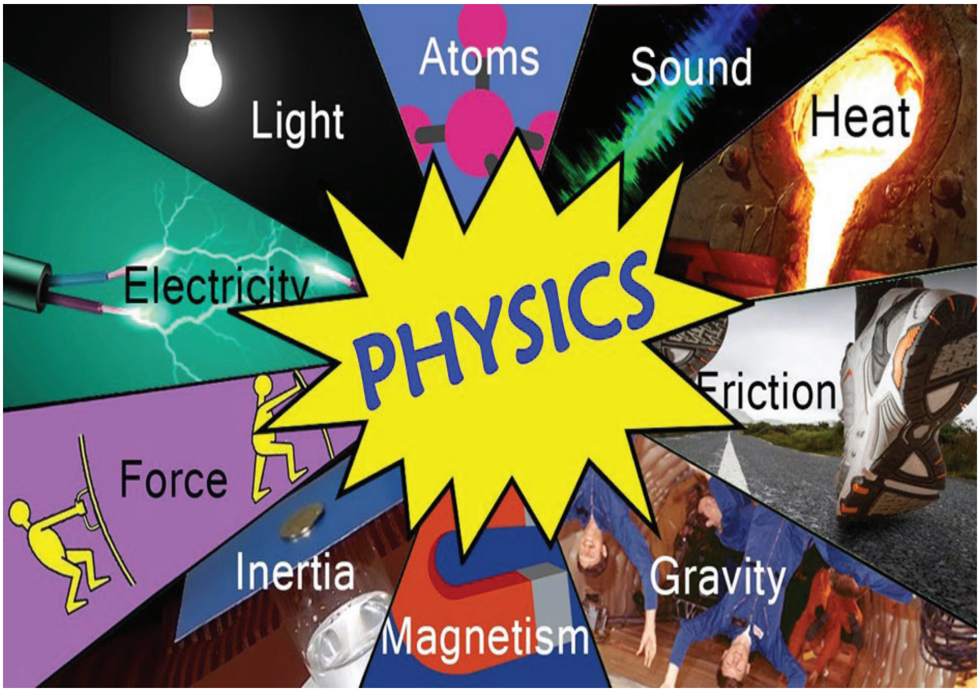
Chapter 1:
INTRODUCTION TO PHYSICS



Key words	***By the end of this chapter, you should be able to:***
▪ Science ▪ Physics ▪ Matter ▪ Energy ▪ Laboratory ▪ Apparatus	▪ understand the meaning of physics. ▪ understand why it is important to follow the laboratory rules and regulations.

Introduction

At Primary school level, you studied Science as a single subject. At Secondary school level, however, Science is divided into independent subjects like Physics and Biology. Can you name other Science subjects?

In this Chapter, you will understand the meaning of physics and why it is important to study physics.

You will also learn the safe practices of conducting science experiments in the laboratory.
Look at the pictures below:

Fig. 1.1: Science is all around us!

What is happening in each picture in Figure 1.1?

To answer this question and many others, you need knowledge of a new subject known as Physics.

Think:

Are there some things that you have always wondered how they work, or how they happen?
Make a list of those things. Then ask your teacher to explain to you.

What is physics?

The word physics comes from the Greek word "physis" which means "nature".

Physics is a branch of natural science that deals with the study of **matter** and how it is related to **energy**.

Natural science deals with the physical and natural world. Can you identify the other branches of science?

Matter refers to anything which occupies space and has weight.

Energy is the ability of the body to do work.

Branches of physics and what they deal with

Physics is divided into several branches or themes as indicated in Table 1.1 below. Each branch deals with different aspects of Physics.

Table 1.1: The branches of physics and their meanings

Branch	What it deals with
Mechanics	It deals with the behaviour of physical objects or particles under the action of forces.
Heat	It deals with heat, as a form of energy, its transmission and applications.

Branch	What it deals with
Light	It deals with the nature of light and its properties, how it travels and its applications.
Electricity	It deals with the production of electricity, its transmission and applications.
Magnetism	It deals with the properties of magnets, their production, properties and applications.
Wave motion	It deals with the transfer of energy from one point to another without movement of substances.
Modern physics	It deals with recent developments in physics and their applications

Activity 1.1: Identifying the applications of the different branches of physics

What to do

Look at the pictures in Figure 1.2 and:

i) identify the branch of physics being applied.

ii) explain what is happening in each picture.

Fig. 1.2: Applications of the different branches of physics

The importance of studying physics

Think:

1. Now that you know what physics is and what it involves, why do you think we need to study physics?
2. Can you think of ways in which physics is important to

	***Physics is important for good health*** Machines, such as those used in hospitals to treat cancer and those used to study the brain, broken bones and babies developing in the womb, are made using knowledge gained from the study of physics.
	***Physics makes communication easy*** Physicists play an important role in the manufacture of computers, radios, televisions and mobile phones. These make communication easy.

Fig. 1.3: Importance of physics

Activity 1.2: Identifying the applications of physics

What to do

Look at the pictures in Figure 1.4 (a-d) below and explain how physics is applied in each case.


(a)


(b)


(c)


(d)

Fig. 1.4: Some applications of physics

Did you know?

Archimedes, Galilleo, Isaac Newton are some of the personalities whose discoveries shaped what is done in physics today. What did they discover? Ask your teacher.

Careers in physics

Think:

1. What would you like to become in the future?
2. What job or work would you like to do?
3. Talk to your friends in a discussion.
4. Ask your teacher to find out which of the careers is

The physics laboratory

Most of the practical works in science, for example, experiments, tests, observations or investigations are conducted in a special place called a laboratory.

A laboratory is a building, part of a building or other place specifically designed for scientific work. It contains many pieces of apparatus and materials for practical use.

Apparatus is equipment or tools needed for a particular scientific activity or purpose. We use apparatus when we are carrying out an experiment.

Experiment is a scientific step-by-step process undertaken to make a discovery, test a proposed law or theory, or demonstrate a known fact.

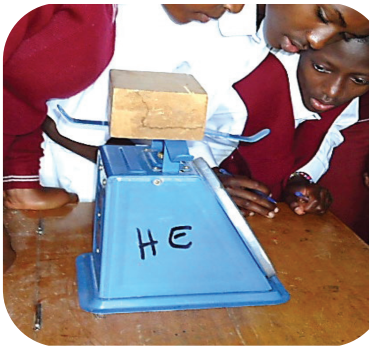


Fig. 1.5: Learners performing an experiment in the laboratory

The laboratory and its safety rules

Activity 1.3: A visit to the Physics laboratory

What you need

- Laboratory or room serving as the laboratory
- Variety of laboratory equipment

What to do

a) The teacher will lead you on a guided tour of the laboratory and tell you how to behave in the laboratory. He/she will also show you various apparatus and explain how they are used.

b) At the end of the lesson, discuss the following:

1. Suggest some laboratory rules.
2. What is the importance of laboratory rules and regulations?
3. Give the name and importance of the apparatus shown below.

Fig. 1.6: Some laboratory apparatus

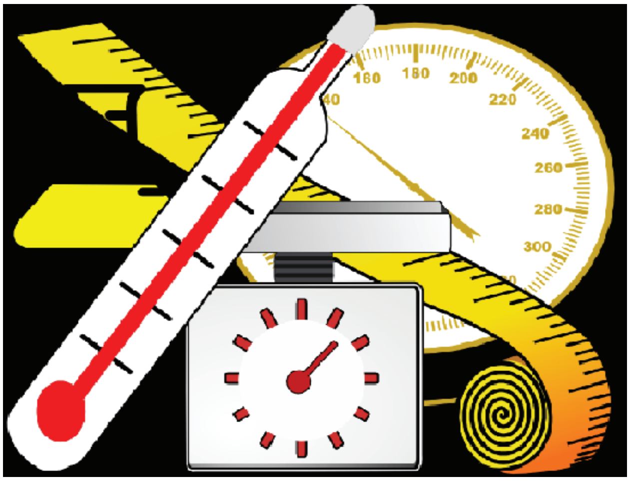
Activity of integration

You have been elected as the prefect in charge of the laboratory in your school. The S1 class is about to report for First Term. Many of the students have never heard about a Physics laboratory.
Prepare a short speech about the laboratory for the new S1 students. The speech should last not more than 10 minutes.

Chapter summary
In this chapter, you have learnt that:

- physics is a branch of science which deals with matter, energy and how they are related.
- the study of physics involves different branches such as mechanics, light, heat and others.
- physics helps us to explain the things around, us such as sunshine, electricity, rainfall and many others
- the study of physics has applications in medicine, communication, agriculture, energy, entertainment and many others.
- a laboratory is a specialised place where scientific experiments are carried out.

Chapter 2:
MEASUREMENTS IN PHYSICS



Key words	*By the end of this chapter, you should be able to:*
▪ Estimating ▪ Measuring ▪ Fundamental/base quantities ▪ Derived quantities ▪ Vectors and scalars ▪ SI units ▪ Significant figures ▪ Scientific method ▪ Density ▪ Relative density ▪ Purity ▪ Floating ▪ Sinking	▪ estimate and measure physical quantities using appropriate equipment and units. ▪ explain how to choose and use the right measuring instruments and the right units, ensuring accuracy. ▪ identify the potential sources of errors in measurements and devise strategies to minimise them. ▪ understand the various methods of presenting data. ▪ use scientific notation and significant figures in measurements and calculations. ▪ understand the scientific method of investigation.

Key words	*By the end of this chapter, you should be able to:*
▪ Ocean currents	▪ understand the meaning of density and its application to floating and sinking. ▪ determine densities of different materials and relate them to purity. ▪ understand the global nature of ocean currents and how they are driven by changes in water density and temperature.

Introduction

The physical properties of matter can be classified as **intensive** (do not depend on quantity of matter) and **extensive** (depend on the quantity of matter). The quantity of matter is determined by measurements. In this chapter, you will learn how to estimate and measure physical quantities in standard units, and the importance of making accurate measurements.

Estimation and measurement

When you go to a butchery, you buy meat in kilograms. When you go to a tailor, your cloth is cut according to your size. What is the general term used to describe the above cases?
Give examples of everyday life situations where the above process is applied. Explain what is done in each case.

Note: In the above process, you assign a numerical value and a unit to a physical quantity.

Scientific measurements

In this section, you will learn how to measure some basic physical quantities: length, mass and time. You will also learn how derived physical quantities (volume and density) are obtained from the basic physical quantities.

Modern scientists use the metric system of units called the International System of Units (SI units) in measurement. Therefore, when measurement of a physical quantity is taken, the quantity must be presented in terms of a **numerical value** and a **unit**. Table 2.1 shows a list of some of the physical quantities, their SI units and the instruments used to measure them.

Table 2.1: Physical quantities, units and instruments

Physical Quantity	Name of Unit	Abbreviation	Instrument
Mass	Kilogram	Kg	Beam balance
Length	Meter	M	Metre rule
Time	Second	S	Stop clock
Temperature	Kelvin	K	Thermometer
Area	Square meter	m^2	
Weight	Newton	N	Spring balance
Volume	Cubic meter	m^3	Measuring cylinder
Density	Kilogram per cubic meter	kg/m^3	

Instruments used to measure some quantities are shown in Figure 2.1 below. Can you identify them and what they are used to measure?

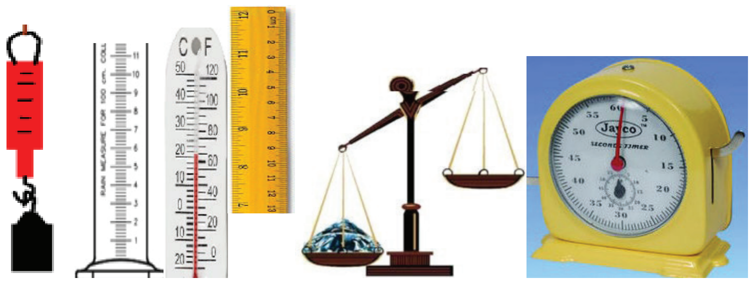


Fig. 2.1: Instruments used to measure some physical quantities

Measuring length

Length is about a distance between two points. Length answers questions like "how far?", "how long?", “how tall?” and "how high?"

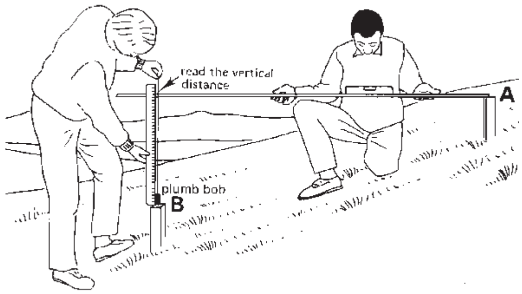


Fig. 2.2: Measuring distance between two points

Remember that the SI unit for measuring length is metres (m). The metric system is based on units of ten for example:

1 centimetre (cm) = 10 millimetres (mm)
1 decimetre (dm) = 10 cm
1 metre (m) = 10 dm
1 decametre (dm) = 10 m
1 hectometre (hm) = 10 dm
1 kilometre (km) = 10 hm

Activity 2.1: Conversion of units of length

Key question
Can you change from one unit of length to the other?

What to do

a) In groups or individually determine how many: (i) centimetres are in 1 metre; (ii) milimetre are in 1 metre; (iii) kilometres are in 1 centimetre.
b) In groups or individually, convert the following measurements into the units indicated in brackets:
(i) 4.25 m (cm) (ii) 0.256 km (m) (iii) 367.5 dm (Dm)

Look at your friend and try to suggest his/her height. When you do this, you are **estimating** the height of your f**riend**.

In this section, you will estimate how long something is and then you will **measure** it to see how good you are at estimating. Remember you should always record your work. Write down all the estimates and measurements you make in this section in a table. You will be using some of these results later.

Activity 2.2: Finding the height of your friend

Key question
How tall are you and your friend?

What you need

- Ruler

What to do
Work with your friend and:

1. estimate your height and your friend's.
2. think of a way of measuring your friend's height accurately (to the nearest centimetre) and then measure it. Do the same to yourself.
3. record the results.

You are not only **estimating** and **measuring**, you are also planning when you think of an appropriate way of doing the work. How did you do it? Perhaps you made a mark on the wall or the doorpost at the exact height of your friend. Did you ask your friend to take off his or her shoes first? Give reasons for your answer.

