2 Measurement

To give a general idea about things around us, we use terms like large, heavy, slow, and so on. However, quite often we need to say exactly how large, heavy or slow something is. To do so, we need to measure its 'largeness', 'heaviness' or 'slowness'.

We measure things every day. A grocer or a vegetable seller weighs things on a weighing scale. A tailor takes a person's measurements with a measuring tape, and then uses a scale to measure the cloth before cutting it. A petrol pump automatically measures the petrol being filled in a car. Each one of us keeps track of the time continuously with the help of a watch.

In science, a quantity that can be measured is called a physical quantity. The length of a piece of cloth, the time at which school begins and the volume of petrol are all physical quantities.

Measuring a Physical Quantity

Any measurement is a process of comparison. We compare an unknown physical quantity with a known physical quantity. The known quantity is called the unit of measurement.

Suppose we wish to measure the length of a room. Then the length of the room is the unknown quantity. We first need to choose a known standard length with which we can compare the length of the room. One metre is a known quantity. Let us choose this as our unit of length. Then we compare the length of the room with this unit. Suppose we find that this length is 5.4 times the unit. We then say that the length of the room is 5.4 metres.

In this example, the length of the room is a physical quantity. The measured value, in this case 5.4 metres, is called the magnitude of the physical quantity. Thus, the magnitude has two parts—a number (5.4) and a unit (metre). Remember: the magnitude of a physical quantity consists of a number and a unit.

UNITS

A unit is a known measure of a physical quantity with which physical quantities of the same kind are compared. The centimetre, metre and inch, for example, are units of length. Each of these represents a particular length. The unit we use in a measurement is a matter of choice and convenience. For example, you could choose to measure the width of a small box in centimetres or inches. But to measure the length of a curtain, you would find it more convenient to use the metre.

Traditional Units

In ancient times, different parts of the body, such as the hand or foot, were used to measure length.

Obviously, measurements using such units varied from person to person. In Indian villages, you will still find distances being expressed in *kos* (about 3 km), and units such as *kattha* and *bigha* being used as units of land area. These units often have different values in different regions. Another unit which has different values in different regions is the gallon. One gallon represents different volumes in the UK and the USA. Units that are not clearly defined and which do not have the same value everywhere are considered nonstandard.

Fig. 2.1 Different parts of the body were used to measure length earlier.

ACTIVITY Find as many units as you can for measuring distances and land areas. Find out the exact value of each of these. Are there any units whose values are not clearly defined? How many of them are in use at present?

The use of nonstandard units leads to many problems. For example, the same experiment could yield different results in different parts of the world. To avoid such problems, we need a set or system of standard units which has the following characteristics.

1. The system of units should be used everywhere.
2. The units should be precisely defined and have the same value everywhere.
3. The units should be of convenient size. (For example, if the mile were the only unit of length, we would find it inconvenient to measure small lengths.)

The Metric System

Near the end of the 18th century, a system of standard units called the metric system was developed in France. The units for length, mass, volume and area were called the metre, gram, litre and are respectively in this system. The metric system is a logical and convenient system for the following reasons.

- A single unit is defined for each physical quantity, such as length and mass.
- Larger or smaller forms of a unit can be created by multiplying it by factors, such as $1000 (= 10^3)$ or $0.01 (= 1/10^2)$. In other words, the larger and smaller forms of a unit are related to each other by powers of 10.

Multiples and submultiples of units

The factors for creating larger and smaller forms of a unit, called multiples and submultiples of the unit respectively, are also defined clearly. Each factor is represented by a prefix, which denotes its value. These prefixes are added before the name of the basic unit to form multiples or submultiples of the unit. Some prefixes, their symbols and the factors they represent are given in Table 2.1.

Table 2.1 Factors and prefixes

Factor	Prefix	Symbol of prefix
1000 ($=10^3$)	kilo-	k
100 ($=10^2$)	hecto-	h
0.01 ($= 1/10^2 = 10^{-2}$)	centi-	c
0.001 ($= 1/10^3 = 10^{-3}$)	milli-	m
0.000001 ($= 1/10^6 = 10^{-6}$)	micro-	µ

Let us consider the metre, which is the unit of length in the metric system. All lengths or distances can be expressed in terms of its multiples or submultiples. Here are a few examples.

- Large distances, like the distance between towns, are measured in kilometres (km). The prefix 'kilo-' represents the factor 1000. So, the kilometre, a multiple of the metre, is 1000 times the metre (m), i.e., 1 km = 1000 m.
- Smaller lengths, like the length of an eraser or the thickness of a pencil, are measured in centimetres (cm) or millimetres (mm). These units are submultiples of the metre: 1 cm = 0.01 m and 1 mm = 0.001 m.
- Very small sizes, like the thickness of a hair, can be measured in micrometres (µm). One micrometre equals 0.000001 m.

SI Units

Though the metric system was adopted by many countries, scientists soon realised that it needed certain improvements. In 1960, representatives from different nations put together a system of units, based on the metric system, which is now used all over the world. It is called *Système International d'Unités* (International System of Units), SI in short. This system defines the units of seven quantities, called base quantities or fundamental quantities. Of these, we will require the four given in Table 2.2.

Table 2.2 Some base quantities, their units and symbols

Quantity	Unit	Symbol of unit
Mass	kilogram	kg
Length	metre	m
Time	second	s
Temperature	kelvin	K

It is enough to define the units for the base quantities because the units for other quantities can be obtained by combining the base units. For example, we can get the unit of area from its formula, which is 'length × length'. Since the unit of length is the metre, the unit of 'length × length' is 'metre × metre', written as metre^2 or m^2. Similarly, the unit for volume is m^3.

In SI, the multiples and submultiples of units are formed as in the metric system.

Writing units correctly

In SI, we follow certain rules for writing units.

- If a unit is named after a person, we use small letters when writing it in its full form. For example, we write kelvin, and not Kelvin. Similarly, we write watt, newton and joule, although these units are named after persons.
- When we write the symbol of a unit named after a person, we use a capital letter. For

example, we write K for kelvin, W for watt, N for newton and J for joule.

- When we write units which are not named after persons, we use small letters for the units and their symbols. For example, metre or m, second or s.
- The plural form of a unit is used when it is written in full. But an 's' is not added if the symbol of the unit is used. Thus, we write 2 metres or 2 m, but not 2 ms. Note that ms stands for millisecond.
- The symbols of the prefixes are written in small letters. For example, the symbol for kilo- is k, so the symbol for kilometre is km, and not Km. K stands for kelvin.

MEASUREMENT OF LENGTH

Any measurement requires some measuring device or instrument. When we measure the length of an object, the device we choose depends mainly on the size of the object. For small objects, like books, you can use either a 6-inch (15-cm) plastic scale, or a 12-inch (30-cm) ruler. For somewhat larger objects, like a table, you would have to use a tape measure. Tape measures are available in various lengths, such as 1.5 m and 2 m.

Fig. 2.2 Devices used for measuring length

Fig. 2.3 Measuring the length of a rectangular box

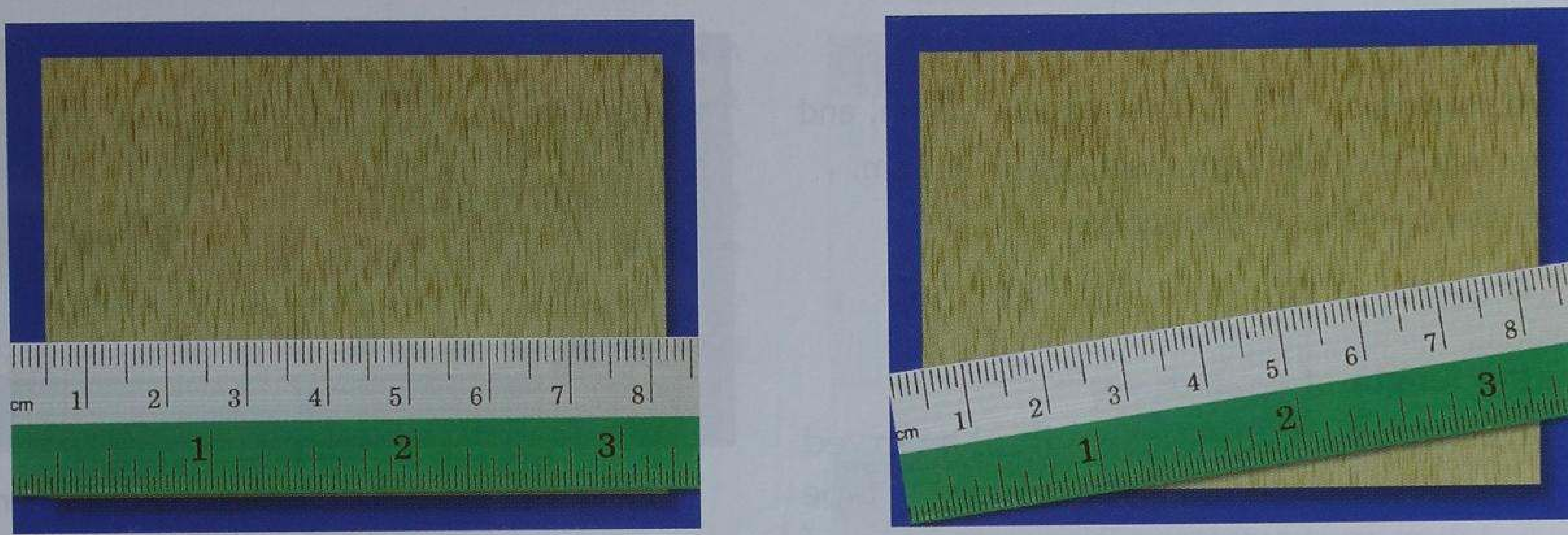
Figure 2.3 shows how to measure the length of a small rectangular box, for example, a cassette case. The scale is placed parallel to one of the longer edges of the case in the figure. The left edge of the case is exactly at the 2-cm mark of the scale, while its right edge coincides with the 12.8-cm mark. The difference between the readings gives the length of the case, which is (12.8 – 2.0) cm = 10.8 cm.

ACTIVITY Use a 30-cm ruler to measure the breadth of this book. Use a tape measure to measure the length of your desk.

Precautions Involved in Measurement of Length

You should take the following precautions in order to measure the length of an object correctly.

