used to measure time.

Prefixes for units

When writing units in science, we often use what we call prefixes. A prefix is a word written at the start of a unit which indicates the size of the unit. For example, one prefix you will probably know is kilo. This means one thousand times. So one kilometre means one thousand times one metre, which is one thousand metres. The most important prefixes which you need to know are:

kilo	means	1000	times
deci	means	1/10th	(one tenth)
centi	means	1/100th	(one hundredth)
milli	means	1/1000th	(one thousandth)

Summary

- An observation is information gained from our senses. These senses are sight, hearing, smell, taste and touch.
- Care should be taken when using smell and taste for observations. Poisonous chemicals may cause harm.
- Scientific instruments can be used to extend our senses.
- Sight can be extended by microscopes, telescopes and hand lenses.
- Hearing can be extended by microphones, amplifiers and stethoscopes.
- A measurement is a number obtained when making an observation using an instrument.
- Measurements are more accurate and reliable than observations made using the senses alone.
- Temperature is measured by thermometers.
- Mass is measured by scales and balances.
- Length is measured by a rule, micrometer, screw gauge or vernier callipers.

- The surface area of regular-shaped objects can be calculated from length measurements.
- The volume of regular-shaped objects can be calculated from length measurements.
- The volume of irregular-shaped objects can be measured using a displacement can.
- The volume of a liquid is measured by a measuring cylinder or beaker.
- Time is measured with a timer.
- The following units of measurement are used:

Temperature	degrees Celsius (°C)
Length	metres (m), centimetres (cm), millimetres (mm), kilometres (km)
Mass	grams (g), kilograms (kg)
Volume	cubic centimetres (cm^3), cubic metres (m^3)
Liquid volume	litres (L), millilitres (mL)
Time	seconds (s), minutes (min), hours (h).

Questions

1 **a** What is an observation?
b Which senses are used in making observations?
2 **a** Describe the safest way to smell an unknown gas in a test tube.
b Why is this method used?
3 What instruments could you use to extend your sense of:
a sight, and
b hearing?
4 **a** What is a measurement?
b Why do scientists use measurements?
5 What instrument would you use to measure the temperature of:
a a cup of hot water, and
b your body if you thought you may have a fever?
6 What instruments are used to measure:
a the mass of an object, and
b the length of an object?
7 What units are usually used to measure:
a length,
b temperature,
c mass, and
d time?
8 Convert the following:
a 4000 g to kg,
b 100 mL to L,
c 0.04 m to cm,
d 5.7 L to mL,
e 600 s to min,
f 100 mm to m, and
g 120 min to h.

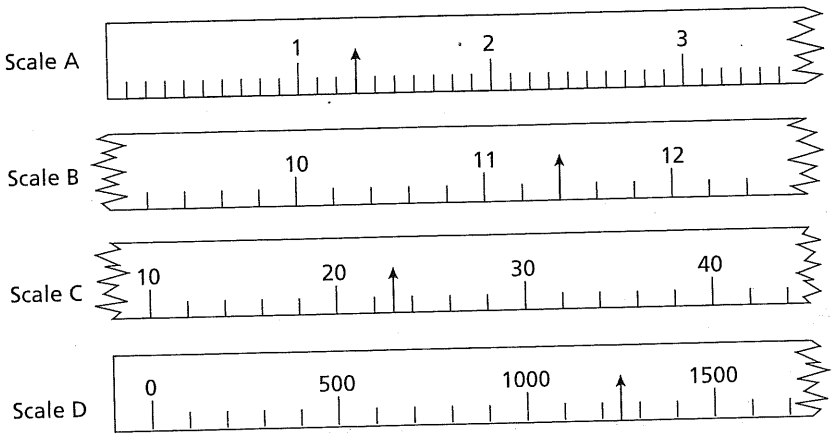


Figure 3.16 Use these scales to answer Question 9. The arrow on each scale shows the reading on the instrument.

9 What are the readings on each of scales A, B, C and D in Figure 3.16?

10 A student wanted to find the area of a rectangular piece of paper. She found the length was 29 cm and the width was 21 cm. What was the area in cm^2?

11 What is the volume of sand in a trailer if the trailer is 182 cm long, 122 cm wide and 30 cm deep?

12 Describe how you could find the volume of a rock which was about the size of a table tennis ball, but which was an irregular shape.

13 **a** What instrument would you use to measure the volume of water in a cup?
b Describe how to accurately read the level on the scale.

14 **a** How many metres in a kilometre?
b How many litres in a decilitre?
c What part of a gram is a milligram?
d How many centimetres in a metre?

15 Use the library to find out what the following instruments are used to measure:
a sphygmomanometer,
b voltmeter,
c glucometer,
d barometer, and
e tachometer.

16 **a** Find the names of five instruments that are used in your home or car to measure quantities.
b What does each instrument measure?
c In what units does each instrument measure?