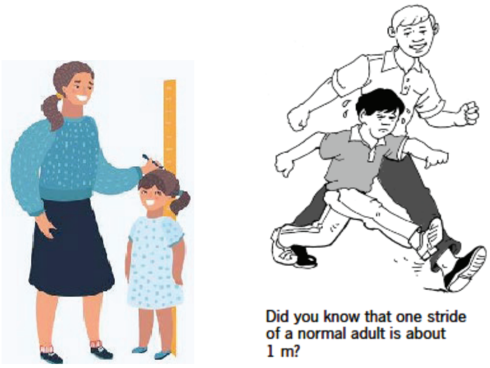


Fig. 2.3: Measuring the height of a person

Group Assignment: Find out how long and wide the football pitch is.

Science, Technology and Society

Sometimes the lengths are too small to be measured using the instruments used in Activity 2.2. For very small lengths like the thickness of an iron sheet or diameter of a wire, engineers use a special instrument called the micrometer screw gauge. For bigger objects like the diameter of an iron bar engineers use the Vernier caliper. It is also used to measure internal and external diameters of tubes.

Micrometer screw gauge

Vernier calipers

Fig. 2.4: Instruments for measuring small lengths

Questions

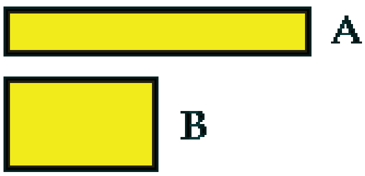
1. Discuss with a friend why you think the measurements you made in Activity 2.2 and the group assignment may not be accurate.
2. How can you make the measurement more accurate?

Note: *You should note that for you to obtain more reliable answer for a measurement, you should take several readings of the same quantity and then obtain their average. The average is the one that is closest to the more reliable answer.*
In case several readings are taken, those that differ significantly from others can be ignored. Then the required readings can be presented appropriately using tables for further analysis

Measuring area

How much surface is occupied by an exercise book? To answer this question, another quantity, **area**, is required.
Every unit of **length** has a corresponding unit of area, namely the square of the unit of the given **length**. Thus, areas can be measured in square metres (m^2), square centimetres (cm^2), square millimetres (mm^2), square kilometres (km^2) and square miles (mi^2) for land measurements.

Compare the **amount of space** covered by two different figures A and B below. Do these figures occupy the same space, or is one bigger than the other?



You cannot tell which shape is bigger unless you measure their length and breadth (width). You multiply the length by the breadth to find the area. If you measure the sides of the rectangle in *centimetres* (cm), the area will be in *square centimetres* (cm^2). If you measure the sides of the rectangle in *metres* (m), the area will be in *square metres* (m^2).

Exercise 2.1

Estimate the area of a table top at home or at school. Then measure the sides and calculate the area. How good was your estimate?

How would you measure the area of irregularly shaped figures or of figures which differ in shapes? For example, how would you measure the area of your hand? Compare your hand with that of your friend who has a bigger or smaller one, and explain how you would get the area of your hand.

Exercise 2.2

Estimate the area of your palm and design an investigation to measure the area of your palm.

Hint: You can use a graph paper.

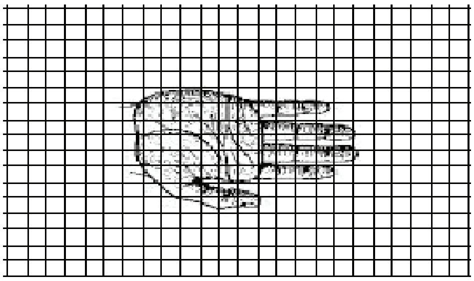


Fig. 2.5: Estimating the area of a palm

Note: *Regular shapes such as square, rectangle, triangle and circle have a formula for calculating their area. Write down the formula for calculating the area of these shapes. You did this work in the Primary school Mathematics.*

Measuring mass

What is the amount of matter in a block of wood, a lump of sand or a heap of stones? The amount of matter in each of these materials is called **mass.** Do you know your mass?

The instrument used to measure mass is called a beam balance.
Examples of beam balances are shown below.

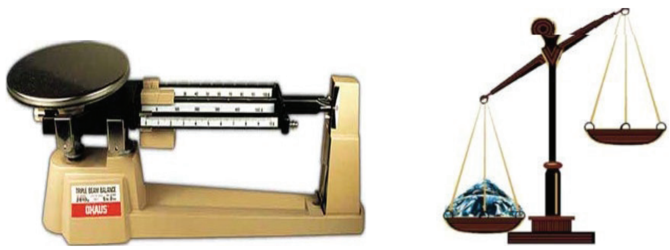


Fig. 2.6: Different types of beam balances

There are different types of beam balances but all measure mass. Mass can also be measured using electronic balances.

Fig. 2.7: An electronic balance

The SI unit of mass is *kilograms* (*kg*).
Mass is also measured in grammes. (g).

Activity 2.3: Measuring mass

What you need

- A pen, exercise book, ruler, small stones, etc.
- Beam balance

What to do

Measure and record the masses of each of the materials provided. One litre of pure water has a mass of one kilogram. So if you do not have 1-kg mass for the next activity, you can use a 1-litre bottle of water.

Activity 2.4: Estimating the mass of an empty 20-litre jerry can

Key question

What is the mass of an empty 20-litre jerry can?

What you need

- A beam balance reading up to 1 kg
- 1 kg mass
- 20-litre jerry can
- 100 g mass

What to do

a) Hold the 1 kg and 100 g masses to get some idea of how heavy they are.
b) Estimate how heavy your 20-litre jerry can is.
c) Check your estimate by weighing the 20-litre jerry can on the beam balance.
d) Was your estimate close to the actual mass?
e) Repeat the experiment with something much lighter, such as your plastic mug. Then repeat it with something much heavier, such as yourself.

The mass of small objects such as your plastic mug is usually measured in grams. The mass of larger objects such as your 20-litre jerry can or yourself is usually measured in kilograms.

Question:

What is the likely source of error in the measurement of mass in activities 2.3 and 2.4? How can they be minimized?

Weight and mass

In everyday life, we usually talk of weight, not mass. Later, you will learn that mass and weight are not the same. When you talk about the weight of a bag of sugar or cement, you probably are talking about their masses in reality.

Weight is measured using a *spring balance* and its value changes from one place to another. *Mass*, on the other hand, is measured using a beam balance, and it does not change value from place to place. The SI unit of weight is the Newton (N), while that of mass is the kilogram (kg). Examples of spring balances are shown in Figures 2.7 and 2.8.

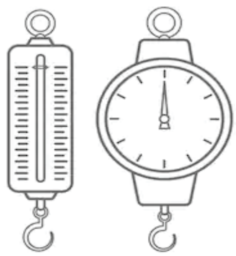


Fig. 2.8: Spring balances

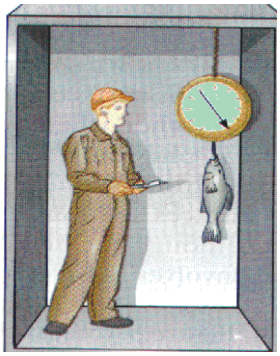


Fig. 2.9: Weighing a fish using a spring balance

Note: A spring balance can be calibrated in kilogramme to measure mass.

Volume

What happens when you pour water or sand in a container? How do you record the amount of water? What you record is the amount of space occupied by the water or the **volume of water**.

Measuring the volume of a rectangular object

Do you remember how to calculate the volume of regular solids like a rectangular block?

You measure the **length,** the **width** and the **height** and get their product.

If you measure the sides of the rectangular block in *centimetres* (cm), the volume will be in *cubic centimetres* (cm^3). If you measure the sides of block in *metres* (m), the volume will be in *cubic metres* (m^3). However, the SI unit of volume is *cubic metres* (m^3).

Activity 2.5: Interconversion of units of volume

Key question: How many cm^3 are in $1m^3$?

What to do

a) Convert 1 m to cm.
b) Multiply 1 m by 1 m by 1 m to 1 m^3.
c) Multiply also 100 cm by 100 cm by 100 cm. What do you get?
d) Compare the volume in m^3 to the volume in cm^3.
e) Then convert 200 cm^3 to m^3.

Activity 2.6: Finding the volume of a classroom

Key question

What is the volume of your classroom?

What you need

- Ruler or tape measure

What to do

a) Estimate the length and width and height of the room and find their product to estimate the volume of the room. Compare your answer with that of a friend.
b) Now measure these with a ruler or tape measure and calculate the real volume of the room. How close was your estimate? Did you do better than your friend? What could have caused a difference in your readings?

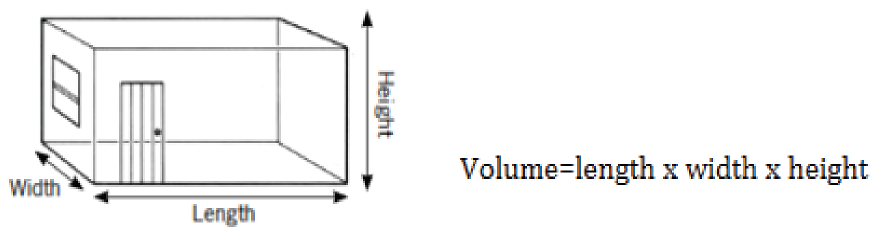


Fig. 2.10: Illustration of measuring volume of a classroom

***Note**: Regular shapes such as sphere, cylinders and cones have formulae for calculating their volume. Write down the formulae for calculating the volumes of these shapes.*

Measuring the volume of a liquid

It is easy to measure the volume of a rectangular object by measuring its sides. How would you measure the volume of a liquid? Another common unit of volume is the litre (l) or milliliter (ml). We often use these units when measuring the volume of liquids using the instruments shown in Figure 2.11.

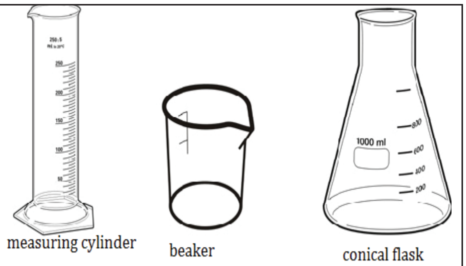


Fig. 2.11: Apparatus for measuring volume of liquids

Did you know? 1000 cm^3 = 1 litre

Activity 2.7: Finding the volume of a liquid

Key question

How can we measure the volume of a liquid?

What you need

- Small bottle containing water
- Measuring cylinder

What to do

a) Estimate the volume of the liquid in the bottle in litres, millilitres and cubic centmeters.
b) Pour the liquid into a measuring cylinder. Remember to read the bottom of the meniscus.

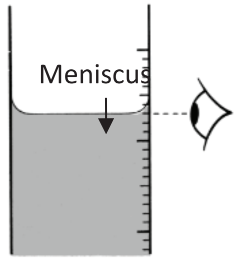


Fig. 2.12: Position of eye while measuring using a measuring cylinder

Can you make your own measuring cylinder out of a plastic bottle? How accurate can it be?

NOTE: *For more accurate and specific measurement of the volume of liquids, a burette and a pipette are used. These instruments are fragile and should be handled carefully.*

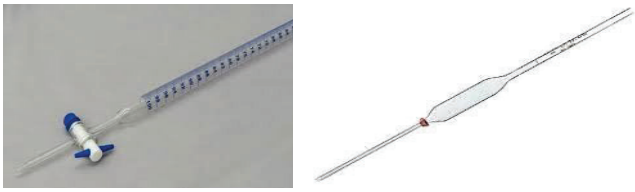


Fig. 2.13 (a) burette (b) pipette

Volume of irregular solids

A regular solid is one with straight sides, for example a book. An irregular solid does not have straight sides, for example a stone. We can measure the volume of irregular shaped solids by putting them in water in a measuring cylinder and finding out how far the water rises. We can only do this for objects which sink in water.

Activity 2.8: Measuring volume of an irregular object

Key question

How can we find the volume of a stone or any other irregular object?

What you need

- Measuring cylinder
- Water
- Stone (small enough to go into the measuring cylinder)

What to do

a) Estimate the volume of the stone.
b) Put some water in the measuring cylinder and read the volume (*x cm*^{3}) .
c) Put the stone in the water in the cylinder and read the new volume (*y cm*^{3}).
d) The difference between the two volumes is the volume of the stone.

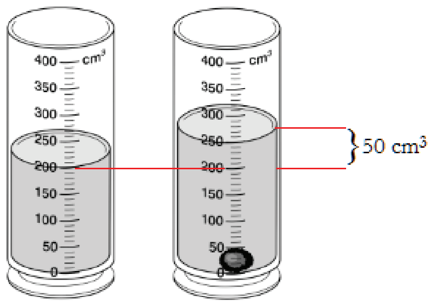


Fig. 2.14: Determining volume of irregular object

The stone in the above activity has a volume of 50 cm^3. How good were you at estimating the volume? What could have caused an error in the measurement?

You can use the stone to measure the volume of an object that floats, such as a small piece of wood. First find the volume of the stone with a rubber band round it. Then attach the piece of wood to the stone with the rubber band. Then find the volume of the stone and the wood fastened together in the same way.

Finally, subtract the volume of the stone (and rubber band) that you found first from the volume of the stone and the wood fastened together.

Volume of stone with rubber band around it = $x\ cm^3$
Volume of stone with wood fastened on it using the rubber band = $y\ cm^3$
Volume of wood = $(y - x)\ cm^3$

Measuring time

Our great grandfathers used different ways to measure time. These included observing the shadow, flowing sand, heartbeat and cockcrow. Many of these methods were, however, inaccurate or unreliable. Nowadays, engineers have developed more accurate clocks for measuring time. Here are some old and new methods of measuring time:

Fig. 2.15: Different ways of measuring time

How good are you at estimating time? Can you count so that you say one number each second? Try it.

A good way of measuring a second is to make a pendulum by tying a stone to a piece of string. If the string is 1 m long, the stone moves from one side to the other in 1 second. The SI unit of time is second. Other units of time are minutes, hours, days and weeks. Can you think of other units of time?