1. Avoid using the ends of the scale Do not use the ends of a scale while taking measurements. The edges of a scale sometimes get damaged with use and this can lead to errors. This is why the left edge of the case in Figure 2.3 is not placed at the zero mark of the scale.



(a) (b)

Fig. 2.4 (a) Correct placement of scale (b) Incorrect placement of scale

2. Place the scale properly Place the scale parallel to the length you are measuring. Also, place it as close to the object as possible. Figure 2.4 shows two situations. You can make out that the results are different in the two cases.

3. Place your eye correctly When looking at a scale placed horizontally, your eye should be vertically above the mark you are reading. Similarly, if the scale is upright, your eye should be horizontally in line with the mark you are reading.

Figure 2.5 shows a sharpened pencil placed above a scale. The readings corresponding to the tip of the pencil seen from three different positions of the eye are also shown. You can see that the correct reading is obtained only when the eye is placed vertically above the mark being read. In the other positions, the reading is either more or less than the actual value. This type of error, caused by positioning the eye wrongly, is called parallax error.

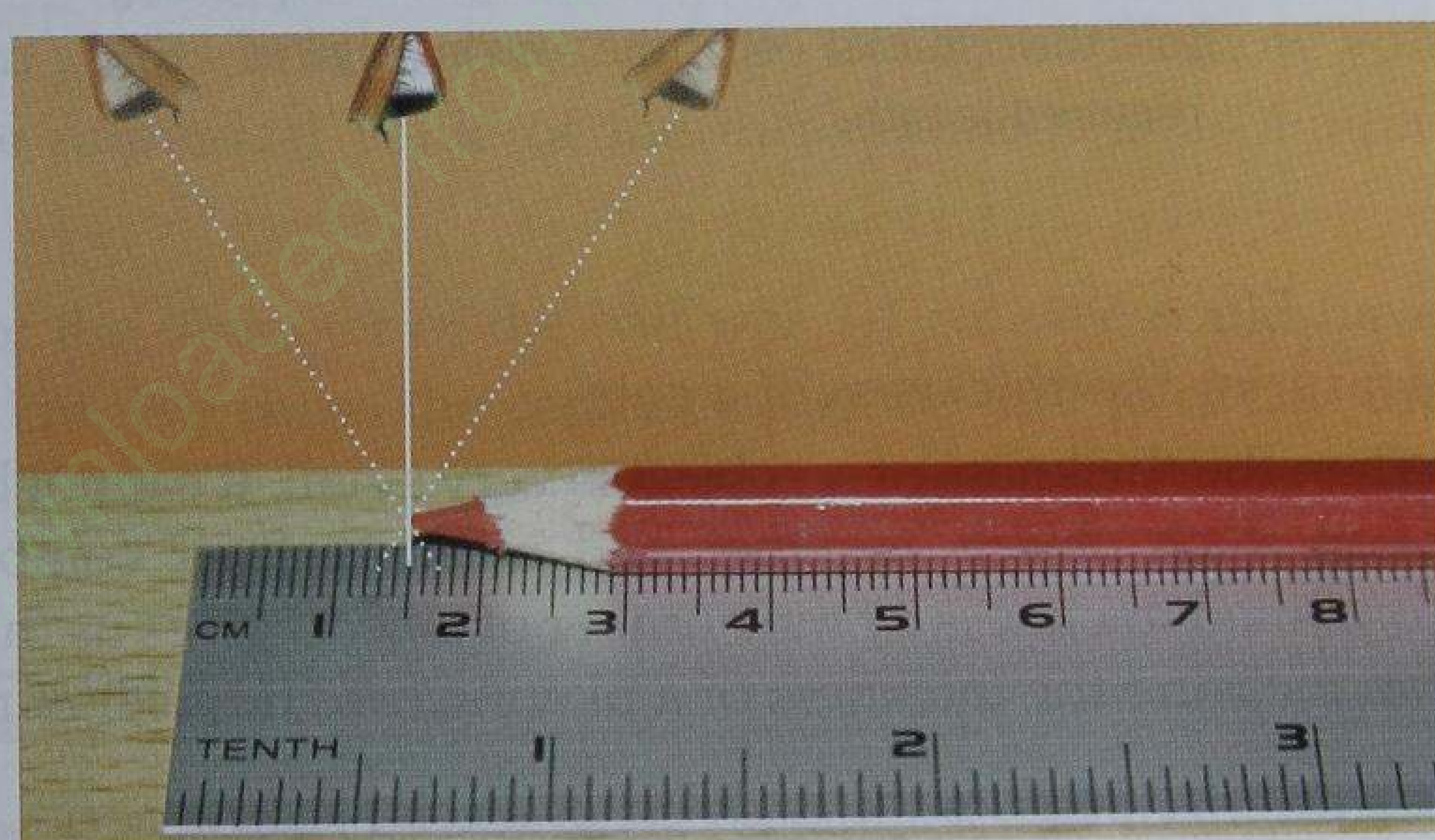


Fig. 2.5 Positioning the eye wrongly causes parallax error.

Indirect Measurements of Length

We sometimes face situations in which direct measurements are not possible. For example, we cannot measure the diameter of a sphere or the length of the curved edge of a tray directly by placing it against a scale. To measure such things we use indirect methods.

Measuring the diameter of a sphere

ACTIVITY To measure the diameter of a sphere (ball), place it between two blocks. Place a scale against the blocks, as shown in Figure 2.6. Then read the position of the inner edge of each block on the scale. The difference between the readings is equal to the diameter of the sphere.

In Figure 2.6,

the reading of the left inner edge = 1.0 cm, and

the reading of the right inner edge = 4.1 cm.

So, the diameter of the sphere

= 4.1 cm – 1.0 cm = 3.1 cm.

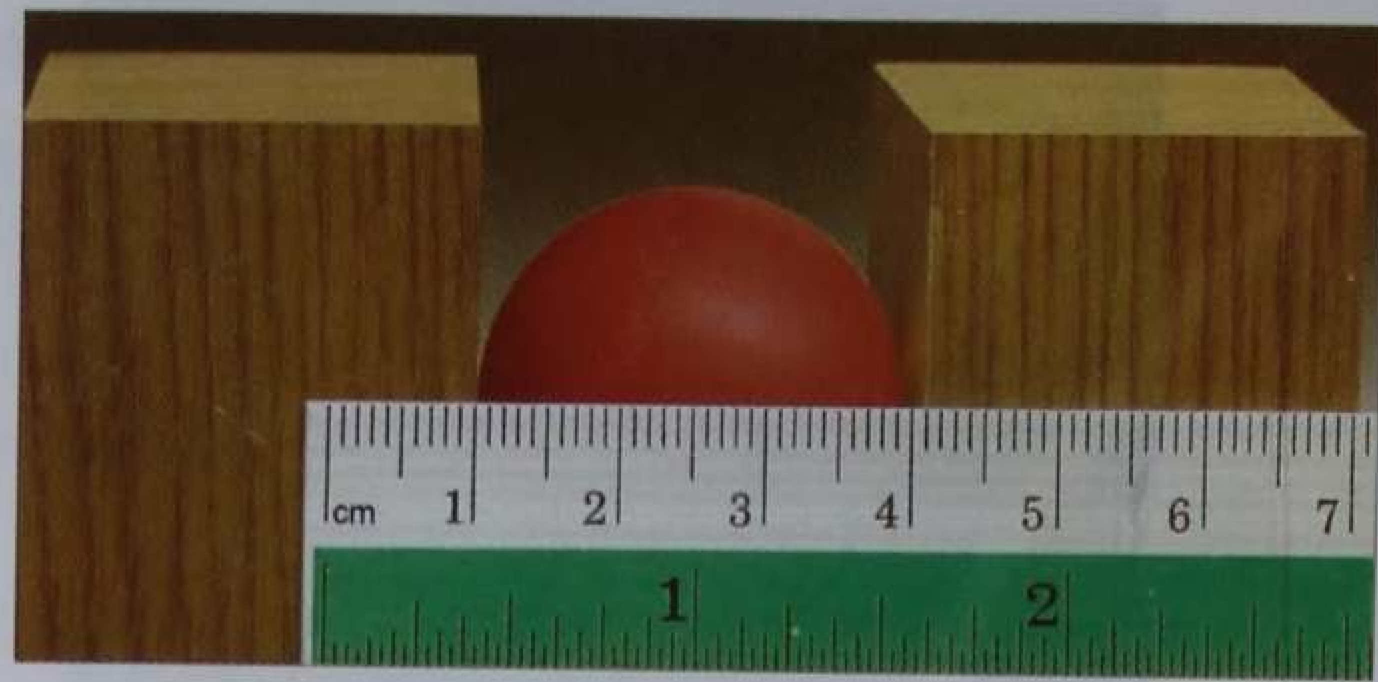


Fig. 2.6 Measuring the diameter of a sphere

Measuring the length of a curve

You can sometimes measure the length of a curved surface or edge with the help of a common tape measure. A tailor measures the circumference of your neck or waist this way. You can also use a string and a scale to measure the length of a curved line or a curved surface indirectly. Let us find out how.

ACTIVITY Choose two points on a curved surface (like that of a cup). Stretch a string tightly along the surface between these points. Use a pen to make marks on the string coinciding with the points. Straighten the string, and place it on a scale. The difference between the readings corresponding to the marks on the string gives the required length.

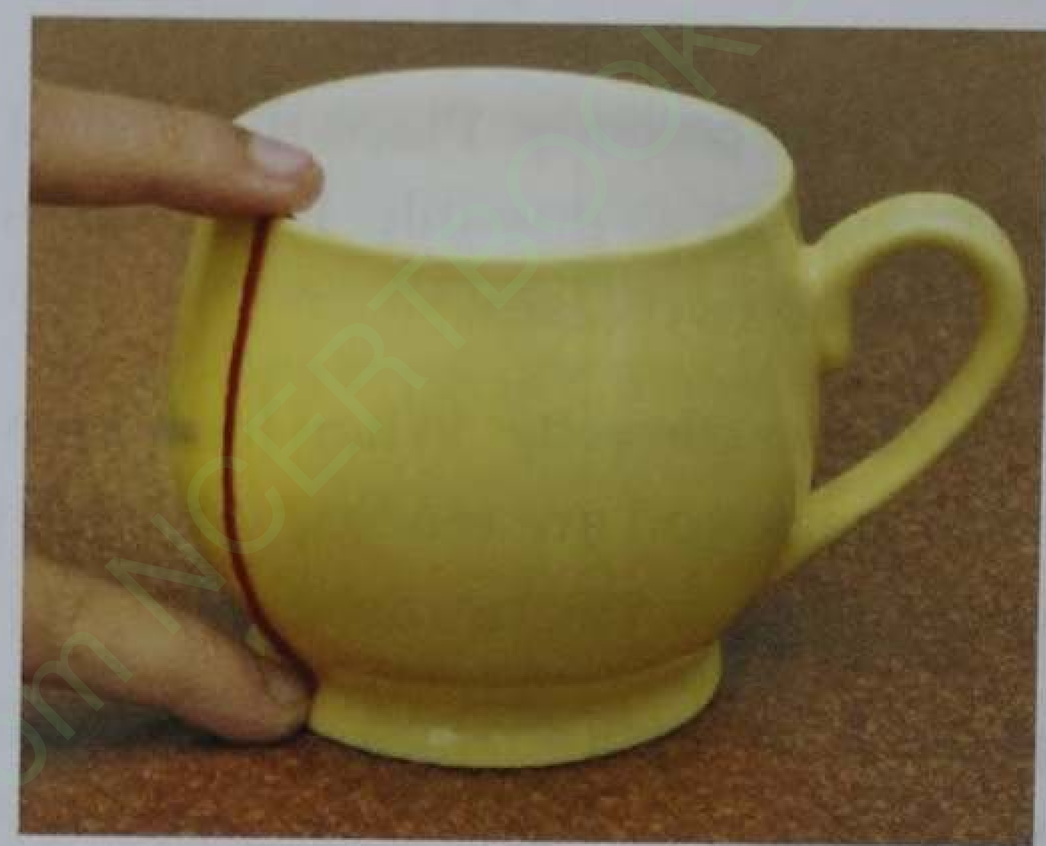


Fig. 2.7 Measuring with a string

Measuring the thickness of a coin

When the thickness of an object is very small, it cannot be measured directly with a scale. Then we put many such objects together and measure their combined thickness. Dividing the measure of the combined thickness by the number of objects gives us the thickness of the object. Using this method, we can measure the thickness of a playing card, a sheet of paper or a coin.

ACTIVITY To measure the thickness of a coin, make a neat pile of 10 similar coins. Measure the combined thickness of the coins, as shown in Figure 2.8.

The number of coins = 10.

The combined thickness of the coins

= 6.4 cm – 3.5 cm = 2.9 cm.

So, the thickness of 1 coin

$$= \frac{2.9}{10} \text{ cm} = 0.29 \text{ cm} = 2.9 \text{ mm}.$$

Fig. 2.8 Measuring the thickness of a coin

Measuring the thickness of a wire

To measure the thickness (diameter) of a wire, we can use the principle used in measuring the thickness of a coin. The following activity will make this clear.

ACTIVITY Wind about 30–40 turns of the wire around a pencil. (If the wire is very thin, wind about 100 turns.) The turns of the wire should touch each other. Measure the combined thickness of all the turns with the help of a scale (Figure 2.9). Divide the measured length by the number of turns to get the thickness of the wire. In Figure 2.9,

the number of turns = 34, and

the thickness of 34 turns

$$= 12.2 \text{ cm} - 10 \text{ cm} = 2.2 \text{ cm}.$$

So, the thickness of 1 turn

$$= \frac{2.2}{34} \text{ cm} = 0.06 \text{ cm} = 0.6 \text{ mm}.$$

Thus, the diameter of the wire is 0.6 mm.

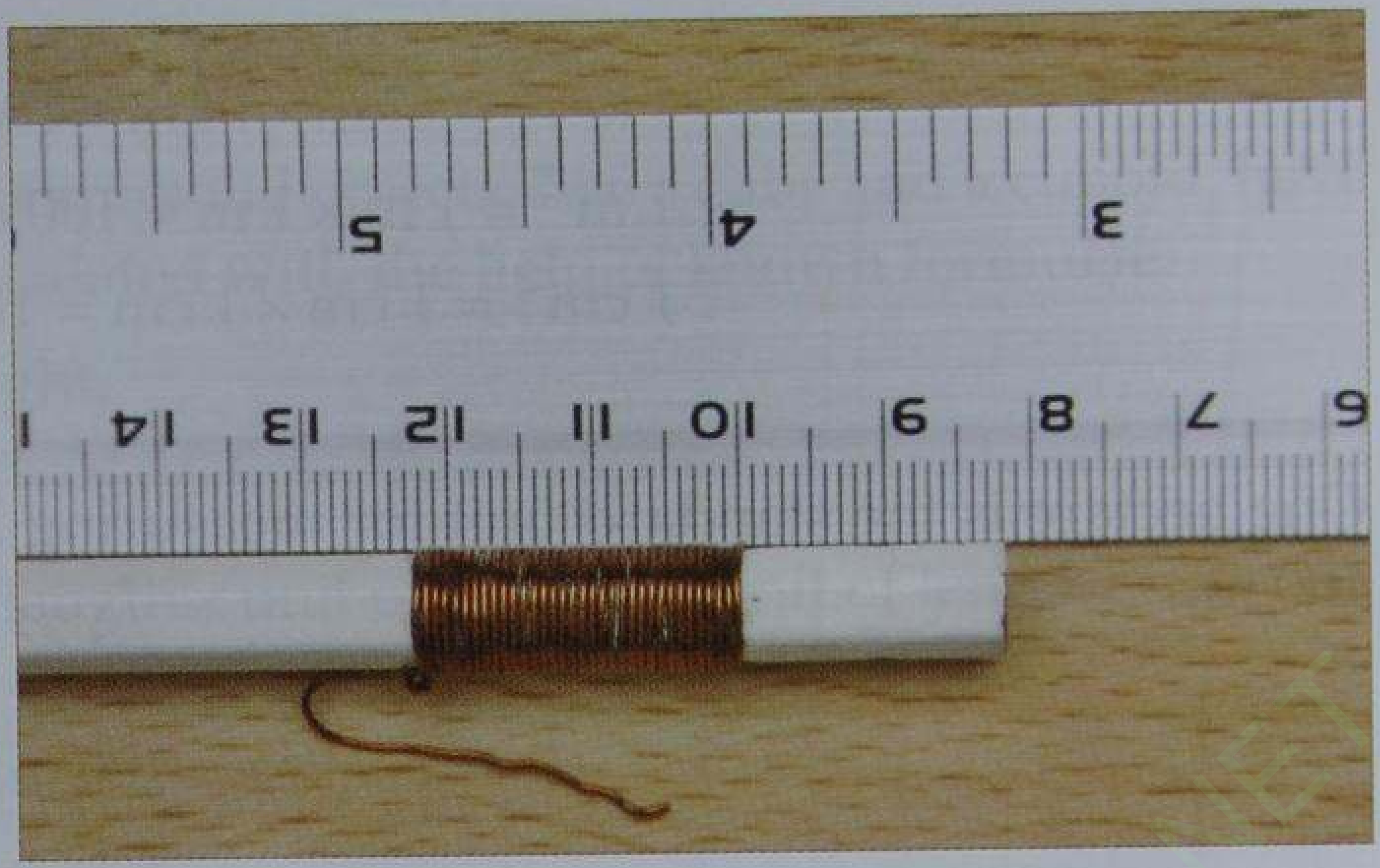


Fig. 2.9 Measuring the diameter of a wire

Selection of Units

In the activities we have discussed, we have used different units of length. We expressed the diameter of a wire in millimetres and the diameter of a small sphere in centimetres. We often express the length of a room in metres and the distances between places in kilometres. A little thought will show you that we select a unit in such a way that the numerical value of the measurement is as simple as possible.

To take an example, the measured value of the diameter of the ball was 3.1 cm. We could have written this as 31 mm or 0.031 m or 0.000031 km. We chose the centimetre as the unit to obtain the simplest possible numerical value.

MEASUREMENT OF AREA

Area is the measure of the region inside a closed line. Circles, squares, rectangles and triangles are common examples of figures formed by closed lines. We can calculate the areas of such figures with the help of known formulae. You are already familiar with some of these.

The area of a rectangle = length × breadth.

The area of a square = side × side = side^2.

So, the unit of area

= unit of length × unit of length

= (unit of length)^2.

Thus, if length is measured in metres, the unit of area will be metre^2, or m^2. This is the correct abbreviation for the unit of area, and is read as 'metre square'. Some other units of area are mm^2, cm^2 and km^2. The relations between these units are as follows.

$$1\ \text{km}^2 = 1\ \text{km} \times 1\ \text{km} = 1000\ \text{m} \times 1000\ \text{m} = 1{,}000{,}000\ \text{m}^2$$
$$1\ \text{m}^2 = 1\ \text{m} \times 1\ \text{m} = 100\ \text{cm} \times 100\ \text{cm} = 10{,}000\ \text{cm}^2$$
$$1\ \text{cm}^2 = 1\ \text{cm} \times 1\ \text{cm} = 10\ \text{mm} \times 10\ \text{mm} = 100\ \text{mm}^2$$

One hectare is the standard unit for measuring land area. It is equal to the area of a square of side 100 m.

$$1\ \text{hectare} = 100\ \text{m} \times 100\ \text{m} = 10{,}000\ \text{m}^2$$

EXAMPLE A square field has sides measuring 1 km. Express its area in hectares.

The area of the square = 1 km × 1 km

$= 1000\ \text{m} \times 1000\ \text{m} = 1{,}000{,}000\ \text{m}^2.$

$\because$ $10000\ \text{m}^2 = 1$ hectare,

$1000000\ \text{m}^2 = \dfrac{1000000}{10000}$ hectares $= 100$ hectares.

$\therefore$ the area of the square = 100 hectares.

Measuring Irregular Areas

To find the area of a figure with a regular geometric shape, like a square, rectangle or triangle, we need to make only one or two measurements. Then we can obtain the area using standard formulae. However, to find the area of an irregular shape, we have to use a graph paper.

A graph paper has a number of parallel lines, both horizontal and vertical. The thicker lines are 1 cm apart, while the thinner lines are 1 mm apart. Thus, the entire paper is divided into small squares of area 1 mm^2 each, and larger squares of area 1 cm^2 each.