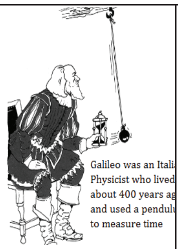
Exercise 2.3

State the most appropriate units in which you can express the following times

a) Your age

b) The time it takes to drink a cup of tea
c) The time the school assembly takes
d) The gestation period of a goat

Activity 2.9: Estimating time



What you need

- Clock or watch
- 1 m pendulum

What to do

a) You must work outside with two friends.
   1. Mark out a short distance, say about 100 m that you can run (a good idea is to run across a football field).
   2. One of you will run the distance; the second will estimate the time taken using a pendulum and the third will measure the time taken using a clock.
   3. Do this three times so that each of you has a chance to run, estimate and measure.
   4. Do the experiment several times to see if you get better at estimating time.

b) Record your results in a table like the one below.

Name	***Time (seconds)***	
	Estimated	***Actual***

Did you know?

The physical quantities that we are measuring and others are classified as:

a) Fundamental/base quantities such as length, mass, time, temperature i.e. those quantities that are not obtained by combining any two other quantities.

b) Derived quantities such as area, volume, density, weight, speed i.e. those quantities that are obtained by combining the fundamental quantities using a formula.
c) Scalar quantities e.g. mass, time, volume, etc. They have only size or magnitude but with no direction.
d) Vector quantities e. g weight, velocity, etc. They have both size or magnitude and direction.

You will meet some of the above quantities in upper classes.

The use of Scientific Notation and significant figures in measurements

When making measurements in science, it is important to understand that the way a measurement is taken affects its accuracy. The accuracy of the measurements depends on the number of significant figures or decimal places of the instrument used.

Please Note

Significant figure is a digit used to express a physical quantity. For example, 01 has 1sf while 10 has 2sf. Decimal places are the fractional places of a number. For example, 1.24 has 2 fractional place values.

Rounding off means writing a number to a required place value. The result is less accurate, but easier to use. For example, 3.52 cm to 1 decimal place is 3.5 cm.

Decimal place is the position of a digit to the right of a decimal point. A time of 6.50 hours has two decimal places; 5 is the first and 0 the second decimal figure.

Rules for finding significant figures

Rule 1:	All non-zero digits are significant figures.
Example:	Distance of 4362 m has 4 significant figures

Rule 2:	All zeros occurring between non-zero digits are significant figures.
Example:	Mass of 605 g has 3 significant figures
Rule 3:	Zeros right of a decimal point and left of non-zero digit are not significant.
Example:	Area of 0.00325 m^2 has 3 significant figures.
Rule 4:	All zeros right of a non-zero digit in the decimal part are significant.
Example:	Height of 1.4750 cm has 5 significant figures

Exercise 2.4:

State the number of significant figures in the followi measurements:

(a) 300 cm

(b) 0.105 km

(c) 0.050 g

(d) 5.1090 m^2

Rules for rounding off significant figures

Rule 1:	If the digit to be dropped is less than 5, the preceding digit is left unchanged.
Example:	1.54 is rounded off to 1.5
Rule 2:	If digit to be dropped is 5 or greater than 5, the preceding digit is raised by one.
Example:	2.49 is rounded off to 2.5
Rule 3:	When multiplying or dividing numbers with different significant figures, the answer takes the **lower** number of significant figures.
Rule 4:	When adding or subtracting numbers with different number of decimal places, the answer takes the **lower** number of decimal places.

Exercise 2.5:

A rectangular block of wood has a length of 5.24 cm, a height of 3.645 cm and a width of 0.63 cm.
Calculate the volume of the block of wood. Give the answer to the appropriate number of significant figures and decimal places

Scientific Notation (Exponential or Standard Notation)

Scientific notation is a short and convenient way of writing or expressing very large or very small numbers using powers of 10.

Examples are shown below:

a) 40 can be written as 4×10^1
b) 2000 is written as 2×10^3
c) (c) 0.0003 is written as 3×10^{-4}

Since very large or very small numbers are written using fewer digits, scientific notation helps to make working with digits easier and with fewer mistakes. For example:

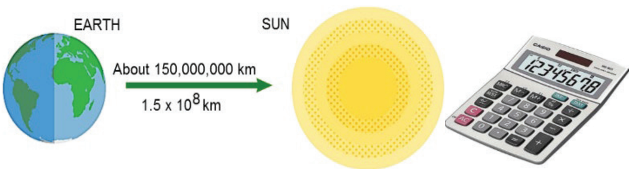


Fig. 2.16: Scientific notation helps to write very large or very small numbers using less digits

The scientific method

The scientific method is a process for experimentation that is used to explore observations and answer questions. Physics relies upon the practice of making observations and carrying out experiments. In science, we observe, raise questions, experiment and make discoveries.

The scientific method follows these steps:

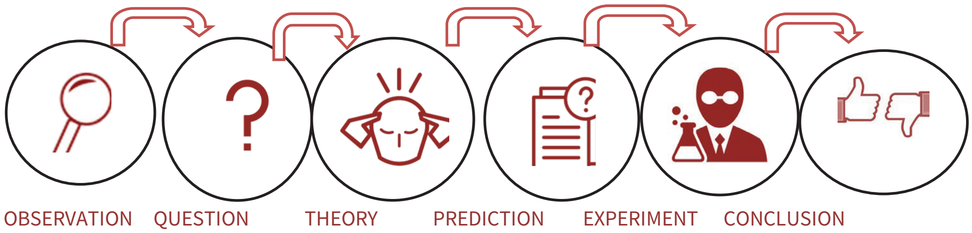


Fig. 2.17: The steps in a scientific method

1. Make an observation, for example: A torch does not light.
2. Ask a question, for example: Why doesn't the torch light?
3. Form a theory, or an explanation that you can test, for example: May be the torch doesn't light because the bulb is blown.
4. Predict what will happen based on the theory, for example: A new bulb will make torch light.
5. Test the prediction through experimentation, for example: Remove the top and replace the bulb with a new one.
6. Use the results to conclude or make new theories, for example: The torch did not light because the bulb was blown, or failure to light is not due to a blown bulb.
   In the second case, look for another theory to answer your question and test it. Repeat until you get the correct theory.

Fig. 2.18 Observing using a microscope

When we **observe** in science, we normally use four of our senses to notice things.

- We look at things when we use our sense of *sight.*
- We feel things when we use our sense of *touch.*
- We listen to things when we use our sense of *hearing.*
- We smell things when we use our sense of *smell.*

(We do not usually use our sense of taste as that could be dangerous.)

Activity 2. 10: Solving a problem using the scientific method

What you need

- A radio which does not work but with old dry cells inside.
- A pair of new dry cells.

What to do

a) Copy the table below in your book.

b) Use the guideline provided in steps 1 – 6 above to carry out an investigation to identify the problem with the torch and record your results in Table 2.2 below.

Table 2.2

Observation	
Question	
Theory	
Prediction	
Experiment	
Conclusion	

Meaning of density

How do you compare two objects to see which one is bigger than the other? The task may be difficult, because even if the size of a body is larger, it does not necessarily mean that the particles in the body are closely packed. It may not even be heavier.

In this section, you will learn a more convenient way of comparing objects and why it is important to compare objects using the concept of density. You will also relate density to floating and sinking of objects.

Fig. 2.19 Comparing objects

Assignment
Look at the objects in **Figure 2.19**. Which is the biggest and which is the heaviest? Do you agree with your friend? Why may the biggest not be the heaviest?

Do we mean: Which object has the greatest mass? Which object has the most matter in it?
Or do we mean: Which object has the greatest volume? Which object takes up the greatest amount of space?
Some objects in **Figure 2.19** have a small mass but a large volume. The polystyrene block is one of these. The brick, however, has a large mass but a small volume. We say that the brick has a large **density** but the polystyrene block has a small density. What is density?

The **density** of a substance is the mass of 1 cm^3 of the substance, also known as **mass per unit volume**. The density of gold is 19.3 g / cm^3; the density of copper is 8.9 g / cm^3 and the density of water is 1 g per cm^3.

What does it mean when we say that the density of copper is 8.9 g/cm^3?

You can find the density of an object if you know its mass and its volume. *To find the density of a substance, we divide its mass by its volume:*

$$density = \frac{mass}{volume}$$

Think back to what you did earlier in this chapter to remind yourself about how you measure mass. Do you remember the different ways of measuring the volume of regular and irregular objects?

Units of density

The units of density will depend on the unit you used to measure mass and volume.

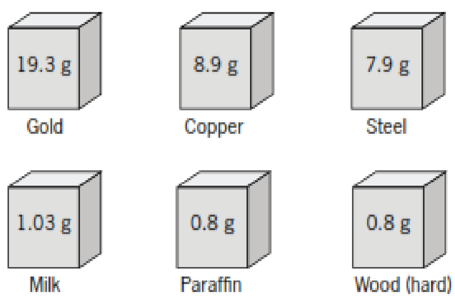
If you measure the mass of a substance in grams and the volume in cubic centimetres then the density will be in grams per cubic centimetre. We can write this unit in two ways: **g /cm³** or **g cm⁻³.** It is also expressed as **kg m⁻³**.

The density of different substances

Density can help us to identify substances. Density can also tell us whether an object will sink or float.

Comparing substances with the same volume

Look at the different objects in the diagram. They all have the same shape and the same volume. They are cubes with a volume of 1 cm^3.



All the cubes have the same volume but they all have a different mass. The lightest cube is 1 cm^3 of paraffin wax and wood (hard), which has a mass of less than a gramme. The heaviest cube is gold, which has a mass of more than twenty times the mass of the paraffin cube. We say that gold is *denser* than paraffin.

Determining density

To determine the density of a substance, we need to know its mass and its volume.

Activity 2.11: Determining the density of different substances

Key question

How can we determine the density of different substances?

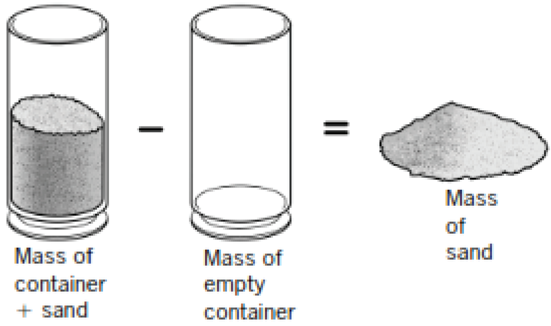
What you need

- Water
- Sand
- Regular solids with rectangular sides (pieces of metal or wood or plastic specially cut, or objects such as a book or a brick)
- Ruler
- Measuring cylinder
- Weighing scale

What to do

a) Find the mass of each substance. To do this for water and sand, you first have to find the mass of a container then put the water or sand in it, and then weigh it again. You then subtract the mass of the empty container from the mass of the container filled with water or sand.

   This will give you the mass of the water or sand.



b) Find the volume of each substance. You can measure its length, width and height and calculate the volume, or you can use a measuring cylinder.
c) Divide the mass by the volume to find the density.

The substances you used in **Activity 2.11** were either regular solids or were substances that you could pour into a measuring cylinder to measure their volume. How would you find the density of an irregular solid, such as a stone?

Changes in density

You earlier on learnt that all matter is made of moving particles. In solids, liquids and gases the particles vibrate all the time. In liquids and gases, the particles can also move around.
You also learnt that when substances are heated, the particles move faster and need more space to move. So the substance expands. Its volume increases.
If the volume of a substance increases but its mass stays the same, its density must decrease. So *when substances are heated and they expand, their density gets less.* When substances cool down, their density increases.

Density and its application to floating and sinking

If we drop a lump of steel into water, we notice that it sinks to the bottom. Why is this so? The next activity attempts to give an answer.

Activity 2.12: Comparing densities of substances with that of water

Key question

Why do some solids sink in water but others float?

What you need

Some different solids such as:

- Pieces of metal
- Plastic
- Wood, etc.

What to do

a) Take different solids and put them in water
b) Observe whether they float or sink
c) Measure their mass and volume
d) Calculate their density
e) Compare the density of each object with that of water and comment on your answer

Those substances with a density of less than that of water (1 g cm^{-3}) will float in water. What can you say about the densities of the objects that sink?

Table 2.3 shows densities of common substances. You can use the approach described in **Activity 2.12** to state which of the substances can float or sink in:

1. water
2. paraffin
3. mercury

Table 2.3: Densities of common substances

Substance	Density (g cm^{-3})	Substance	Density (g cm^{-3})
Aluminium	2.7	Methylated spirits	0.8
Brass	8.5	Paraffin	0.8
Copper	8.9	Petrol	0.7
Cork	0.3	Polyethene	0.9
Glass	2.5	Sand	2.6
Gold	19.3	Tin	7.3
Steel	7.9	Wood	0.6
Lubricating oil	0.9	Water	1.0
Mercury	13.6		

Assignment

Predict, observe and explain

Take a used ballpoint pen top. It is made out of polythene. It has a density of about 0.9 g cm^{-3}. Will it float in water? ***Predict*** what will happen if you put it in some methylated spirit (density 0.8 g cm^{-3}). Try it to find out if your prediction is correct. What do you ***observe***? ***Explain*** your observation.

In West Nile, people living along the Nile use canoes (*o'bo*) made out of wood. The canoe is able to float on water. Can you explain why?

Fig. 2.20: Canoes on a river

Most large ships are not made out of wood, but out of steel. We can see from **Table 2.3** that a lump of steel will not float because it has a density of 7.9 g cm^{-3}. How then can a large ship made of steel float?

Fig. 2.21: A ship and ferry floating on water

This ship is made of steel and weighs 105, 000 tonnes, but it can float on water. The ship is made of steel, but inside it there are many other things, including air. Air has a very low density.

The air and the steel together have a density that is smaller than 1 g cm^{-3}. As this is less than the density of water, the ship will float.

Do you know how a submarine works? Explain how it is able to sink and rise in water?

Predict, observe, and explain

Take two empty cold drinking cans. Crush one as small as you can by stamping on it. Put both cans in a bucket of water.

a) *Predict* what will happen.

b) *Observe* what happens.

c) *Explain* your observation.

Floating in the sea

The density of seawater is greater than the density of fresh water because of the salt dissolved in it. The density of seawater is about 1.03 g cm^{-3}. Try the next activity that uses seawater and see if you can explain your observation.

Activity 2.13: Comparing how much an object sinks in seawater and fresh water

Key question

How deep does a block of wood float in fresh water and in seawater?