ACTIVITY Place a piece of paper or cardboard with an irregular shape on a graph paper and draw its outline. To find the area enclosed by the outline, count the number of squares inside it. You will find that some squares lie partially inside the outline. Count a square only if half or more of it lies inside the outline. The total number of squares, multiplied by the area of each square, gives the area inside the outline. For the shape in Figure 2.10, we have the following.

The number of complete squares within the outline = 10.

The number of squares with half or more within the outline = 7.

The total number of squares = 17.

$\because$ the area of each large square = 1 cm^2,

the area of the irregular shape = 17 × 1 cm^2 = 17 cm^2.

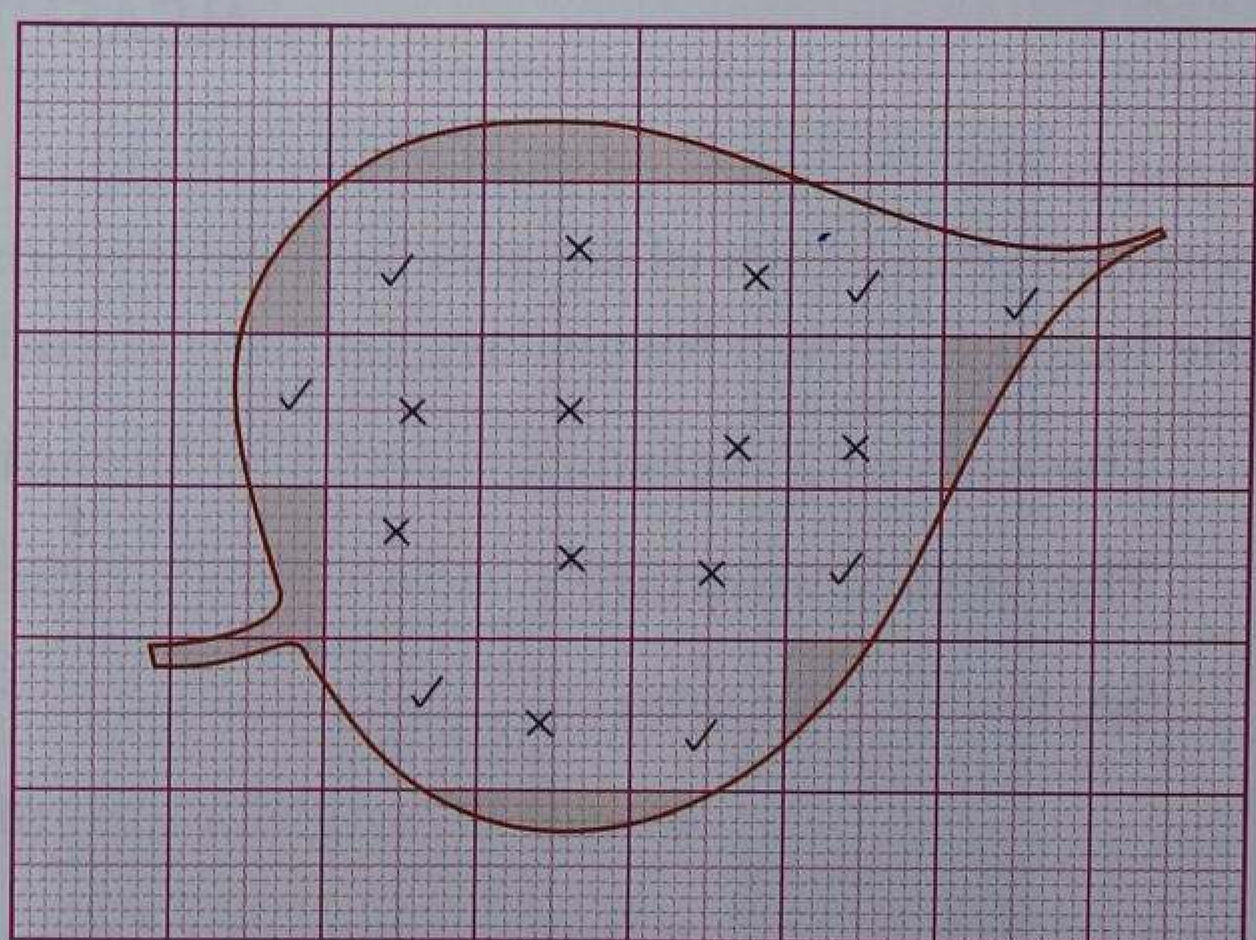


Fig. 2.10 Measuring the area of an irregular shape

MEASUREMENT OF VOLUME

The volume of an object is the space occupied by it. Some solid objects, like a cube and a cuboid, have regular geometric shapes. Their volumes can be calculated with the help of known formulae.

The volume of a cuboid = length × breadth × height.

The volume of a cube = side × side × side = $side^3$.

So, the unit of volume = unit of length × unit of length × unit of length = $(\text{unit of length})^3$.

Thus, if length is measured in metres, the unit of volume is $metre^3$, or m^3. This is read as 'metre cube'. A widely used unit of volume is the cm^3, which is also written as cc (cubic centimetre). The litre (symbol L) and the millilitre (mL) are other popular units of volume. These are generally used to measure the volume of liquids.

$$1\ m^3 = 1\ m \times 1\ m \times 1\ m$$
$$= 100\ cm \times 100\ cm \times 100\ cm = 1{,}000{,}000\ cm^3$$
$$1\ L = 1000\ cm^3$$
$$1\ mL = 1\ cm^3$$

Measuring the Volume of Liquids

The volume of a liquid is measured using special containers. The volume of liquid which a container can hold is called its capacity. Capacity has the same unit as volume.

Some containers used for measuring the volume of liquids have fixed capacities. Figure 2.11 shows two such containers. Conical measuring cans are generally used to measure liquids which are sold by volume, such as kerosene. Metal cups with long handles are commonly used for measuring milk or cooking oil.

Fig. 2.11 Containers with fixed capacities

Containers with fixed capacities have some disadvantages. They cannot be used to measure smaller volumes. A milkman using a 500-mL container, for example, cannot measure 250 mL of milk. Also, to measure 2 L of milk, he has to fill the container four times. If he makes an error in each measurement, the total volume of milk measured could be considerably less than 2 L.

To measure the volume of a liquid with greater accuracy, a graduated container is used. The wall of such a container has graduations, or lines to show measurements. Measuring cylinders and measuring cups are two commonly used graduated containers (Figure 2.12).

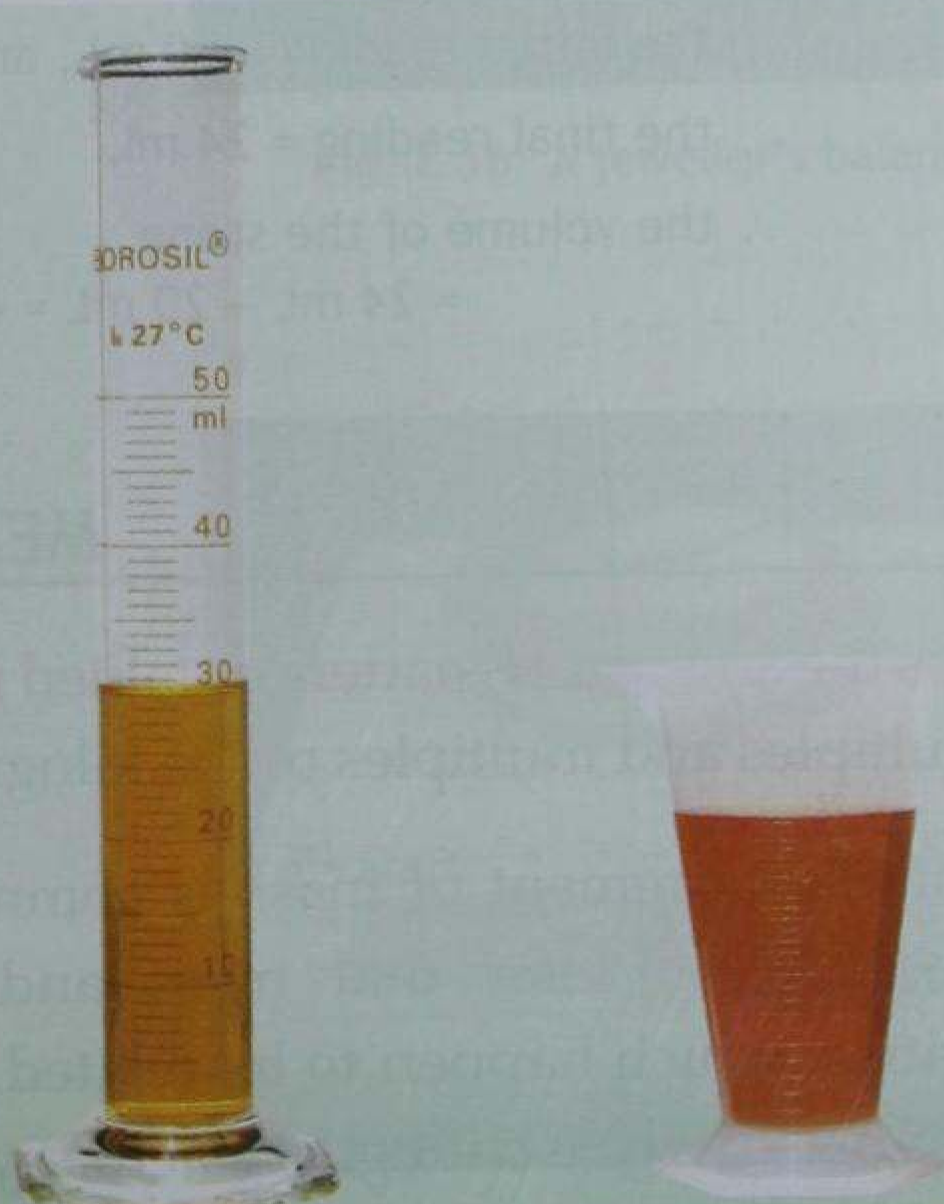


Fig. 2.12 A measuring cylinder and a measuring cup

ACTIVITY Glass or plastic syringes used for injecting medicines are graduated. Use a syringe to find the volume of one teaspoonful of water. We often use a teaspoon to measure medicine or honey. Now you know the volume measured by a teaspoon.