What you need

- Small block of wood
- Bowl
- Water
- salt

What to do

a) Put some water in the bowl. Float the block of wood in it. Make a mark on the wood where the water level is.

b) Make some saltwater (seawater) by dissolving some salt in water. Use quite a lot of salt.

c) Float the same block of wood in your salty water. Mark the water level on the wood.

d) Were the two levels the same?

You will have found that the block of wood floats higher in saltwater than in fresh water. This is because the density of the salty water is higher than that of fresh water. The salt particles when mixed with the water particles make it denser.

Why is it easier to float in the seawater than in the fresh river water?

Predict, observe and explain

Put a fresh egg in a beaker of water. What happens?

Predict what will happen if you add salt to the water and stir (don't break the egg!).

Add salt and stir and *observe* what happens.

Explain your observation.

Does floating occur in air?

If a balloon is filled with a gas which is less dense than air, such as hydrogen or helium, it will go upwards. Meteorologists use balloons filled with hydrogen to find out about weather in the different parts of the world.

Hot air is less dense than cold air. This is because everything expands when it gets hot. If the mass of air expands, its volume will increase while its mass stays the same, so its density will go down. Hot air will rise above cold air.

Fig. 2.22: Cumulus clouds above a landscape.

Look at **Figure 2.22**. Rainclouds (cumulus clouds) often form over landscapes that have become very hot in the sun. So hot air currents are produced and rise upwards. These clouds carry a lot of water as they rise up in the sky. When they reach the high cold air, they form rainclouds from which we get a heavy storm.

Ocean currents and water density

An **ocean current** is a continuous, directed horizontal movement of seawater from one region to another. **Ocean currents** can be generated by wind, density differences in seawater caused by temperature and salinity variations in the water.

Ocean currents act much like a conveyer belt, transporting warm **water** and precipitation from the equator toward the poles and cold

water from the poles back to the tropics. Thus, **currents** regulate global climate, thus helping to counteract the uneven distribution of solar radiation reaching earth's surface.

The density of seawater plays a vital role in causing ocean currents and circulating heat because dense water sinks below the less dense. Salinity, temperature and depth all affect the density of seawater.

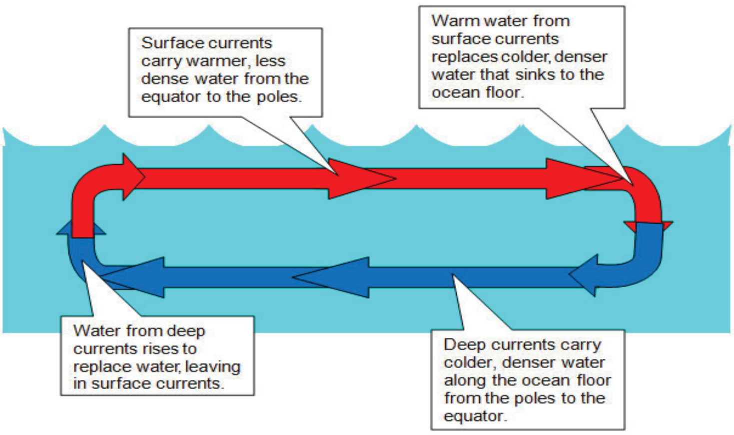


Fig. 2.23: Illustration of ocean currents

Density and purity

We can use density to predict whether a material is pure or not. Pure gold has a density of 19.3 g cm^{-3}. If you want to know whether a golden object is made of pure gold you should find its density. If it is not 19.3 g cm^{-3}, it is not pure gold.

Pure substances always have the same density. This density is different from that of all other substances.

Are there other ways by which you can determine the purity of substances? Can you describe one such method?

Density and relative density

Relative density or **specific gravity** is the ratio of the density (mass of a unit volume) of a substance to the density of a given reference material, which is normally water. It is defined as a ratio of density of a particular substance to that of water.

If the relative density of a substance is less than one, then it is less dense than the reference; if greater than 1, then it is denser than the reference. If the relative density is exactly 1, then the densities are equal, that is, equal volumes of the two substances have the same mass. If the reference material is water, then a substance with a relative density (or specific gravity) less than 1 will float in water. For example, an ice cube, with a relative density of about 0.91, will float on water. A substance with a relative density greater than 1 will sink in water.

Exercise on density

1. Explain what we mean by the statement **'density of a substance is 1 g cm^3 '**
2. a) Explain why a copper coin sinks when put in water.
   b) A log of wood has more mass than a copper coin, but it does not sink in water. Explain why.
3. The density of a metal is 8.9 g cm^{-3}. What does it mean? What is the importance of this value?
4. A rectangular piece of glass has a mass of 145.8 g and measures 2 cm by 9 cm by 3 cm. Find its density and express your answer in kg m^{-3}.
5. 200 cm^3 of a liquid of density 0.7 g m^{-3} is mixed with 100 cm^{-3} of liquid of density 0.9 g m^{-3}. Assuming there was no loss of liquid during mixing and there was uniform mixing, find the density of the mixture.

Chapter summary

In this chapter, you have learnt that:

◊ physical properties are properties of matter that can be observed and measured.

◊ determining the quantity of a physical property of matter by guessing is called an **estimate**, while the use of an instrument is called **measuring**.

◊ measured values should be recorded with appropriate units.

◊ most measurements have errors and hence the errors should be minimised.

◊ scientific method has several steps.

◊ the density of a substance is the mass of 1 cm^3 of the substance and is expressed in $g\ cm^{-3}$ or $kg\ m^{-3}$.

◊ to calculate the density of a substance you must measure its mass and its volume. You then use the formula:

$$density = \frac{mass}{volume}$$

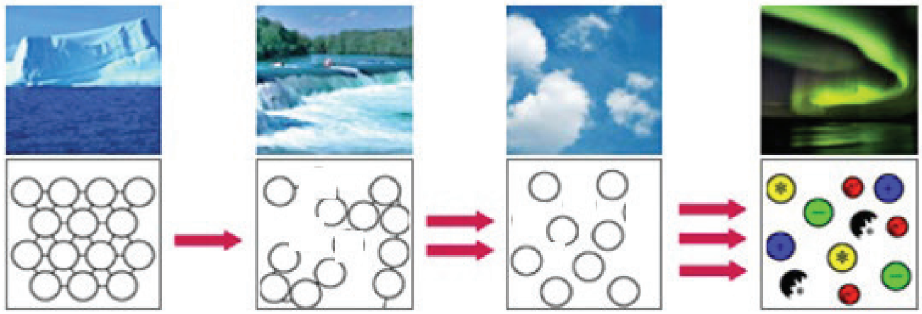
◊ the density of a pure substance is always the same. For example, the density of pure water is always 1.0 $g\ cm^{-3}$ and the density of pure gold is always 19.3 $g\ cm^{-3}$.

◊ ocean currents are a result of density changes in water and this affects climate.

Activity of integration

A chief finds a glittering stone which he shows to the family. The family assures him that the stone is pure gold but he doubts. Prepare a message of what you can do with the stone to give the chief and his family the best advice.

Chapter 3:
STATES OF MATTER



Key words	*By the end of this chapter, you should be able to:*
▪ Plasma ▪ Diffusion ▪ Particle theory ▪ Brownian motion ▪ Change of state	▪ *understand the meaning of matter.* ▪ *understand that atoms are the building blocks from which all matter is made.* ▪ *appreciate that the states of matter have different properties.* ▪ *apply the particle theory of matter to explain Brownian motion and diffusion and their applications.* ▪ *understand how the particle theory of matter explains the properties of solids, liquids and gases; change of state.* ▪ *understand that a change from one state to another involves either heat gain or loss.* ▪ *understand the meaning of plasma in physics.*

Introduction

When you are at the lake or river shores or the beach, you see hips of sand, water and even feel the air breeze. All these things are different but made up of tiny particles. The study of matter and its states will help you understand this.

What is matter?

All the things around us are called matter. Matter takes up space. It also has weight. Matter exists in many shapes, colours, textures, and forms. Water, rocks, living things, and stars are all made of matter. The study of matter is important because it guides us to classify things.

Study Figure 3.1. List at least five different things in the figure which are made of matter. Compare your answer with those of your friends.

Fig. 3.1: Heaps of sand at the lake shores

States of matter

In Primary school, you learnt that matter exists in different states, namely solids, liquids, gases and plasma.

Exercise 3.1

Look at the items in Figure 3.2. Make a table with three columns labelled 'solid', 'liquid' and 'gas', and classify the items indicated.

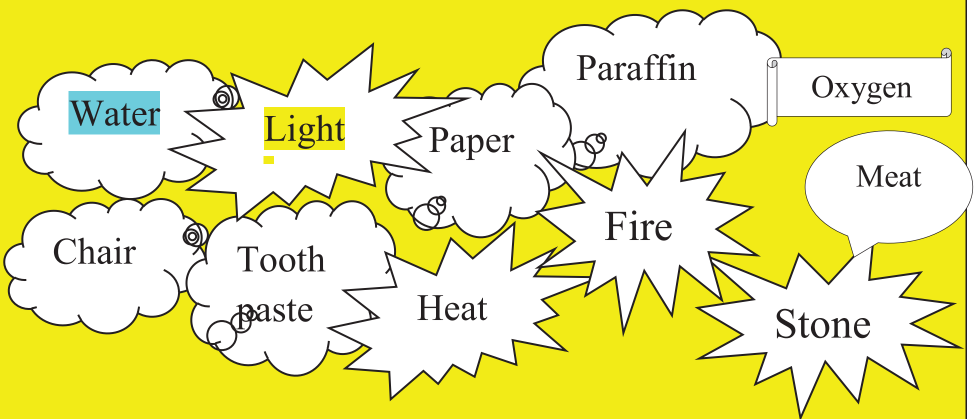


Fig. 3.2: Group of assorted items

In the above Figure, are there items which are not matter? If so, what are they? They could be energy (heat and light)

What are properties of solids, liquids and gases?

Activity 3.1 Categorising materials according to their properties

In Figure 3.2, categorize the items according to the following physical properties:

1. Can be held and kept in the hand
2. Changes shape (have no definite shape)
3. Flows (pours) into a heap
4. Flows (pours) but not in a heap

A solid

i) It cannot move unless something or someone moves it.
ii) It keeps its shape unless it is broken or burned.
iii) Its volume stays the same (unless it is heated or cooled).

A liquid

i) It can flow.
ii) It takes the shape of the container.
iii) Its volume stays the same (unless it is heated or cooled).

A gas

Have you ever smelt the flavour of the food when it is being prepared in the kitchen? What if one opens a bottle of perfume from one corner of the room, can a learner in another corner smell the perfume? This is what happens. If someone is cooking in the kitchen, it doesn't take long for the smell to travel around the house to other rooms. Gas particles from car exhaust fumes, perfumes or flowers move through the atmosphere. The particles in gaseous form move through air from food or any other thing that has a smell. This movement is called **diffusion**. Gas has the following properties:

i) It can flow.
ii) It will spread out as far as it can.
iii) It will change its shape.
iv) Its volume will change when it spreads out.

Did you know that liquids and gases are referred to as ***fluids*** *because they can both flow?*

Of recent another state of matter has been discovered. This state of matter is called plasma.

Plasmas are a lot more like **gases**, but the atoms are different because they are made up of free **electrons** and ions of an element such as **neon**. You do not find naturally occurring plasmas too often when you walk around. They aren't things that happen regularly on earth. While natural plasmas aren't found around you that often, human-made plasmas are everywhere. You encounter them every day, but you may not recognize them. Figure 3.3 shows some examples of the forms of plasma: stars (including the Sun) and lightning.

Fig. 3.3: Forms of plasma

Plasma has these properties:

i) Plasma is ionized gas.
ii) Plasma is a very good conductor of electricity and is affected by magnetic fields.
iii) Plasmas, like gases, have an indefinite shape and an indefinite volume.

The arrangement of particles in the different states of matter

The properties of substances depend on how the particles in these substances are arranged, and how they are held together.

To investigate the properties of solids, liquids and gases including their shape, pouring and compressing, it is important to study the arrangement, the forces between the particles and the movement of the particles.

Forces between particles

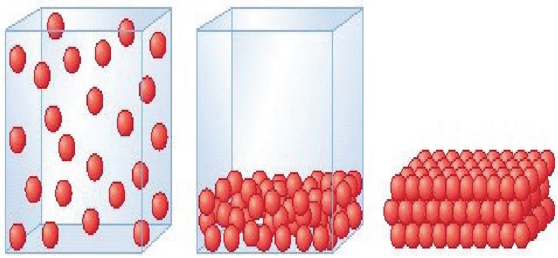
	It is easier to run fast on land than it is to swim fast. Why is this? Particles are held together by forces. The forces holding water particles together are much greater than the forces which hold air particles together. Therefore, when you swim, you have to use more force to break the water particles apart.

Fig. 3.4: Arrangement of particles in solids, liquids and gases

Particles in solids

The particles in solids are fixed in position and are very close. The forces between these particles are strong. The particles can vibrate but cannot move past each other.

Particles in liquids

The particles in liquids vibrate and can move past each other. They are close together, touching each other, but not as close as in a solid. The forces between the particles are not as strong as in solids to support particles in one position. Therefore, liquids flow to take up the shape of the container.

Particles in gases

The particles in gases are not touching each other; they are a long way apart. They are often moving quickly around and so they spread out. If squashed, they move closer together.

The next activity compares a liquid with a gas. It provides *evidence* for the idea that particles are closer together in a liquid and far apart in a gas.

Activity 3.2: To find out if gas or liquid can be compressed

Key question
Which is easiest to compress: a gas or a liquid?

What you need

- A syringe
- Water

What to do

a) Draw some air into a syringe.
b) Close the opening with your finger so the air cannot get out.
c) Press down on the plunger (piston) as shown in the picture. Observe what happens.
d) Do the same with a syringe containing water.
Observe what happens.

You will have found that it was easy to compress (squeeze) the syringe full of air, but impossible to compress the water. This tells us that the water particles are already close together and cannot be pushed closer together. In the gas, the particles are far apart and can easily be pushed closer together.

The particle theory of matter

Describing the composition of matter is not easy since the actual composition can only be inferred rather than observed. Suppose you take a piece of charcoal and break it up into tiny pieces and then break these tiny pieces into dust. It is still charcoal. Then take the dust and further divide it until it is no longer visible. These invisible particles are still charcoal.

As early as 400 B.C., the Greek philosopher, Democritus, thought that matter could be broken down until it can no longer be subdivided. He called these invisible particles **atoms** (from the Greek word meaning not divisible). By observing how particles behave in water and smoke, scientists developed a model to identify the composition of matter.

i) All matter is made up of extremely tiny particles. There are spaces between the particles.
ii) Each pure substance has its own kind of particles, different from the particles of other pure substances.
iii) Particles of matter attract each other.
iv) Particles are always moving or vibrating at fixed positions.
v) Particles at a higher temperature move (or vibrate) faster on average than particles at a lower temperature.

There are things we experience in our daily life which also explain that solids, liquids and gases are made of small particles which we cannot see with our naked eyes. For example, when your clothes are drying or when sugar mixes (dissolves) in water, we cannot see what is happening. Scientists use the idea of **particles** to explain what is happening. The particles are so small that we cannot see them.

What do you think happens to the water particles when clothes dry, and to the sugar particles when they dissolve in the water?

The water particles on your clothes escape into the air. The sugar particles get absorbed into the water.

Fig. 3.5: Dust particles rising behind a speeding car

If a rock breaks, it forms a fine powder of particles which we call dust. When you travel on a dusty road, you may have noticed that dust rises and stays in air for a long time and can also easily get inside the car or bus. Although you can see the dust with your naked eye, each grain of dust is made up of even smaller particles which you cannot see. It takes millions of small particles to make the grain of dust which you can see.

Think about air

We cannot see air particles because they are very much smaller than grains of dust. We know that they exist because we breathe in air particles. We also feel the wind when many air particles are moving and hitting us.

What evidence is there for particles?

We cannot see particles because they are too small. But scientists believe they exist. This is a **scientific theory**. Scientists think up theories to explain their observations. Then they look for **evidence** to prove that their theory is correct. Evidence is something that you can see or hear or touch that can be explained by the theory.

The next activity provides some *evidence* for particles. You will make an observation that can be explained by the theory of particles.

Activity 3.3: Investigating the evidence of particles using a balloon filled with air

Key question

How can we explain what happens to a balloon full of air?

What you need

- A balloon
- String

What to do

a) Blow up a balloon.
b) Tie the string tightly around the neck of the balloon many times.
c) Look at the balloon every day to see if it has changed size.

Did you see that the balloon gets smaller and smaller? This is because the air is escaping. How is it escaping?

Can you think of an explanation why the balloon goes down? Here is an explanation that uses the theory of particles.

Look at the picture in Figure 3.6. It shows the rubber skin of the balloon. The skin is made up of rubber particles packed closely together. But there are places where the air particles can get out through holes between the rubber particles. The air particles inside the balloon are constantly moving around and hitting the skin of the balloon. A few manage to get out of the balloon.

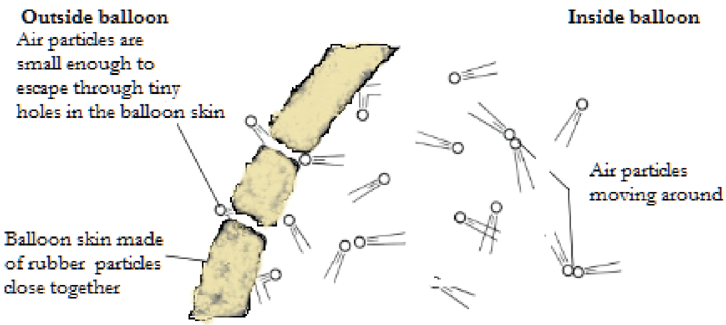


Fig. 3.6: Evidence for particles in air

Solids and liquids are also made of particles. When we mix a cool drink powder (a solid) in water (a liquid), we notice that the powder seems to disappear into the water. The water takes the colour of the powder and tastes different.

The next activity provides more *evidence* for particles. This time the particles are in a liquid.

Activity 3.4 Investigating evidence of particles using liquid

Key question
How do we know that solids and liquids are made of particles which are in a state of random motion?

What you need

- A crystal of potassium permanganate
- A drop of ink
- Water
- Two small transparent containers

What to do

a) Fill the containers with water and allow the water to settle.
b) Carefully place a crystal of potassium permanganate in the water on one side of one container as shown in Figure 3.6.
c) At the same time a friend must carefully place a drop of ink in the water on one side of the other container.
d) Do not move the containers. Look at what happens to them during the rest of the lesson. Leave them overnight and look again. What is the difference between them

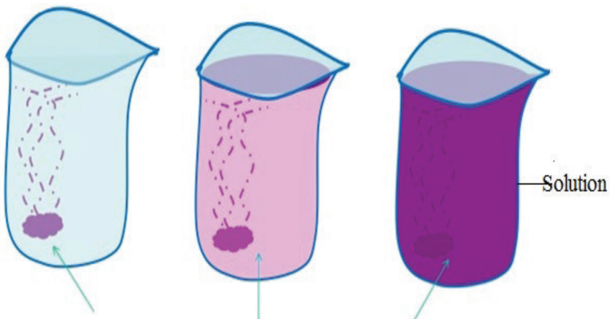


Fig. 3.7: Particles of a solid dissolving in water

What happened to the crystal of potassium permanganate? Did you see that the crystal of potassium permanganate changed the colour of the water? This can be explained by the idea of particles.

Each particle that leaves the crystal moves in between the particles of water and spread. You cannot see each particle because the particles are very, very small. When particles of a substance spread from one region to another, the process is called **diffusion**. After some time, all the particles from the potassium permanganate crystal have spread evenly throughout the water to form a **solution**. This is why the crystal cannot be seen any more. It has **dissolved**.

Think of a coloured liquid like ink. What would happen to the colour of water if a drop of ink is put into a glass of water?

The particles in the ink (which is a liquid) will also diffuse (spread) throughout the water until the colour becomes the same throughout the solution.

Brownian motion

Brownian motion is the continuous irregular (non-uniform, zig-zag, erratic) motion exhibited by small particles immersed in a fluid. Such random motion of the particles is produced by the collisions they suffer with the molecules of the surrounding fluid.

For example, after sweeping your classroom, observe the motion of dust particles using light coming in from one of the ventilators. **Describe the motion of the dust particles**.

Brownian motion can be observed under a microscope. This is done by confining smoke in a smoke (glass) cell, illuminating the cell with a powerful source of light and then observing the smoke particles under a powerful microscope as shown in Figure 3.8. The smoke particles are seen to move in all directions. Raising the temperature of the cell increases the speed of the random motion of the smoke particles.

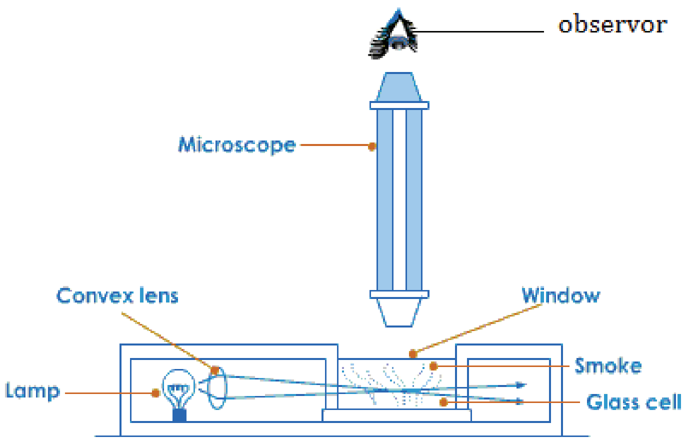


Fig. 3.8: Smoke cell experiment

Diffusion in gases

If someone is cooking in the kitchen, it doesn't take long for the smell to travel around the house to other rooms. This is because of diffusion. Gas particles from car exhaust fumes, perfumes or flowers diffuse through the atmosphere. Our nose detects the small particles. This is how we smell things around us.

You don't have to mix the gases by waving your arms around — they mix on their own. You can easily show this with a gas that has a smell such as butane in a burner. One person should turn on the burner for a few seconds in the front of the classroom. Are you able to smell anything?

Activity 3. 5 Investigating particles in gases

Key question

How do we know that gases are also made of particles?

What you need

- Gas of bromine vapour
- Cover plate
- Two empty gas jars

Caution: Bromine vapour is poisonous and should not be inhaled.

What to do

a) Fill one of the gas jars with bromine gas and carefully cover it with a plate.
b) Invert the second gas jar and place it on top of the jar full of bromine with its cover.
c) Carefully remove the cover plate and let the two open ends of the jars be in contact.
d) Do not move the jars. Look at what happens to the bromine gas.
e) What is the difference between the two jars?

This can be explained by the idea of particles.

Each particle that leaves bromine vapour, moves in between the particles of air in the jar on top. The bromine gas spreads (diffuses) rapidly into the air to produce a uniform pale brown colour in both jars. You cannot see each particle because the particles are very, very small. But you see the brown colour spreading throughout the two jars.

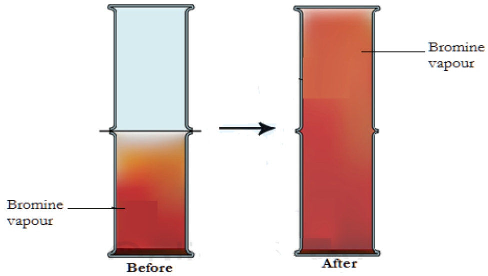


Fig. 3.9: Demonstrating motion of gas particles

Diffusion in gases is quick because the particles in a gas move quickly. Gas particles are further apart than liquid particles and so other gases can diffuse between them easily. It happens even faster in hot gases.

What happens to particles in a solid when they are heated?

Look again at Figure 3.4 which shows the arrangement of particles in a solid, a liquid and a gas. In a solid, the particles are arranged in lines next to each other. You know that when you heat a solid, such as ice, it will turn into a liquid. When you heat the solid you are giving it **energy**.

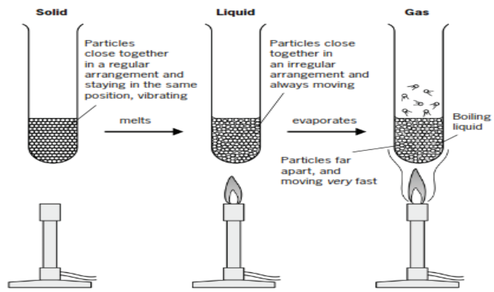


Fig. 3.10: Effect of heating on particles in matter

The energy is heat energy and it makes the particles in the solid vibrate faster. The heat energy is turned into movement energy of the vibrating particles. If the particles are given more heat energy, some of them will vibrate so hard that they start moving past each other. This means that they have acquired so much energy to overcome the forces holding them in one place. The particles are still touching each other, but are moving past each other and are not arranged in lines.

What happens if you add more energy? The particles move around faster and faster. Some of them get enough energy to overcome the forces holding them together. They escape from the liquid. They become gas particles.

Exercise 3.2: **A change of state play**

Make a small play that shows everyone what happens when ice particles turn to water particles and water particles turn to water vapour. Everybody in your class must be water particles. At the beginning you are particles in ice. You are in rows but you are vibrating. The ice is warmed and you vibrate faster.

Then the ice melts. Work out what you will do. Then the water boils. How can you act out the change into water vapour? Finally, you can lose energy and cool down. You condense and freeze again.

Exercise 3.3

1. We learn that matter is made up of small particles. Give some experimental observations that show this.
2. Explain the following observations by using the idea of moving particles:
   a) Wet clothes hanging on a line become dry even in cold weather.
   b) If you put some sugar in tea, the tea will become sweet even if you do not stir it.
   c) A car tyre is full of a gas, air, but the part of the tyre underneath the wheel does not look flat.
   d) If you place a balloon over the top of a test tube that contains water and you then heat the water, the balloon blows up.

Changes of state

Many of the uses of the different states of matter rely on their changing from one state to another. For example, purifying water relies on a change of state from liquid to gas and back again, as does the formation of rain. The burning of candle relies on the wax changing from a solid to a liquid and then to a gas.

Understanding that when things change from one state to another requires energy (heat) gain or loss is very important. Substances can move from one state to another when specific **physical conditions** change. For example, when the temperature of a substance goes up, the particles in the substance becomes more excited and active. If enough energy is added to a substance, a change of state may occur as the matter moves to a more active state.

The particle model will help you to explain how substances change from one state to another. An example of this is the changing of ice (solid) to water (liquid) and finally to water vapour (gas).

Look at the diagram in **Figure 3.11**. Explain what happens to arrangement of particles and forces holding the together when energy heat increases at every state. Do the same to explain what happens when heat energy decreases at every state.

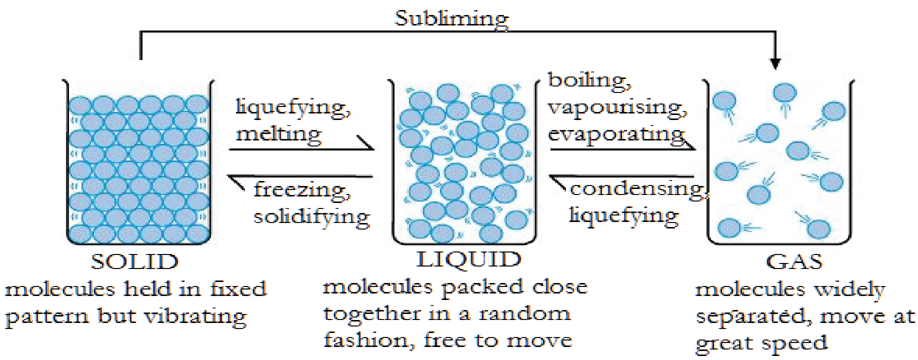


Fig. 3.11: Change of state

Exercise 3.4:

1. What is the economic application of change of state?
2. Why is it important to regulate temperatures in mammals?
3. What is a water cycle?
4. How can you make ice scream?
5. What happens when water vapour comes in contact with a cold bottle of soda? Why is it so?

Chapter summary

In this chapter, you have learnt that:

◊ All substances are made up of matter. Matter can exist in four states: solid, liquid, gas and plasma.

◊ In solids the particles vibrate but stay in one place. In liquids the particles vibrate and move around but stay touching each other. In gases the particles are far apart and can move away from each other.