Fig. 2.13

Measuring the Volume of Irregular Solids

When a solid is immersed in water, it makes space for itself by displacing water. Obviously, the volume of water displaced by a solid is equal to the volume of the solid. This fact is used to measure the volume of irregular solids. Let us see how by trying to find the volume of a stone.

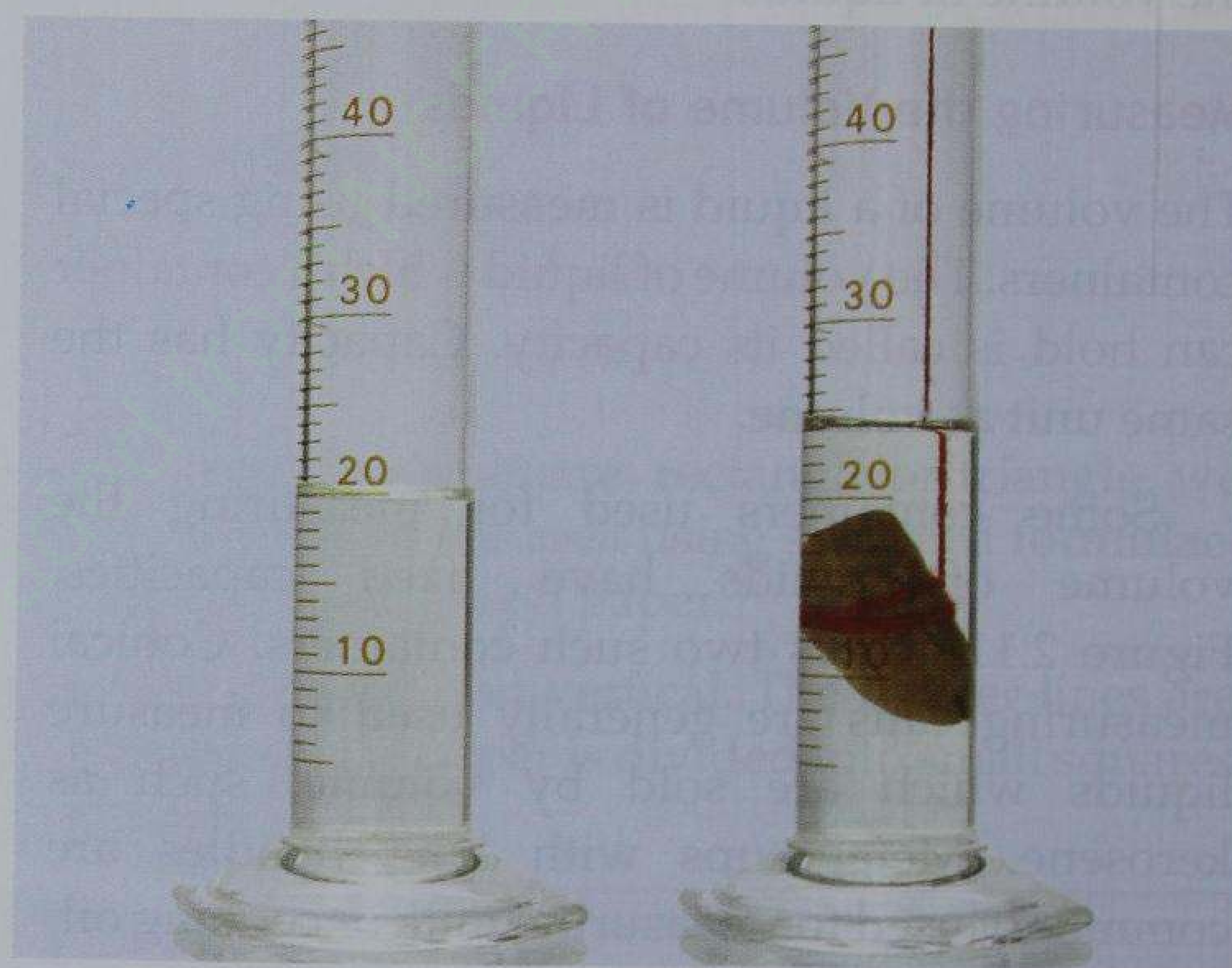
ACTIVITY You will need a measuring cylinder, a small stone which can move easily inside the cylinder, some string and water. Take some water in the cylinder, as in Figure 2.14(a). Read the level of water on the scale marked on the wall of the cylinder. Then tie the string around the stone, and lower it gently into the water till it is completely submerged, as in Figure 2.14(b). Read the level of water again. The difference between the two readings gives the volume of the stone. For the case shown in Figure 2.14,

the initial reading = 20 mL, and

the final reading = 24 mL.

∴ the volume of the stone

= 24 mL − 20 mL = 4 mL.



(a) (b)

Fig. 2.14 Measuring the volume of a stone

MEASUREMENT OF MASS

Mass is the amount of matter contained in a body. The SI unit of mass is the kilogram (kg). The common submultiples and multiples of the kilogram are given in the box.

The measurement of mass is commonly called weighing. You will learn later that mass and weight are different quantities, which happen to be related. When we say that the weight of a body is 10 kg, we actually mean that its mass is 10 kg. Now let us look at some common weighing devices.

1 kg = 1000 grams (g)
1 g = 1000 milligrams (mg)
1 quintal = 100 kg
1 metric ton = 1000 kg

Simple Beam Balance

The simplest weighing device is the common beam balance, or the traditional scales (*tarazu*). It consists of two identical pans suspended from the ends of a beam or rod. The beam can be suspended from its midpoint by a string or handle. Some balances have a metallic pointer at the middle of the beam. This becomes vertical when the beam is horizontal.

Fig. 2.15 Commonly used scales

To find the mass of an object with a balance, we compare it with the known mass of standard weights. The object is placed on one pan, and the standard weights are placed on the other. The beam becomes horizontal when the mass of the object is equal to the total mass of the standard weights on the other pan.

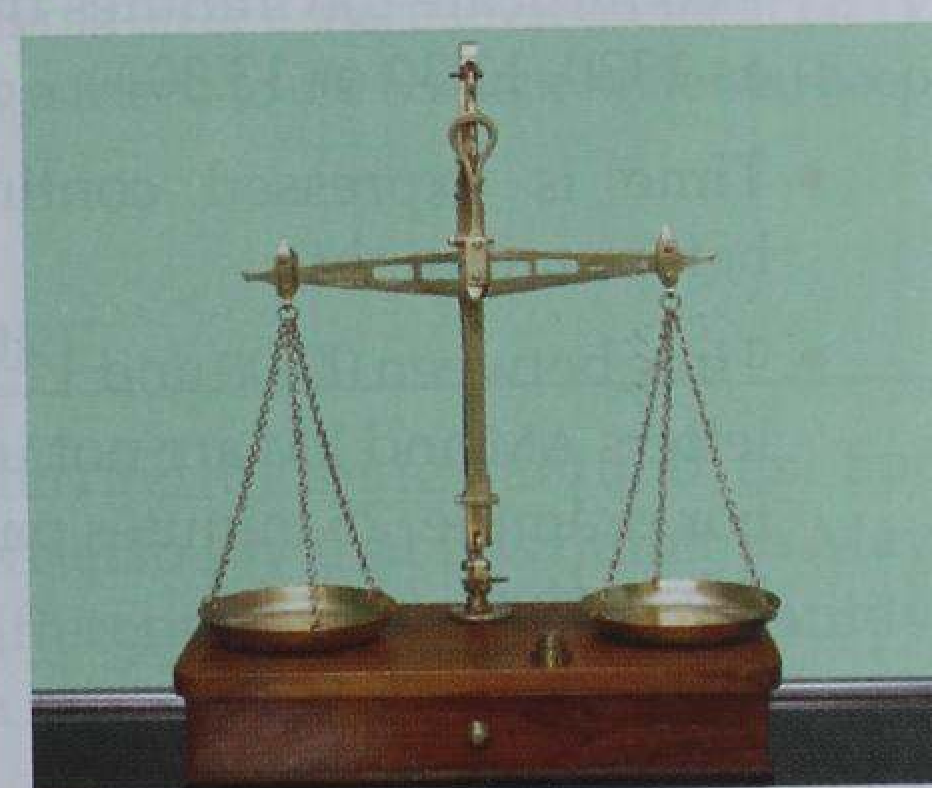


Fig. 2.16 A jeweller's balance

A variation of the traditional scales is widely used in shops selling groceries and sweets. It is somewhat like a see-saw. The pointer at the centre becomes vertical when the masses in the two pans are equal.

Other Weighing Devices

The balances we have discussed cannot measure small masses accurately. That is why jewellers, scientists and others, who need to weigh small amounts of matter accurately, use modified forms of the simple beam balance. The physical balance in your school's physics laboratory is one such balance. Electronic weighing machines are also used for accurate measurements. An electronic weighing machine does not require standard weights for comparison. It displays the mass of an object placed on its pan directly.

Fig. 2.17 An electronic weighing machine

MEASUREMENT OF TIME

The measurement of time plays an important role in our lives. The SI unit of time is the second (s). Minute (min), hour (h) and mean solar day are other common units of time.

1 min = 60 s

1 h = 60 min = 3600 s

One mean solar day = 24 h = 86400 s

The time of day is expressed in hours and minutes, sometimes followed by seconds. Thus, the time 7:28:05 means 7 hours, 28 minutes and 5 seconds after a fixed time. In the commonly used 12-hour-clock system, the day is divided into two 12-hour periods. In this system, to indicate a time between midnight and noon, AM is written after the time. And to indicate a time between noon and midnight, PM is used. Thus, 7 AM is 7 hours after midnight, and 7 PM is 7 hours after noon.

The 24-hour Clock

Services which operate continuously throughout the day and night, such as the railways and the airlines, use the 24-hour clock. In this system, the day is not divided into two 12-hour periods. Instead, time is expressed as the number of hours and minutes that have passed since midnight. The main features of this system are as follows.

- Time is always shown by 4 digits. The first two digits indicate the hours and the next two indicate the minutes that have passed since midnight. Thus, 1:30 PM is expressed as 1330, 13:30 or 13.30.
- Time is expressed continuously from 00:00 (midnight) to 23:59 (one minute before midnight).
- Time between 00:00 and 11:59 denotes AM, and between 12:00 to 23:59 denotes PM. The letters AM and PM are not used in this system because there is no chance of confusion. For example, 25 minutes past noon is 12:25, while 25 minutes past midnight is 00:25 in this system.