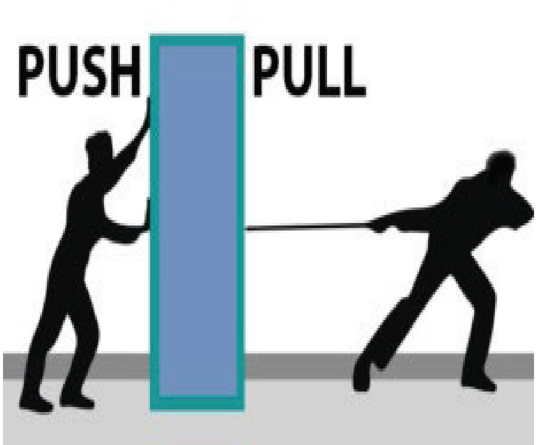
◊ Diffusion and Brownian motion can be explained in terms of particles.

◊ Change of state is a result of heat absorption or evolution and has a variety of applications.

Activity of integration

A worker in a factory has discovered a material that is confusing. It can be stored in a container but can also flow from one container to another. It forms powder after some time. The worker is confused and does not know which state of matter it belongs. As a student of Physics, prepare a message that will help the worker in the factory to properly classify the substance in the right state of matter.

Chapter 4:
EFFECTS OF FORCES



Key words	*By the end of this chapter, you should be able to:*
▪ Force ▪ Newton ▪ Contact forces ▪ Non-contact forces ▪ Resultant force ▪ Gravity ▪ Friction ▪ Intermolecular force ▪ Cohesion ▪ Adhesion ▪ Surface tension ▪ Capillarity ▪ Meniscus	▪ appreciate that a force is a push or a pull, and that the unit of force is the Newton. ▪ appreciate the effects of balanced and unbalanced forces on objects. ▪ understand the importance of friction in everyday contexts. ▪ understand the existence of the force of gravity and distinguish between mass and weight. ▪ appreciate that the weight of a body depends on the size of the force of gravity acting upon it. ▪ understand the meaning of cohesion and adhesion. ▪ explain surface tension and capillarity in terms of adhesion and cohesion.

Introduction

You all have experienced a force in some way. Forces play a role in everything that we do. It may be kicking a ball, turning a tap, or even taking a bite! What shows that there is a force? In this chapter, you will learn different kinds of forces and how they affect objects.

Meaning and measurement of force

Look at the pictures in **Fig. 4.1** below. Can you identify what is being done in each case? What does it involve?

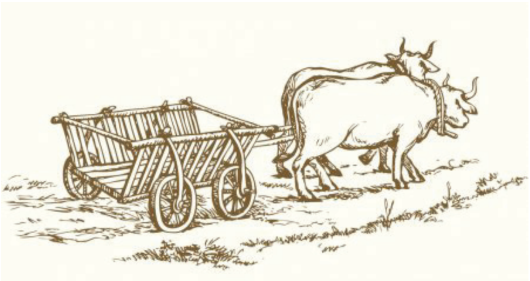


Fig. 4.1 Some uses of forces

A force may be a push or a pull. Can you identify the forces in the pictures shown in **Figure 4.1**?
Force is measured using a spring balance and the unit for measuring force is the **Newton, N**.

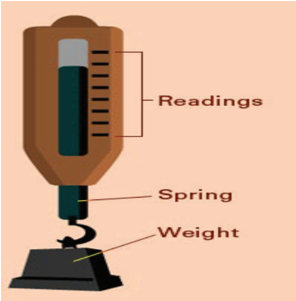


Fig. 4.2: Spring balance

In diagrams, forces are represented by straight lines with arrows. The direction where the arrow points indicates the direction of the force, and the length of the straight line indicates the size or magnitude of the force.

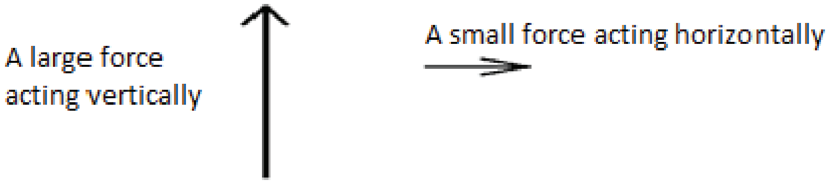


Fig. 4.3 Forces can be represented by straight lines with arrows

Science, technology and society

It takes very large forces to launch rockets into space.

Fig. 4.4: Launching a space shuttle

In order to launch a space shuttle, the engines provide a force of about 30,000,000 newtons.

Types of forces

There are different types of forces e.g. gravity, electrostatic, magnetic, friction, etc. But all forces can be classified into two groups according to whether there is contact between the bodies or not.

Contact forces

A contact force is one that acts at the point of contact between two objects. Examples of contact forces include pushing or pulling objects with different parts of your body. Friction is a contact force between one object moving over another.

Fig. 4.5: A person exerts a contact force when they push or pull an object

Non-contact forces

A non-contact force is a force applied to an object by another body that is not in contact with it.

Fig. 4.6: Gravity is a non-contact force exerted between the planets and the sun

The weight of an object is the gravitational force between the object and the earth. The direction of the weight is towards the centre of the earth.

Force of gravity and weight

Throw up small pieces of chalk or small stones or jump upwards. What happens? You notice that there is falling back in each case. Falling back to the ground is a result of a body's weight.

Weight of a body is always towards the centre of the earth. Weight is a force related to the mass of an object. It is measured using a spring balance and expressed in *Newton*.

Activity 4.1: Investigating the relation between weight and mass

What you need

- A spring balance
- Various slotted masses/different objects

What to do

Weigh various masses on a spring balance and note the mass and weight of each object or mass in the Table 4.1 below.

Table 4.1: Comparing weight and mass

Mass (g)	Mass (kg)	Weight (N)

What do you notice about the relation between mass in kg and weight?

Weight is related to mass by the formula:

$$Weight = Mass\ x\ Acceleration\ due\ to\ gravity$$

The value of acceleration due to gravity on earth is 10 N/kg. It differs at other planets.

Did you know?

The weight of a body varies from place to place on the surface of the earth. This is because different parts of the earth surface are at different distances from the earth centre. It is also different on different planets.

Weight is very important because it keeps air surrounding the earth. Air is important to life.

Effects of forces

Forces affect bodies in different ways.

Activity 4.2: Investigating the effects of forces

The pictures in Figure 4.7 below show some of the effects of forces on different bodies. Look at each picture carefully and describe the effect of the forces being shown.

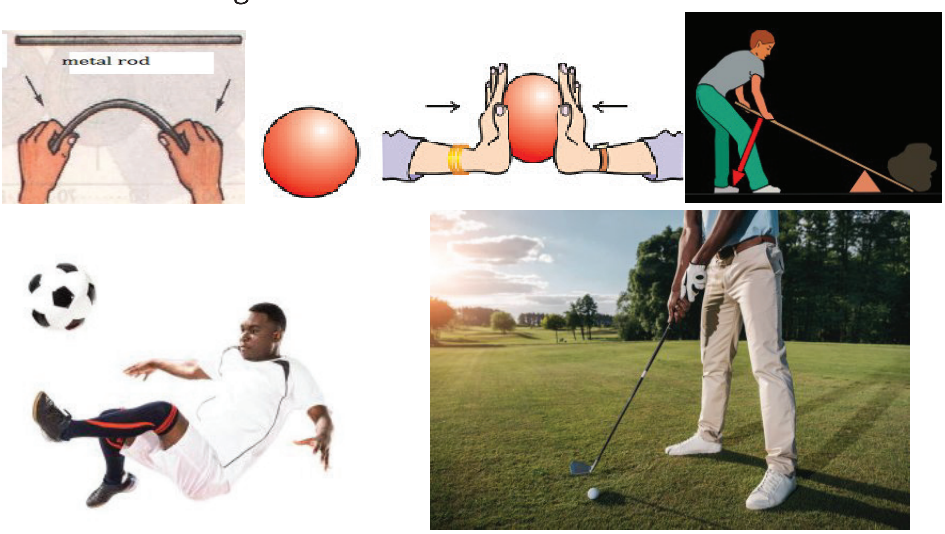


Fig. 4.7: Effects of forces

Can you think of other effects of forces with examples?

Activity 4.3: Investigating forces between charged objects

In this activity, you will investigate electrostatic attraction and repulsion.

What you need

- Two balloons
- A piece of wool
- Small pieces of tissue paper
- Cotton
- Two stand

What to do

a) Blow up one of the balloons.

b) Rub the inflated balloon with a piece of wool to charge it with static electricity.

c) Place the balloon near, but not touching, the pieces of tissue paper.

d) Bring the balloon slowly towards the pieces of paper and observe what happens.

e) Blow up the second balloon.

f) Hang both balloons on stands using cotton threads

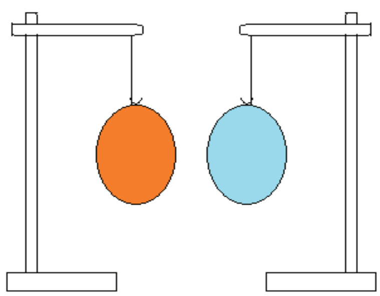


Fig. 4.8: Effect of forces between charged objects

g) Rub both balloons with a piece of wool.

h) Slowly bring the balloons towards each other and observe what happens.

Results

1. What happened when the charged balloon was placed near the pieces of tissue paper?
2. What happened when the two charged balloons were brought near each other?
3. Which kind of effect of force is observed in this activity? Explain your answer.

Balanced and unbalanced forces

When two forces act on an object the net effect will depend on the size and direction of each of the forces.

Fig. 4.9: The forces acting on the stationary book are balanced

When we place a book on the table, the weight of the book acts down due to gravity, and an equal force acts upwards. The upward force is due to a push by the table. The forces are equal in size and act in opposite directions. These forces are said to be balanced. The shape or position of the book does not change.

Did you know?

The difference between unbalanced forces is called the resultant or net force.

Fig. 4.10: The forces acting on the moving container are unbalanced

When a crane raises a container, it must exert an upward force greater than the weight of the container. The forces act in opposite directions but they are not equal in size. These forces are said to be unbalanced. Unbalanced forces cause changes in the shape, position or speed of an object.

Effects of balanced and unbalanced forces on motion

When balanced forces are exerted on a stationary object, it does not move. If balanced forces are exerted on a moving object, its speed will remain unchanged.

When unbalanced forces are exerted on a moving object, it will either move more quickly (accelerates) or less quickly (decelerates) depending on the magnitudes of the resultant force.

Resultant of forces

A stationary object remains stationary if the sum of the **forces** acting upon it — **resultant force** — is zero.

In Figure 5.11 below, if the two children are pushing the box in opposite directions with the same force, the box will not move.

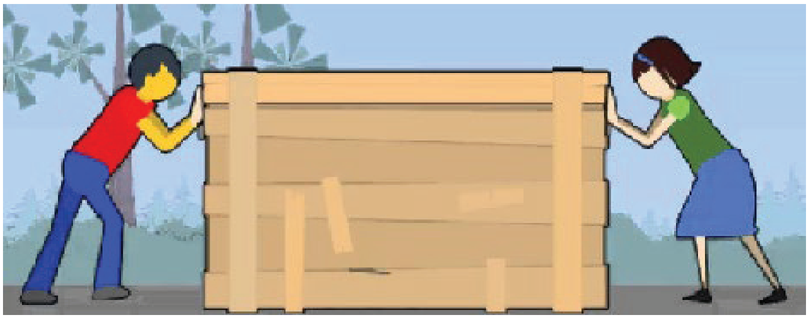


Fig. 4.11: Balanced forces

However, suppose there is a tug-of-war and there are two teams pulling each other as shown below. What do you say about the teams? Which team will move? In which direction will it move? You can try this activity using a rope.

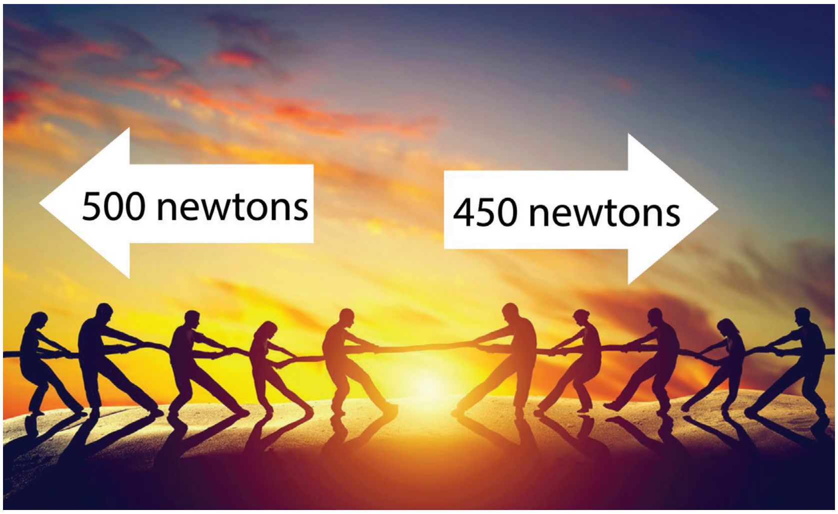
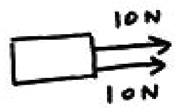
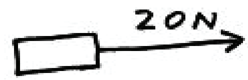
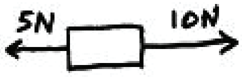
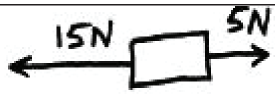
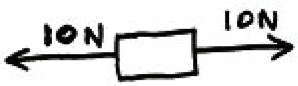
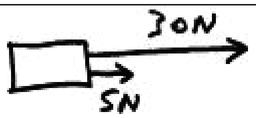
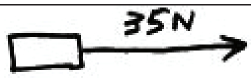


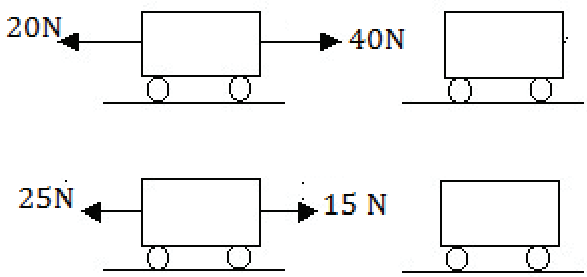
Fig. 4.12: Unbalanced forces

The stronger team is the one that exerts a greater force. The weaker team exerts a smaller force and will move towards the stronger team. This means that for two unbalanced forces in opposite directions, the resultant force is in the direction of the larger force. If the forces are acting in the same direction, then the resultant will be in the direction of the forces.