Conversion

You can easily convert any time expressed in the 24-hour system to the corresponding time in the 12-hour system.

- To convert a time between 00:00 (midnight) and 00:59, add 12:00 to get the time in AM. Thus, 00:00 is 12:00 AM, and 00:55 is 12:55 AM.
- To convert a time between 01:00 and 11:59, simply put AM after the time. Thus, 08:40 is 8:40 AM.
- To convert a time between 12:00 (noon) and 12:59, simply put PM after the time. So, 12:00 is 12:00 PM, and 12:42 is 12:42 PM.
- To convert a time greater than 13:00, subtract 12:00 from it. The remainder is the time in PM. Thus, 21:05 is 9:05 PM (21:05 – 12:00 = 09:05).

ACTIVITY Find a page with the name of your city in a railway timetable. Check the arrival and departure times of different trains given against (the name of) your city. See if you can read them correctly.

Time Intervals

We look at time in two ways, namely, the time of day and intervals of time. The time of day is what is

Fig. 2.18 Instruments for measuring intervals of time

shown by a clock. For example, 'the first period begins at 7:50' and 'the first period ends at 8:30' refer to times of the day.

A time interval is the difference in time between two events. For example, 'the first period is of 40 minutes', refers to a time interval, or a duration. It is the difference in time between two events—the beginning and the end of the period. Here are some common time intervals.

Usual duration of sleep at night: 8 hours

Duration of play in a football match: 90 minutes

Duration of each episode of most TV serials: 30 minutes

Common clocks and watches measure time continuously. When we wish to measure intervals of time accurately, we use stopwatches or stop clocks. These can be started and stopped at any time and measure the exact time interval between being started and stopped. They are commonly used during sports events and in laboratories.

ACTIVITY Train yourself to count seconds mentally. Say 'one, two, three, ...' in such a way that it takes you one second to say each number. Use a watch to practise. Then time a fast bowler's run up or a short advertisement on TV by counting seconds mentally. Find out how accurate you are by asking a friend to use a watch while you keep track of the time in your mind.

MEASUREMENT OF TEMPERATURE

We often use the words 'hot', 'cold', 'hotter' or 'colder' while referring to things around us. For example, we say that ice cream is cold and that a cup of tea is hot. We also say that it is hotter in May than in March. To actually measure the 'hotness' or 'coldness' of different bodies, we use a quantity called temperature. The temperature of an object (or substance) is a measure of its degree of hotness or coldness.

Scales of Temperature

The SI unit of temperature is the kelvin (K). However, ordinarily we use two other units of temperature. The degree Celsius (°C) is used to measure temperature on the Celsius scale, while the degree Fahrenheit (°F) is used on the Fahrenheit scale. These two scales have been constructed on the basis of two fixed points. The lower fixed point is the temperature at which ice melts (or water freezes). It is called the ice point, and is taken as 0°C on the Celsius scale. The upper fixed point is the temperature at which water boils. This is called the steam point and is taken as 100°C on the Celsius scale. The difference between these two fixed points is divided into 100 equal parts. Each of these divisions is called 1°C.

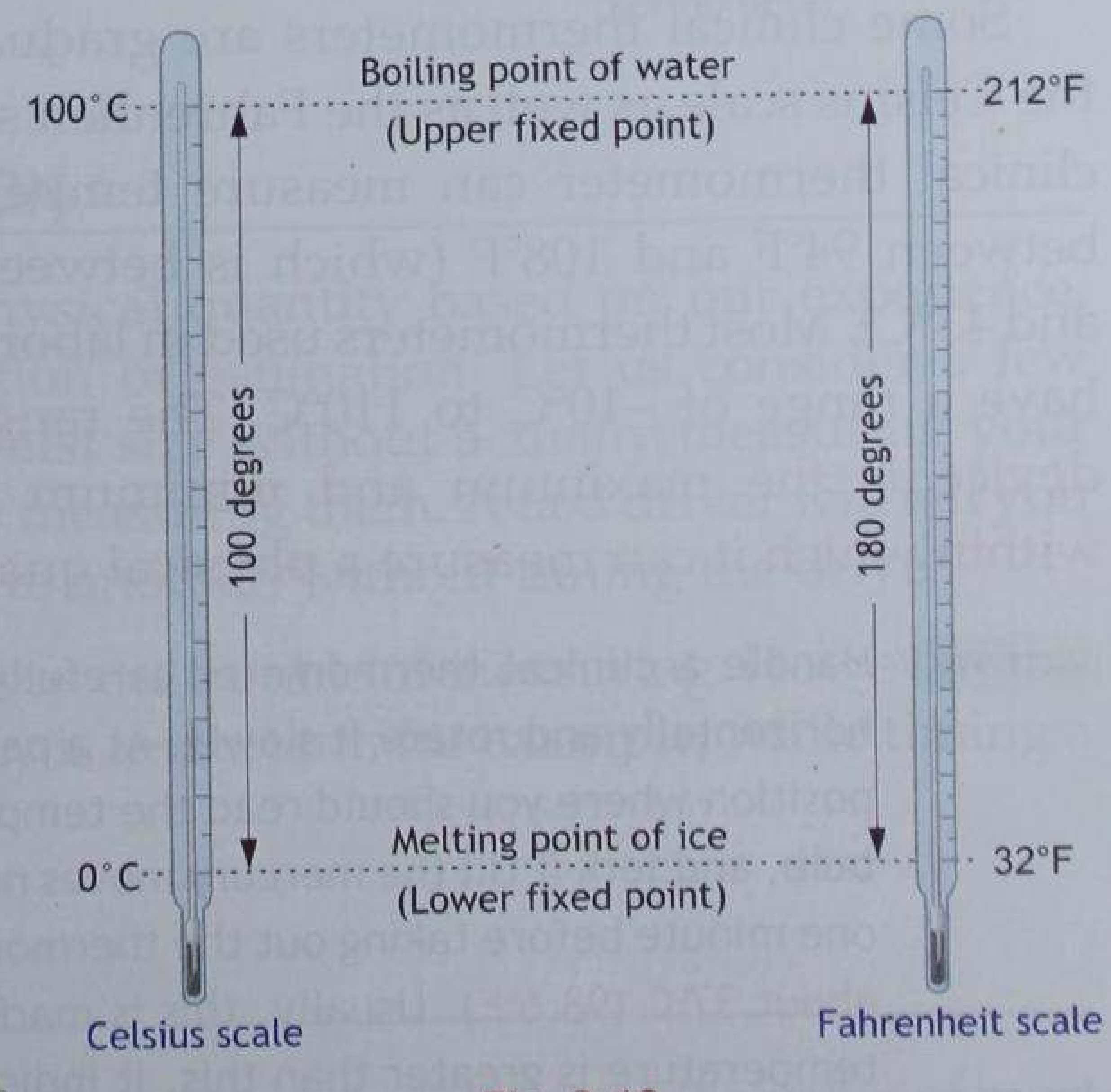


Fig. 2.19

On the Fahrenheit scale, the lower and upper fixed points are taken as 32°F and 212°F respectively. The difference between these two is divided into 180 equal parts. Each of these divisions is called 1°F.

Thermometers

Temperature is measured with the help of a thermometer. You are probably familiar with the clinical thermometer, which is used to measure body temperatures. The thermometers used in laboratories are called laboratory thermometers. Both types use mercury and are, therefore, called mercury thermometers.

Most thermometers have a small bulb at one end of a long glass cylinder called the stem. The bulb holds mercury (a silvery metal) and is connected to a very thin tube inside the stem called the bore. When the bulb is heated, the mercury expands into the bore (things expand when they are heated). It looks like a thin, shining thread. A temperature scale is marked on the stem. The thermometer reading is the temperature mark at the end of the mercury thread.

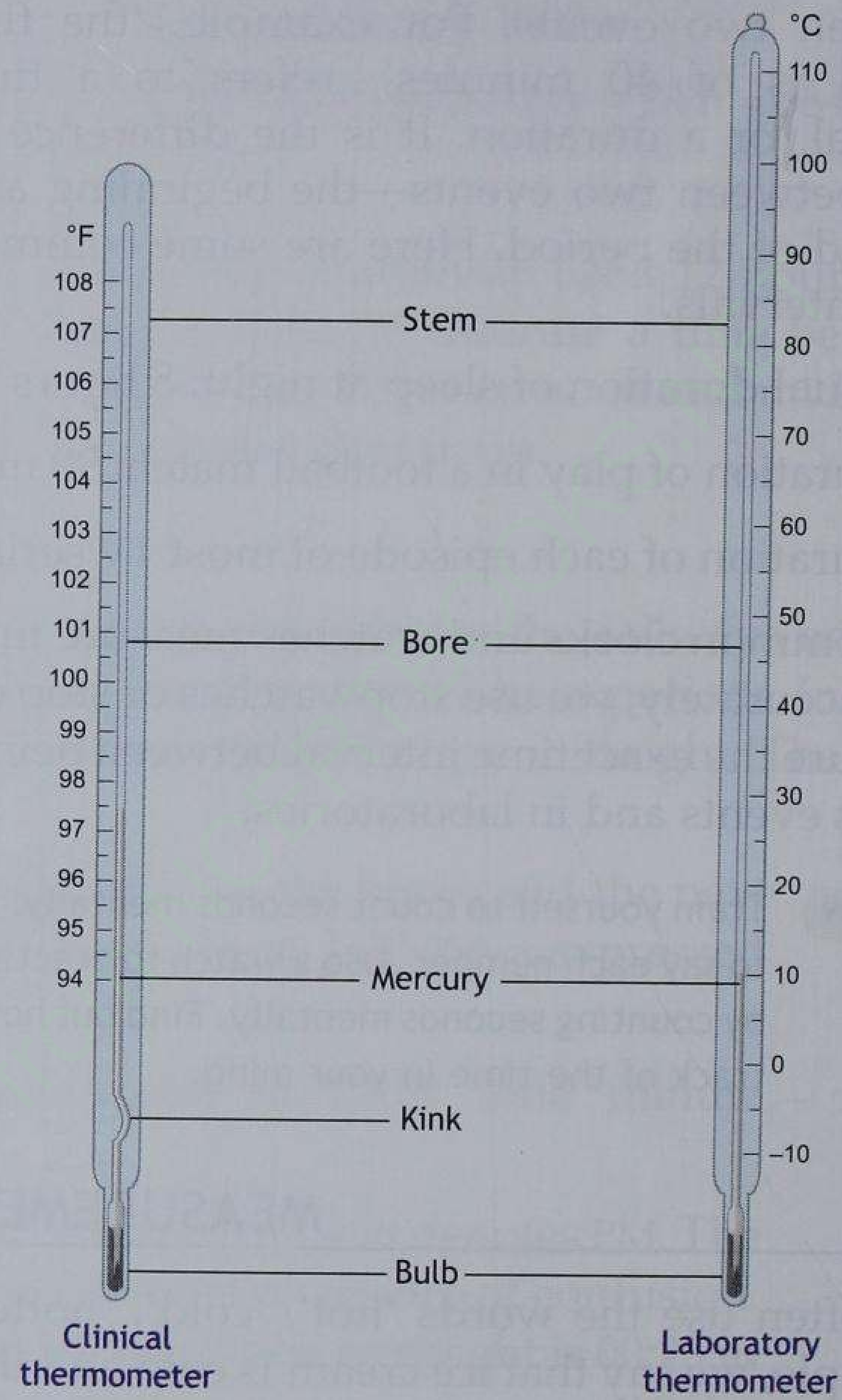


Fig. 2.20

There is one important difference between a clinical thermometer and a laboratory thermometer. Near the bulb of a clinical thermometer is a small bend, or kink, in the tube. The kink does not allow the mercury to move back into the bulb by itself. This allows us time to read the temperature after removing the thermometer from a person's mouth.

Some clinical thermometers are graduated in the Celsius scale as well as the Fahrenheit scale. A clinical thermometer can measure temperatures between 94°F and 108°F (which is between 35°C and 43°C). Most thermometers used in laboratories have a range of –10°C to 110°C. The range of a device is the maximum and minimum values within which it can measure a physical quantity.

Fig. 2.21 A digital thermometer displays the temperature.

ACTIVITY Handle a clinical thermometer carefully because the bulb can break very easily. Hold the thermometer horizontally and rotate it slowly. At a particular position, the mercury thread will appear broad. This is the position where you should read the temperature. Now hold the thermometer firmly at the end opposite the bulb, and jerk it till the mercury moves near the 35°C mark. Place the bulb gently below the tongue. Wait for one minute before taking out the thermometer. Now read the temperature. The normal body temperature is about 37°C (98.6°F). Usually, this is marked on the scale by an arrow or a red mark. If the measured body temperature is greater than this, it indicates a fever.

You can use a laboratory thermometer to find the temperature of a liquid, say tea or milk. Normally, the thermometer is suspended or held by a clamp. You can hold the thermometer with its bulb dipping in the hot liquid. The mercury thread will move up slowly and finally stop. Take the reading on the scale corresponding to the end of the mercury thread. When you take the thermometer out of the liquid, the mercury thread will move down by itself until it reaches the mark corresponding to the temperature of the air in the room. A laboratory thermometer reads the atmospheric temperature when it is not in use.

Maximum and minimum thermometer

Scientists who study the weather are called meteorologists. Meteorologists use a special thermometer called the maximum and minimum thermometer. This thermometer records the highest and the lowest atmospheric temperatures at a place on a given day. It has a U-shaped tube with bulbs at the top of each arm. One bulb is filled with alcohol, while the other has some vapour. The rest of the tube is filled with mercury.

When the temperature rises, the alcohol expands and pushes the mercury below it so that it rises up the other arm. The mercury, in its turn, pushes up a steel marker. When the temperature falls, the alcohol contracts and the mercury moves back up the first arm to fill up the space left by the alcohol. However, it leaves behind the steel marker in the second arm so that we can read the maximum temperature later. As the mercury rises up the first arm, it pushes along another marker which records the minimum temperature. If the temperature happens to rise and the mercury moves down again, it leaves behind the marker in the first arm. This helps us read the minimum temperature.

The instrument can be reset for the next day by moving the steel markers with the help of a magnet.

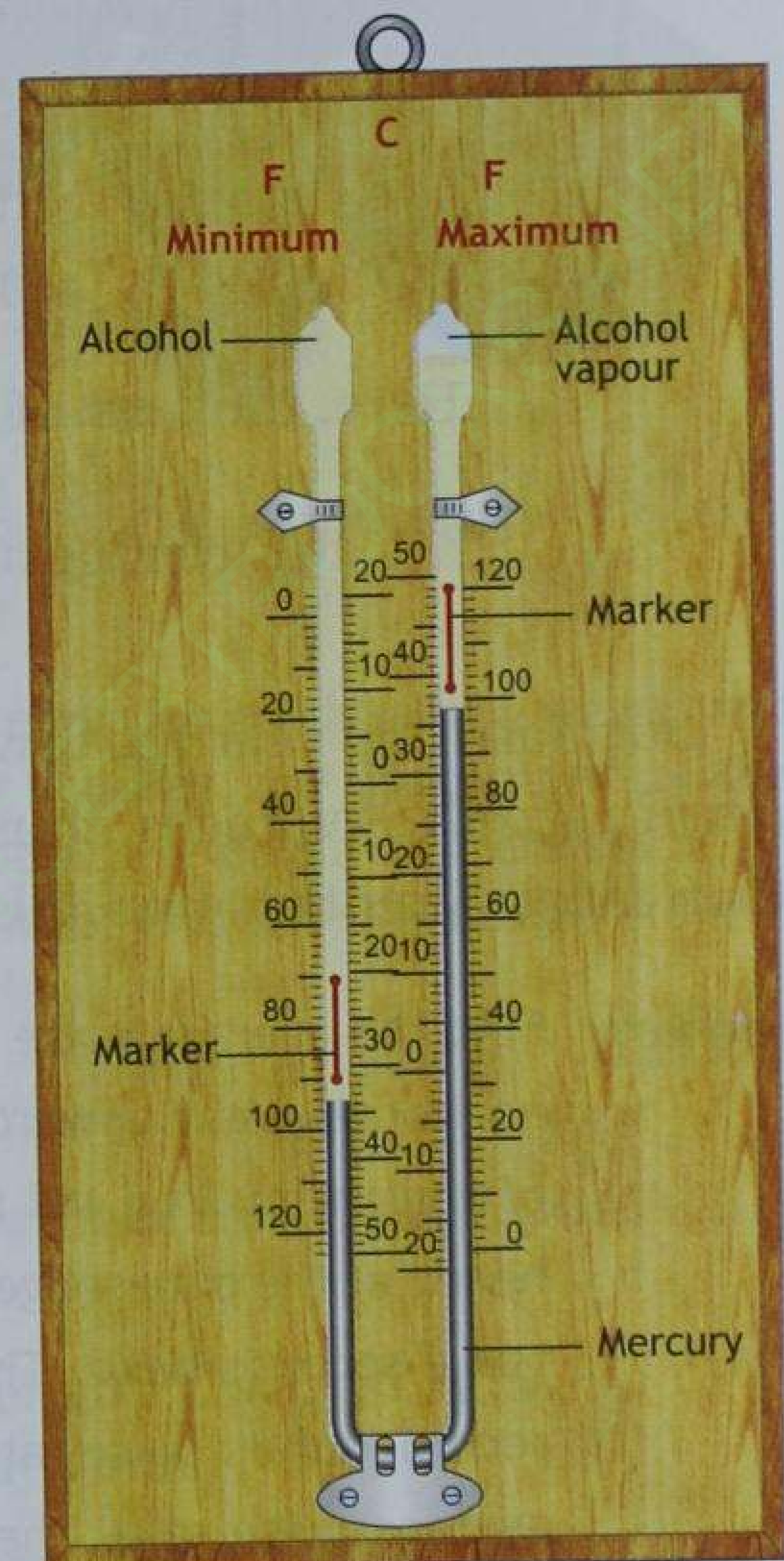


Fig. 2.22 A maximum and minimum thermometer

APPROXIMATION

In everyday life, we often judge the magnitude of a physical quantity based on our experience, without actual measurement. This is called approximation or estimation. Let us consider a few examples. A salesman selling jeans may tell you your waist size without actually measuring your waist. A cook adds spices, salt and sugar, without actually measuring them. A taxi driver will tell you the approximate time it will take to drive from one place to another, without timing the drive.

Approximation can be useful as it saves time and saves us the trouble of measuring. However, it is inaccurate. Actual measurements are made when accuracy is important, for example, while timing a race and buying things by weight.

AVERAGES

The average of a group of similar numbers is a number that gives us a general idea of the value of most of the numbers in the group. For example, when we say that the batting average of a batsman is 40, we mean that when he bats, he usually scores close to 40 runs. This is calculated by adding up the runs scored by him in each innings and dividing the sum by the number of innings he has played. In general,

$$\text{average} = \frac{\text{sum of values}}{\text{number of values}}$$

EXAMPLE The annual rainfall at a town, in cm, during the years 1991 to 2000 is recorded as 91, 83, 87, 105, 95, 89, 98, 88, 100 and 92. Find the average annual rainfall.

Here, the sum of the recorded rainfall is 928 cm. The total number of values is 10.

$\therefore$ the average annual rainfall over this period $= \frac{928 \text{ cm}}{10} = 92.8$ cm.

Suppose one year the town gets 120 cm of rainfall. We will know that it is much greater than the usual rainfall. Averages, thus, allow us to spot exceptions, i.e., values that are much higher or lower than most. Scientists find this useful in spotting exceptions in readings of measurements.

ACTIVITY Find the average pulse rate of the students of your class. To measure your pulse rate, hold your left hand horizontal, palm upwards. Place two fingers of your right hand over your left wrist, just below the lower edge of your palm. You will feel your pulse (the regular beat of blood being pumped into your arteries by your heart) at the outer edge of your wrist. Count the beats and time them with the help of a watch or clock that has a seconds hand. The number of beats in 60 seconds is your pulse rate. When all the students have recorded their pulse rate, add the pulse rates and divide the sum by the number of students. This gives the average pulse rate. The lowest and highest values denote the range of pulse rates. Did you find someone whose pulse rate varied greatly from the average?