The above information can be summarised using the illustration in the table below:

Original forces	Resultant forces
	
	
	
	
	

Now using the above illustration, can you obtain the resultant of the forces below and indicate their direction?

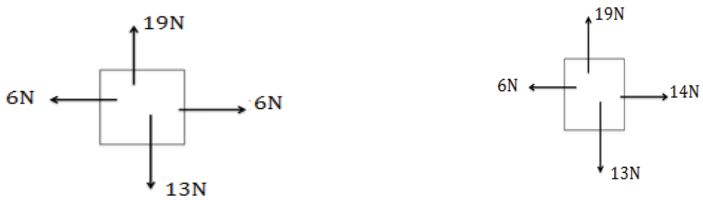


Did you know?

When two forces act on a body at right angles, their resultant is obtained using Pythagoras theorem. What is meant by Pythagoras theorem?

Exercise

Now find the resultant of the following forces.



Friction between surfaces

Friction is a force that acts in the opposite direction to the movement between two surfaces which are in contact. Friction only exists when the two surfaces are moving relative to each other. It does not exist when the surfaces in contact are stationary or moving in the same direction with the same speed.

Activity 4.4: Relating friction with weight

What you need

- A rectangular wooden block measuring 5 x 10 x 20 cm with a hook screwed into the middle of one of the smallest faces. One of the two largest faces should be smooth and the other rough.

- A force meter
- Five 100 g masses
- A flat horizontal wooden table

What to do

a) Place the wooden block on the table so that one of the largest faces is in contact with the table.
b) Hook the force meter onto the block.
c) Keeping the force meter horizontal, gently pull until the wooden block on its smooth surface starts to move.
d) Write down the force needed to move the wooden block.
e) Place a 100 g mass onto the wooden block and repeat steps 3 and 4.
f) Repeat this for different total masses up to 500 g (5 x 100 g) and record your results in the table below.
g) Repeat the experiment when the block is lying on its rough surface.

Results

Mass on the wooden block (g)	**Force needed to move the wooden block (N)**	
	Smooth surface	Rough surface
0		
100		
200		
300		
400		

1. What is the friction force between the wooden block and the surface of the table at the start of the activity?
2. How does the friction force change, if at all, when additional masses are added to the wooden block?
3. Which surface has more friction: a smooth surface or a rough surface?

THINK!
Devise and carry out an experiment to investigate how friction varies with area of contact. Record your results in a suitable table. Use the same materials and equipment. What is your conclusion?

Factors which determine the amount of friction

1. The weight exerted by one surface on the other.
2. The nature of the surfaces.

Methods of reducing or increasing friction between surfaces involves changing one or more of these factors

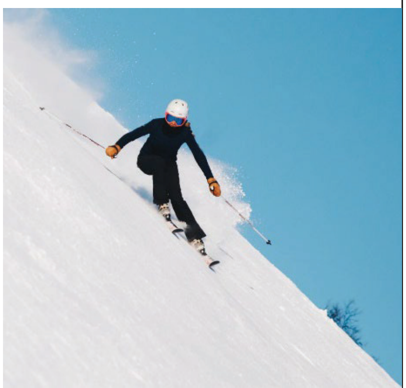
Science, technology and society

Fig. 4.13: Friction allows us to sharpen knives

A grindstone is a very rough surface. When the blade of a knife or a machete is pressed against the moving grindstone, friction wears away some of the metal leaving the knife sharp.

Disadvantages and advantages of friction

In addition to opposing the motion of one surface over another, friction also causes the surfaces to wear each other away. Reducing friction between moving parts of a mechanical device, like an engine, means that it will last longer. Oil reduces friction between moving parts by coating the surfaces so they cannot rub against each other Ball bearings reduce friction. They are often used with oil or grease.

 **Fig. 4.14: Oil reduces friction in a car engine**	 **Fig. 4.15: Ball bearings**
 ***Fig. 4.16: Skiers wax the undersides of their skis*** Skiers rub wax on the undersides of their skis to make them smoother. This reduces the friction between the skies and the snow so they can ski faster. We often think of friction as a bad thing because it opposes motion and causes things to wear away. However, friction also has some important advantages.	 ***Fig. 4.17: Friction between shoes and the ground allows us to move*** If there was no friction between the bottom of the shoes and the ground, a person would not be able to walk or run. Instead of gripping the ground, the underside of the shoes would simply slide under her body. Wearing shoes which have deep grooves cut in them, like running shoes, increases the friction.

If there was no friction between the tyres of a car and the surface of a road the wheel would spin around but the car would not move. The tread on a tyre is designed to ensure the tyres grip the road under different conditions like mud and wet.	 ***Fig. 4.18: Friction between car tyres and the road allows the car to move***

Give examples at your home where friction is good and where it is a problem.

elf-Assessment exercise

1. Distinguish between balanced and unbalanced forces.
2. Does the footballer in Figure 4.19 exert a contact force or a non-contact force on the ball? Explain your answer.
3. a) Give two examples where friction is a disadvantage. Explain why this is the case.

   b) Give two examples where friction is an advantage and explain why is the case.

Fig. 4.19: Exerting a force by kicking a ball

4. You have been given sheets of four different materials: sandpaper, polished wood, rubber and plastic. Design an activity to compare the amount of friction when a wooden block is pulled across each of these surfaces. Your account should include:
   - The apparatus needed.
   - What you would do.
   - The results you would expect to obtain.
   - How you would use the results.
5. Two forces of 12N and 5N act at right angles to each other. Calculate the resultant of these forces.

Intermolecular forces

Have you ever noticed that while washing glass utensils water remains attached to the utensils or small insects can walk on water because their weight is not enough to penetrate the **surface**? These and other phenomena result from the forces within substances. These are intermolecular and forces have effects and applications.

Intermolecular forces are forces that exists between molecules. The molecules may be of the same substance or of different substances.
Intermolecular forces are **cohesion force** and **adhesion force**.

a) Cohesive force

Cohesion is the force of attraction between the molecules of the same kind. Cohesive forces cause a tendency in liquids to resist separation of its particles.
An example is rain which falls in droplets rather than a fine mist. This is because water has strong cohesion which pulls its molecules tightly together, forming droplets.

b) Adhesion

Adhesion is the force of attraction between molecules of different substances. Adhesion causes the liquid to cling to the surface on which it rests.

An example is water climbing up a paper or paper towel that has been dipped into a glass of water. This is because the adhesive forces between water and paper are strong enough to pull the water molecules out of their spherical formation and move them up the paper.

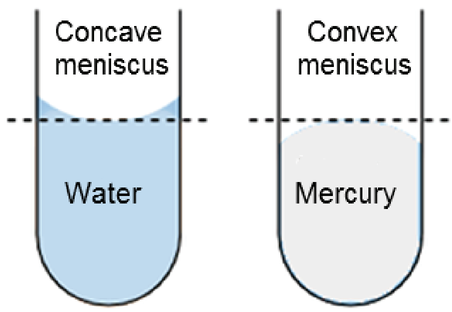
Fig. 4.20: Cohesion and Adhesion: Which pictures show cohesive forces?

Note: When a liquid is placed on a smooth surface, the shape that the liquid takes depends on which of cohesive and adhesive forces acting on that liquid is stronger.

Example:

Explain why water in a narrow glass tube has a concave meniscus while mercury, in the same tube, has a convex meniscus.

Solution:

 ***Fig. 4.21: Shapes of meniscus***	For water in the glass tube, the force of adhesion between the water and glass molecules is greater than the force of cohesion among the water molecules; so water clings to glass forming a concave meniscus. On the other hand, the force of cohesion among mercury molecules is greater than that of adhesion between mercury molecules and glass molecules, so, mercury molecules cling to each other forming a convex meniscus.

Please Note	***Wetting* is the ability of a liquid to maintain contact with a solid surface, resulting from strong adhesive forces when the two are brought together, like water in a test tube, ink spreading on a paper or paint on a wall.**

Surface tension

The cohesive forces among liquid molecules at the surface hold them together and it acts as if it were a stretched elastic layer.

Surface tension is the force on a liquid surface that makes the liquid surface behave as if it is covered with thin elastic membrane/skin.

Examples that show surface tension include:

a) When water drops slowly, it breaks into a continuous stream and forms drops. This shape of the drops is caused by the surface tension of the water.

b) Several insects are able to walk on water, for example, the water strider.

c) A pin or sewing needle, when gently put on the surface of water in a container, it floats due to surface tension.

Fig. 4.22: Effect of surface tension

Activity 4. 5 Studying surface tension in liquids

	***What you need:***	• Dish or beaker with cold water, a piece of paper • A sewing needle or metallic paper clip
	Caution:	Needles are sharp. Handle them with care!
What to do		

a) Take a sewing needle and set it down on top of the water in the bowl. Observe what happens.
b) Cut a small piece of paper (larger than the needle) and set it to float on the water.
c) Gently set the needle on top of the floating paper.
d) Carefully press down on the sides of the paper so that they get water logged and the paper sinks (or you can just wait until the paper sinks on its own). Observe what happens.

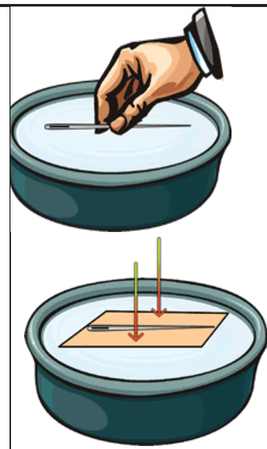


Fig. 4.23: Surface tension in liquids

Questions:

1. What happened on putting the needle or paper clip on water
   (a) directly?
   (b) using a paper?
2. Explain your answer in each of the cases above.

Add soap solution or oil on the surface of the water and repeat the above procedures. What do you notice?
Surface tension in water can be reduced. Can you suggest ways of doing this?

Capillarity

Capillarity is the tendency of a liquid in a capillary tube (small tube) or absorbent material to rise or fall. Capillary action is the result of surface tension and adhesive forces. There are two cases:

Activity 4.6 Studying capillarity in liquids

What you need

Paraffin (or kerosene), a dry wick, beaker

What to do

a) Put kerosene in a clean dry beaker.

b) Deep one end of a wick in the beaker containing kerosene.

What do you observe? Explain your observation.

Capillary rise of liquids in tubes

Capillary rise and fall is due to the intermolecular forces in the liquid.

a) Liquids that rise in a capillary tube (attraction)

Activity 4.7 Studying capillary rise in liquids

What you need

Two capillary tubes of different sizes and a beaker of water

What to do

a) Place water in a beaker till it is half-full.

b) Place a capillary tube in the water vertically. Leave it for some time until the water is no longer rising in the tube.

c) Note and mark the level of water in the capillary tube.

d) Replace the first tube with another one of a different size.

e) Note and mark the water level.

f) Alternatively, you can dip the two capillary tubes into a beaker of water to the same depth at the same time.

What do you observe? Explain your observation.

You may have seen that the levels of the water in the two tubes appears like Figure. 4.24 below.

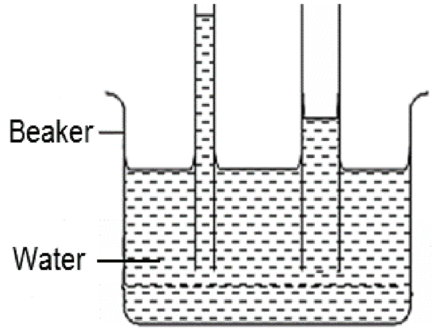


Fig. 4.24: Capillarity in water

b) Liquids that fall in a capillary tube (repulsion)

Here, the cohesive forces are greater than the adhesive forces. The level of the fluid in the tube will be below the surface of the surrounding fluid. This is because the force of cohesion between mercury molecules is greater than the force of adhesion between them and the glass, and the liquid clings to itself.

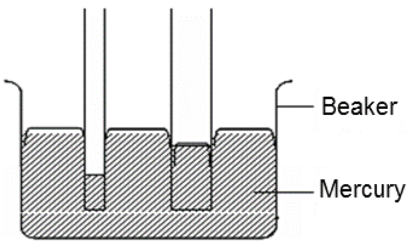


Fig. 4.25: Capillarity in mercury

Please Note	The amount of elevation, or depression of a liquid in a capillary tube depends on the internal diameter or size of the tube. The liquid rises higher or sinks lower when the diameter is smaller.

Examples of capillarity

i) Water moving up a straw or glass tube.

ii) Water being absorbed by a paper or cloth towel.

iii) Movement of water through a plant.

iv) Blotting paper absorbing liquids.

v) Paraffin rise in wicks of stoves and lamps.

vi) Towels and soft tissues rinsing water

Chapter summary

In this chapter, you have learnt that:

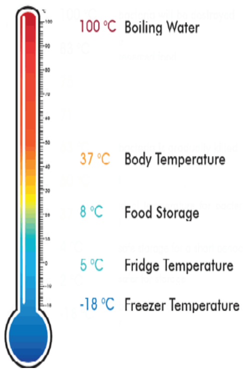
- **a force is a pull or a push and its unit is a Newton.**
- **balanced forces are forces acting on an object which are equal in magnitude and opposite in direction, while unbalanced forces are not equal in magnitude though they may act in opposite directions.**
- **friction is a force that prevents or slows motion between two surfaces in contact. It has both advantages and disadvantages.**
- **weight of force of gravity has various consequences to life on earth.**
- **intermolecular forces exist within the same substance or different substances.**
- **cohesion, adhesion, surface tension and capillarity are due to intermolecular forces.**
- **Surface tension can be observed in many different phenomena.**
- **Capillary rise has a variety of applications.**

3. What is the significance of capillarity?

Activity of integration

The lower part of the walls of a house (near the floor) appear dump and begin to peel off a few years after construction. This happens most especially when the house is constructed in a location near wetlands.
Task: Advise someone who wants to construct a house with walls that do not peel.

Chapter 5:
TEMPERATURE MEASUREMENT



Key words	***By the end of this chapter, you should be able to:***
▪ Temperature ▪ Temperature scales ▪ Thermometric property ▪ Upper fixed temperature ▪ Lower fixed temperature ▪ Clinical thermometer ▪ Digital thermometer	▪ understand the difference between heat and temperature. ▪ understand how temperature scales are established. ▪ calibrate a thermometer and use it to measure temperature. ▪ compare the qualities of thermometric liquids. ▪ describe causes and effects of the daily variations in atmospheric temperature.