STANDARD WEIGHTS AND MEASURES

Dishonest traders often use defective measuring devices to cheat customers. To prevent this, the Department of Weights and Measures of the government certifies the weights and measures used in trade. This department also carries out checks to ensure that only devices of certified quality are in use.

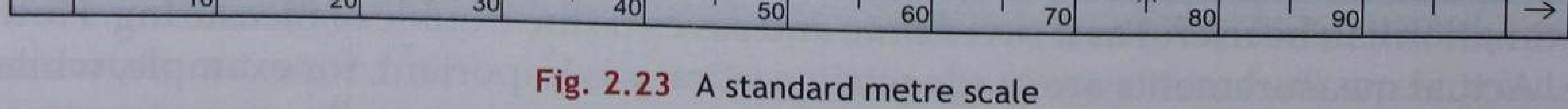


Fig. 2.23 A standard metre scale

Standard metre scale

The metre scale used for the correct measurement of length is shown in Figure 2.23. It has arrow marks, ← and →, at the two ends, and the stamp of the department on the reverse side. The graduation marks on the scale are 10 cm apart.

Standard weights

A standard weight is made of metal and weighs a particular amount. The value of the weight is marked on the top surface. The heavier standard weights are made of iron and are hexagonal in shape. The lighter ones are made of brass and are circular. Each iron weight has a hole at the bottom. Some lead (a metal) is poured into this hole to get the exact weight. The lead bears the stamp of the Department of Weights and Measures.

Fig. 2.24 Standard weights

Standard measures of volume

Measuring cans used to measure the volume of liquids are available in different capacities ranging from 250 mL to 5 L. Transparent measuring cups, with volumes marked on the walls, are used to measure small volumes of liquid, such as 50 cm^3 of Mobil at a petrol pump.

ACTIVITY Visit a number of grocery shops, chemists and general stores. Make separate lists for goods sold by weight and those sold by volume, including those sold in standard packets, bottles or pouches. Are the contents of the pouches specified by weight, volume or both? Is there any mention of temperature? Hold a class discussion on why certain things are sold by weight, while others are sold by volume. Also, find out why temperature is mentioned on some packages.

Dishonesty in Measurements

Dishonest traders use various means to cheat customers. Let us look at some of these means and what we can do to avoid being cheated.

- The metal scale used by a trader may be less than one metre in length. Check for the arrow marks and the stamp to make sure that the scale used is authentic.
- The metal weights used by a trader may weigh less than the proper value. In a correct weight, there should be lead in the hole and a proper stamp on the lead.
- Balances may have the following defects: (a) the beam may be fixed rigidly to the handle used to suspend the balance, (b) the two arms of the beam may be unequal, and (c) the pans may be unequal in weight. Some traders may use nonstandard balances. The beam of a standard balance is stamped on both sides.
- In measuring cans, the actual capacity can be made less than the correct value by (a) pushing up the bottom by hammering, or (b) by pouring some lead into the can. These can be detected by looking at the base, which should be flat, and by checking that the can is not unusually heavy.

POINTS TO REMEMBER

- A quantity that can be measured is called a physical quantity.
- Measurement is a process of comparison. We compare an unknown physical quantity with a known physical quantity, called a unit.

- A unit is a known measure of a physical quantity with which physical quantities of the same kind are compared. The magnitude of a physical quantity consists of a number and a unit.
- A system of units should be such that its units are precisely defined, are of the same value everywhere and are of convenient size.
- In the metric system, all multiples and submultiples of units are related by powers of 10.
- In SI, the units of seven base quantities are defined, among which are the kilogram (kg) for mass, the metre (m) for length, the second (s) for time and the kelvin (K) for temperature.
- Area is the measure of the region inside a closed line. Its SI unit is m^2.
- Mass is the amount of matter contained in a body. Its SI unit is the kilogram (kg).
- The volume of any object is the space occupied by it. The SI unit of volume is m^3.
- The capacity of a container is the volume of liquid which it can hold. It has the same unit as volume.
- In the 12-hour-clock system, AM and PM are written after the time to indicate whether it is between midnight and noon (AM), or between noon and midnight (PM).
- In the 24-hour-clock system, time is always shown by 4 digits. 00.00 to 11.59 denote AM and 12.00 to 23.59 denote PM.
- A time interval is the difference in time between two events.
- Temperature measures the 'hotness' or 'coldness' of a body. The SI unit of temperature is the kelvin (K). The Celsius and Fahrenheit scales are in common use.
- The lower fixed point (ice point) is the temperature at which ice melts (or water freezes). The upper fixed point (steam point) is the temperature at which water boils. The lower and upper fixed points are 0°C and 100°C respectively on the Celsius scale, and 32°F and 212°F respectively on the Fahrenheit scale.
- Clinical thermometers have a range of 35°C to 43°C and are used to measure body temperature. Laboratory thermometers have a range of –10°C to 110°C.
- Approximation is a judgment of the magnitude of a physical quantity based on our experience, without actual measurement. It saves time, but may be inaccurate.
- $\text{Average} = \dfrac{\text{sum of values}}{\text{number of values}}$

EXERCISE

Short-Answer Questions

1. What is meant by the unit of a physical quantity?
2. Give two examples showing how the magnitude of a physical quantity is expressed as a number and a unit.
3. Mention two advantages of the metric system.
4. How many units are defined in SI? Give the SI units of three base quantities.
5. What is mass? Mention three units of mass.
6. Distinguish between volume and capacity.
7. Distinguish between the time shown by a clock, and a time interval. Give one example of each.
8. Mention two scales of temperature used in everyday life. Give examples.
9. What are the lower and upper fixed points of the Celsius scale?
10. Why does a clinical thermometer have a kink?
11. Why is it not necessary to write AM or PM in the 24-hour-clock system?
12. Mention one advantage and one disadvantage of approximation.
13. How will you find the average of a number of values?
14. How would you identify a standard metre scale?

15. Mention the defects which may be present in a beam balance used in the market.

Long-Answer Questions

1. Describe the precautions required while measuring length.
2. Describe how you would measure (a) the diameter of a table tennis ball, and (b) the radius of a thin wire.
3. Name three instruments used for weighing. Mention three defects that balances may have.
4. How would you measure the volume of an irregular solid?
5. Describe the construction of a laboratory thermometer.

Objective Questions

Choose the correct option.

1. The magnitude of a physical quantity consists of
   (a) a number and a unit
   (b) a number
   (c) a unit
   (d) a unit and its symbol
2. The SI unit of length is the
   (a) millimetre (b) centimetre
   (c) metre (d) kilometre
3. Which of the following represents the magnitude of a temperature correctly?
   (a) 10 k (b) 10 Kelvins
   (c) 10 Ks (d) 10 K
4. The error in measurement caused by positioning the eye incorrectly is called
   (a) parallel error (b) standard error
   (c) eye error (d) parallax error
5. Which of the following is not true of the standard weights certified by the Department of Weights and Measures?
   (a) Larger weights are made of iron.
   (b) Smaller weights are made of lead.
   (c) The value is written on the top.
   (d) They are either hexagonal or circular in shape.
6. Which of the following is a time interval?
   (a) The time when you wake up
   (b) The time you take for your bath
   (c) The time when school gets over
   (d) The time when you go to bed
7. Stopwatches and stop clocks are used
   (a) as 24-hour clocks
   (b) as 12-hour clocks
   (c) for accurate measurement of time intervals
   (d) for finding average time

Fill in the blanks.

1. Measurement is basically a process of ....
2. A unit is so chosen that the numerical value of a measurement is as ...... as possible.
3. The correct symbol for kilometres is ....
4. The prefix 'milli-'denotes the factor ....
5. The volume of a body is the ...... occupied by it.
6. Mass is the amount of ...... contained in a body.
7. 1 metric ton = ... kg.
8. The ...... point is used as the upper fixed point on the Celsius scale.
9. Laboratory thermometers have a range of ...... to 110°C.
10. A railway ticket mentions the time of departure as 19:20, which is ...... PM.

Write true or false.

1. When we use the symbol of a unit named after a person, we use small letters.
2. The range of a clinical thermometer is 35°C to 43°C.
3. At a grocer's shop, all commodities are sold by weight.
4. The unit we use to measure a physical quantity is a matter of choice.
5. The area of a piece of cardboard of irregular shape can be found by using a string and a scale.
6. A simple balance can measure small masses accurately.
7. Usually, while cooking, we add salt by approximation.
8. An average gives us an idea of the largest value in a group of numbers.
9. Meteorologists use maximum and minimum thermometers to find the average temperature of a day and night.

Numericals

1. Express the length 100 centimetres in metres.

2. The masses of five old cricket balls are 195 g, 198 g, 205 g, 202 g and 203 g. Find the average mass of the balls.
3. The volume of water in a measuring cylinder is 55 mL. When a stone tied to a string is immersed in the water, the water level rises to 83 mL. Find the volume of the stone.
4. A string is wound around a pencil 50 times. The total width of all the turns is 5 cm. Find the thickness of the string.
5. The clock at a railway platform read 23:47 when a train arrived and 00:08 when it left. How long did the train stop at the station? The next train arrived at 01:05. What was the time interval between the departure of the first train and the arrival of the second train?

Answers

1. 0.1 mm **2.** 200.6 g **3.** 28 mL **4.** 1 mm
5. 21 minutes, 57 minutes

Defining Units down the Ages

You have read that parts of the body were used to define units earlier. Here are some examples.

Cubit The Egyptians defined cubit as a measure of length equal to the distance between the elbow and the tip of the middle finger.

Yard The yard was defined by early English kings as the length of the sash worn around a man's waist. A sash or a rope worn around the waist served as a convenient measuring device. Legend has it that King Henry I later decreed that the yard was to be the distance between his nose and the thumb of his outstretched arm.

Foot It is said that the foot was defined by the Greeks as the length of Hercules' foot.

Inch The inch was defined as the width of a man's thumb. Later, King Henry II decreed it to be the length of three grains of barley placed end to end.

ACTIVITY Make a list of devices used for weighing at home and in shops in your neighbourhood. For each device, try to find out (a) the range, and (b) the sensitivity, that is, the minimum difference between two weights which it can measure. You will find that usually the sensitivity of measuring instruments decreases with increase in range.

❑