Introduction

In Chapter One, you learnt that physics deals with the study of matter and its relation with energy. One of the forms of energy is heat. Heat has different effects on matter. One of the effects is the change in temperature. In this chapter, you will learn how temperature is measured and how the environmental temperature changes with time.

Heat and Temperature

As you learnt earlier, **heat** is a form of energy. When a body absorbs heat, it becomes hotter; and when an object loses heat, it becomes colder. Therefore, the amount of heat in a body influences the body's temperature.

Can you differentiate between hotness and coldness?
Can you now define temperature?

Have you heard statements like 'it is very cold today' or 'It is hot'? Do such statements make sense? How hot is hot, and how cold is cold? All these are related to the temperature of bodies. **Can you differentiate between hotness and coldness?**

Measuring temperature

How good are you at estimating temperature? Can you estimate the temperature of:

1. a hot day?
2. a cup of hot tea?
3. warm bathwater?
4. normal human body temperature?

The following are some common temperature estimates:

- A comfortable temperature for working is 25°C.
- A cold morning is about 19°C to 21°C.
- A hot day is about 29°C.

Temperature is measured using a thermometer. The unit for measurement of temperature is either degrees Celsius (°C) or degrees Fahrenheit (°F) or Kelvin (K).

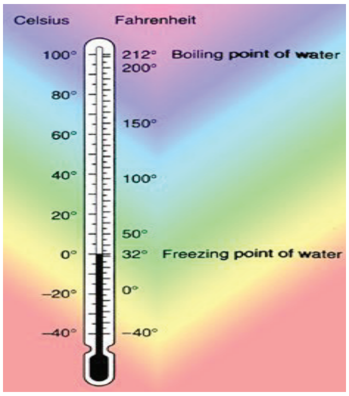


Fig. 5.1: Temperature scales

For example, a temperature of 100°C is equivalent to 212°F or 373 K. From this illustration, it can be seen that the temperature of a body depends on the scale used. Hence, temperature is the **degree of hotness on a chosen scale**.

Activity 5.1 Measuring temperature of the environment

Key question

How hot is it at various places around the school?

What you need

- A thermometer

What to do

Estimate the temperature at different places around the school: indoor, outdoor in the sun and outdoor in a shade. Then measure the temperature in these places with a thermometer. Do not forget to record your results as in Table 5.1 one below.

Table 5.1: Temperature of the environment

Place	***Temperature(°C)***	
	Estimated	***Actual***
Classroom Under tree Laboratory		

You should have tables with all your estimates and all your measurements. Did you find that you got better at estimating as you worked through the activities?

Assignment

Listen to the weather forecast or check for the forecast in a newspaper. What is the temperature of the hottest and coldest parts in Uganda for the day recorded? Record the temperature of these places for a week. What is the average temperature for each of the places? What causes daily variation in temperature of the environment?

Types of thermometers

The thermometer makes use of a physical property of a substance which changes continuously and uniformly with temperature. The physical property is referred to as thermometric property.

Examples of thermometric properties

Thermometric property	*Type of thermometer*
Volume expansion of a liquid	Liquid-in-glass thermometer
Volume expansion of a gas	Gas thermometer
Electrical resistance	Resistance thermometer

How a liquid-in-glass thermometer works

A liquid-in-glass thermometer consists of a tube with a bulb and a narrow capillary or bore. When the thermometer is put in a warm or hot substance, the liquid in the bulb expands forcing its way in the bore to a length that corresponds with the temperature of the substance.

Fig. 5.2: A laboratory thermometer

Bulb:	It stores the liquid
Bore:	It gives the liquid a route of travel as it expands and contracts. It is very narrow to make the thermometer more sensitive and accurate.
Stem:	This surrounds the bore in the thermometer. It is also a magnifying glass to enable easy reading of temperature.
Expansion Chamber:	This provides space where gases and air inside the capillary collect as the liquid rises.

Please Note

A thermometer is said to be sensitive if it can record very small temperature changes. The sensitivity of the thermometer can be increased by using a large bulb and a narrow capillary tube.

Clinical thermometer

This is the thermometer doctors and nurses normally use in the hospitals to measure the temperature of the human body. It is a liquid-in-glass type of thermometer.

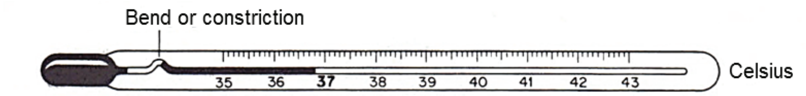


Fig5.3: Clinical thermometer

These thermometers are suitable for measuring body temperature because:

i) Mercury, which is used as the liquid, is very sensitive to temperature changes.

ii) the scale is limited between 35^0C to 43^0C, the only range needed for medical purposes.

iii) there is a constriction or bend which breaks the mercury column and prevents its backflow. This allows enough time for a reading to be taken.

For your study: Based on the features of the clinical thermometer, suggest best practices of the proper handling of a clinical thermometer.

Digital thermometers

Digital thermometers detect body temperature with simplicity. The display allows for easy reading of the detected temperature (oral, under arm and rectal). They are flexible and more comfortable to use. They emit a beep to indicate when the temperature measurement is complete and stores the last measurement taken for a short time.
Look up for a picture of or a physical digital thermometer. Your teacher should help you to draw it.

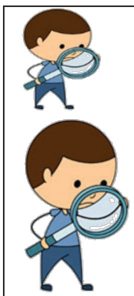
Temperature scales

To determine a temperature scale, fixed points are chosen. A fixed point is a well-defined temperature which can be used as a reference point in measuring other values of temperature. In the Celsius scale of temperature, there are two fixed points.

Table 5.2: Fixed temperature scales

Lower fixed point:	This is the temperature of pure melting ice at standard atmospheric pressure.
Upper fixed point:	This is the temperature of steam from pure water boiling under standard atmospheric pressure.

Activity 5. 2 Determining the lower fixed point

	***What you need:***	• Cracked ice and a beaker or saucepan • A thermometer
	Caution:	Thermometer is fragile. Handle it carefully. Mercury vapour is poisonous.

What to do

a) Fill a beaker with cracked ice as shown in Figure 5.4. When water begins forming from melting ice, place the bulb end of the thermometer well into the ice but leave the stem above the melting ice so that you can read and record the temperature of melting ice.

Fig. 5.4: Determining the lower fixed point on a thermometer

b) Gently stir for five minutes. What do you observe?
c) Read and record this observed temperature of the melting ice in data table.
d) Repeat the entire procedure for a second and third trial, while recording all results in the table.

Results:

1st trial	*2nd trial*	*3rd trial*	*Average*

Questions

1. Are all the values in each of the three trials the same?
2. Is the lower fixed point of the thermometer accurate? If not, give a possible explanation for the difference.

Activity 5. 3: Determining the upper fixed point

What you need:	• Beaker or saucepan, thermometer and water • Bunsen burner/charcoal stove
Caution	Use gloves or cloth to avoid burns and scalds.

What to do

a) Pour water in the beaker until it is half full. Put the beaker over a heat source as shown in Figure 5.5 and boil the water for some time.

b) When the water begins to boil vigorously, what do you observe about the mercury level in the thermometer?

c) Remove the thermometer from the water and hold it in the steam.

d) Read and record this observed temperature of the boiling point in the data table below, for three trials.

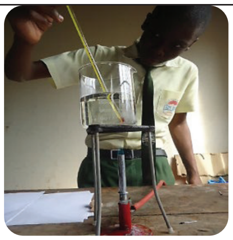


Fig. 5.5: Determining the upper fixed point on a thermometer

Results:

1st trial	*2nd trial*	*3rd trial*	*Average*

Questions

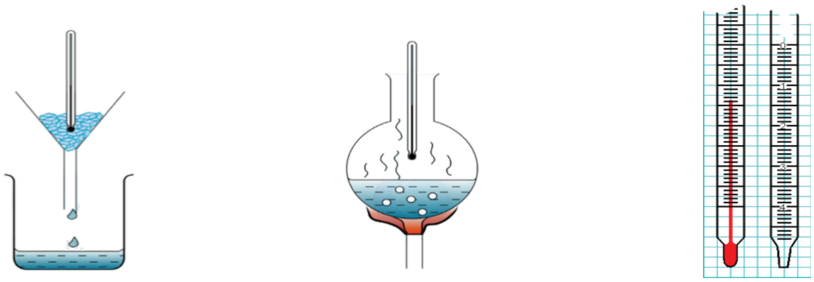
1. Are all three values in the three trials the same?
2. Is the upper fixed point of the thermometer accurate? If not, give a possible explanation for the difference.

Calibration of the thermometer

Calibration refers to the process of graduating an instrument to give quantitative measurements that allow scientists to produce accurate readings. The following steps are taken to calibrate a thermometer:

i) Determine the lower fixed point of the thermometer. Mark the point on the thermometer.

ii) Determine the upper fixed point of a thermometer. Mark the point on the thermometer.



Freezing point of water (0°C)   Boiling point of water (100°C)   Make 100 divisions

Fig. 5.6: Calibration of the thermometer

iii) Divide the difference between the two points into 100 equal points. Mark the points as a scale along the stem either in Celsius scale or Kelvin or both.

iv) Measure the temperature of various objects using your thermometer.

Example

A mercury thermometer is calibrated by immersing it in pure melting ice and then in steam above boiling pure water. If the mercury columns are at 6 cm and 16 cm marks respectively, find the temperature when the mercury column is 8 cm long.

Solution

6 cm corresponds to 0 °C

16 cm corresponds to 100 °C

8 cm corresponds to θ °C

θ = ?

$$\theta = \frac{8-6}{16-6} X\ 100 = \frac{2}{10} X\ 100 = 20\ ^0C$$

Exercise:	The length of a mercury column of a thermometer at ice point and steam point are 2.0 cm and 22.0 cm respectively. What is the reading of the thermometer when the mercury column is 9.0 cm long? What will be the mercury length in the column at 60 °C?

Note

1. The Celsius scale on a common laboratory thermometer ranges from 0 °C which is the freezing point of pure water to 100 °C which is the boiling point of pure water. The interval between these two points is divided into 100 equal parts for which each part represents a change of 1 °C.
2. In the Kelvin or absolute scale, the freezing point of water is 273 K and the boiling point of water is 373 K. The Kelvin (K) is the S.I Unit of temperature.

Relationship between Celsius scale and Kelvin scale

Activity 5.4 Comparing Celsius scale and Kelvin scale

Study the table below and fill the gaps.

Table 5.3: Converting temperature scales

Temperature (°C)	Temperature (K)
0	273
53	

	350
	370
100	373

What is the relationship between temperature in °C and K?

Since 0°C corresponds with 273 K and 100 °C is equivalent to 373 K, when converting from the degrees Celsius to degree Kelvin, a value of 273 ^{0}C is added to the temperature; and when converting temperature from Kelvin scale to Celsius, a value of 273 ^{0}C is subtracted from the temperature.

Exercise:

1. Convert the following temperature readings to Celsius scale:
   (i) 1000 K (ii) 234 K (iii) 100 K (iv) 783 K
2. Convert the following temperature readings to Kelvin scale:
   (i) 40 °C (ii) 68 °C (iii) 34 °C (iv) 25 °C

Thermometric liquids

Liquids whose volumes vary continuously with temperature are called thermometric liquids and they are used to make good liquid thermometers. Examples of thermometric liquids include mercury and alcohol.
The table below compares the characteristics of mercury and alcohol when used in thermometers.

Table 5.4: Comparing thermometric liquids

Mercury	Alcohol
• It is opaque and makes reading easy.	• It is colourless and makes reading difficult. It needs colouring.

• It expands regularly.	• It has a somewhat irregular expansion
• It has a high boiling point, 357^{0}C.	• It boils at 78 ^{0}C.
• It freezes at -39^{0}C.	• It freezes at -115 ^{0}C.
• It has a lower expansivity than alcohol.	• It has a higher expansivity than that of mercury.

Exercise

1. State reasons why mercury is usually preferred to alcohol as a thermometric liquid.
2. What are the advantages of alcohol over mercury as a thermometric liquid?
3. Suggest reasons why water is never used as a thermometric liquid although it is fairly abundant.

Variations in daily and atmospheric temperature

Have you ever wondered why it is normally colder at night than during the day? The difference between the temperature of the day and of the night is called **diurnal change** in temperature.

The change in temperature from day to night is brought about by the daily rotation of the earth. The earth receives heat during the day by solar radiation, but continually loses heat by surface radiation. Warming and cooling depend on an imbalance of solar and surface radiation. During the day, solar radiation exceeds surface radiation and the surface becomes warmer.

At night, solar radiation ceases, but surface radiation continues and cools the surface. Cooling continues after sunrise until solar radiation again exceeds terrestrial radiation. Minimum temperature usually occurs after sunrise, sometimes as much as one hour after. The continued cooling after sunrise is one reason why fog sometimes forms shortly after the sun is above the horizon.

Atmospheric temperature is a measure of temperature at different levels of the earth's atmosphere. It is governed by many factors, including incoming solar radiation, humidity and altitude.

The amount of solar energy received by any region varies with seasons, latitude and time of day. These differences in solar energy create temperature variations. Temperatures also vary with differences in relief and altitude.

The amount of ground-level atmospheric temperature ranges depends on several factors, such as:

- Average temperature
- Average humidity
- Regime of winds
- Proximity to large bodies of water, such as the sea

It is hotter near the earth's surface because heat from the earth warms this air. As the altitude increases the number of air molecules decreases, thus the average of their kinetic energy decreases. However, temperature increases with altitude above a certain height because of increasing amounts of ozone.

Chapter summary

In this chapter, you have learnt:

- the difference between heat and temperature.
- how temperature scales are established.
- the conversion of temperature scales.
- the qualities of mercury, alcohol and water as thermometric liquids.
- the construction of a clinical thermometer.

- the causes and effects of the daily variation in atmospheric.

  temperature

Activity of integration

The daily activities at school are being affected by weather variation, especially temperature. As a Physics student, you have been tasked to prepare a temperature chart and a message about how the chart will be useful.